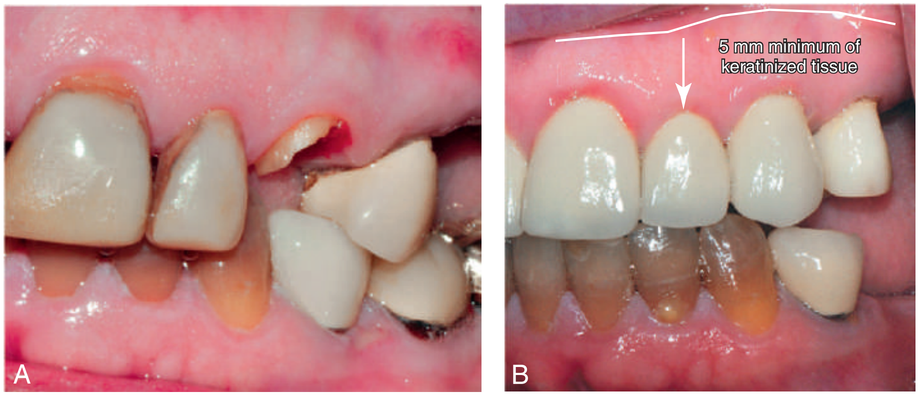

Fig. 5.16 (A) Note the dark discoloration of the teeth and roots. The maxillary left lateral incisor will be extracted and the canine requires endodontic treatment and a post-and-core before a three unit fixed partial denture is fabricated. (B) The restorative margins on the premolar and canine were placed at the gingival crest and elicited no visual evidence of inflammation. The restorative margin on the central incisor was placed subgingivally to cover the dark root and elicited a visible inflammatory response.

Fig. 5.17 (A) Thick biotype. (B) Thin biotype. Note the minimal amount of keratinized tissue and readily visible blood vessels in the patient with the thin biotype.

Gingival Biotype/Phenotype

Responses to biologic width invasion vary by different gingival biotypes. In the field of genetics, the characteristics one portrays as the result of the interactions of their genotype with their environment is known as their phenotype. In the field of dentistry biotype is commonly used instead of phenotype; however, the scientific correctness of the term biotype has been debated.

A combination of thin bone with thin gingiva overlying the bone is termed a thin biotype.[60] The inflammatory response results in swelling, edema, redness, and bleeding, but in thin biotypes, gingival recession and bone loss occur and a new biologic width is established at a more apical level. A thick gingival biotype characterizes two thirds of the population, and most people with a thick biotype are men (Fig. 5.17). A thin gingival biotype is most often found in women. Thin and thick gingival biotypes can exist within the same dentition. If a probe is placed within the gingival sulcus, and if the biotype is thin, the tip of the probe can be seen through the sulcus. Patients with thin gingival biotypes are at high risk for gingival recession during any dental procedures (Table 5.4).[61,62]

Correcting or Preventing Biologic Width Violations

BWVs can be corrected either by traditional crown lengthening (TCL) with surgical removal of bone from below the restorative margin and movement of the attachment apically (Fig. 5.18),[63] by orthodontic extrusion of the tooth (and preparation finish lines) coronally away from the attachment (Fig. 5.19) or by biologic shaping (BS) of the root and tooth during which the existing margin is removed and root anatomy that compromises future plaque removal is eliminated during the surgical procedure.

In earlier editions, we discussed traditional surgical crown lengthening. Crown lengthening is a surgical procedure aimed at exposing more tooth structure for restorative and/or esthetic reasons. Most often this is performed by surgical removal of supporting bone (ostectomy) with concurrent contouring of the adjacent alveolar bone (osteoplasty). The objective is to provide adequate coronal tooth structure to allow retention and resistance for a predicable fixed restoration. Correction of a biologic width invasion uses the previous margin as the reference point from which to create 3 to 5 mm of space apically to result in

TABLE 5.4 Characteristics of Thin Versus Thick Biotype

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

CEJ, Cementoenamel junction.

Fig. 5.18 Surgical correction of biologic width violations: interproximal mandibular right second premolar and first molar. (A and B) Initial clinical views. (C) Interim restoration in place before surgery. (D) Short preparations and a lack of ferrule. (E) Immediately after crown lengthening. (F) Definitive restorations placed.

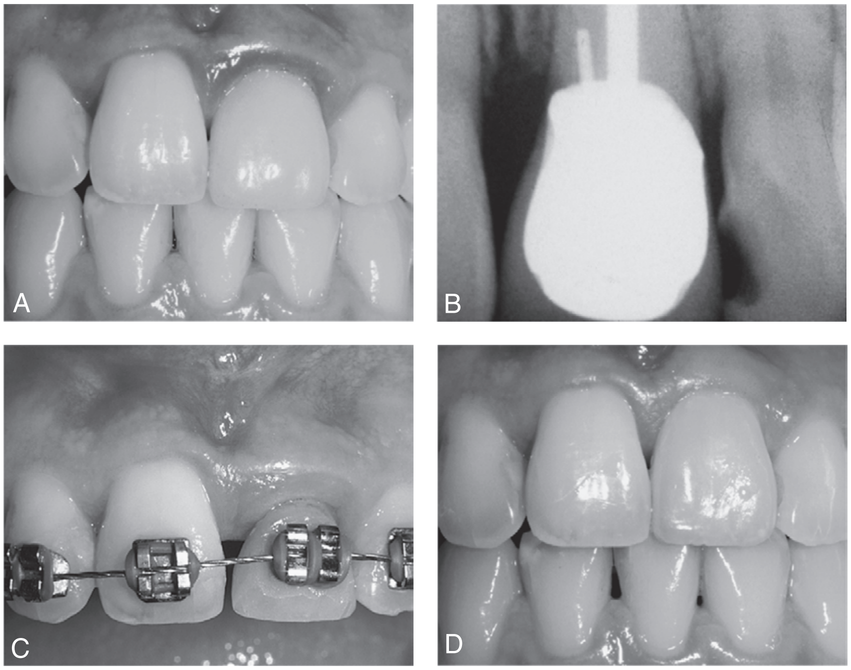

Fig. 5.19 Orthodontic correction of a biologic width violation (BWV). (A) Tooth #9 exhibits red, edematous gingiva adjacent to new crown. (B) Bite-wing radiograph confirms BWV. (C) Orthodontic treatment is utilized to pull gingiva and bone incisally. (D) Surgical removal of newly gained gingiva and bone results in correction of BWV and preservation of gingival esthetics. (From Newman MG, et al. *Carranza's Clinical Periodontology*. 10th ed. St. Louis: Saunders; 2006.)

a new and sustainable biologic width. TCL requires aggressive removal of supporting bone, increases the crown to root ratio, and often exposes root anatomy that can make future plaque removal challenging.

The resulting gingival position is reasonably stable at 4 months, and new margins can then successfully be placed. In the anterior region, it is advisable to wait 6 months before final margin placement because of the increased esthetic demands. Surgical crown lengthening is seldom performed on a single tooth. Bone correction (i.e., recontouring) must be gradual and not result in any abrupt change of direction. Most often, bone must be removed around three adjacent teeth to correct a single biological width violation. In the anterior esthetic zone, surgery is often contraindicated unless all teeth would benefit from a longer tooth length (Fig. 5.20). In the past, in posterior quadrants, surgical crown lengthening has been the treatment of choice. Posterior teeth most often demonstrate retention and/or resistance challenges because of short clinical crowns.[63] Frequently, existing restorations with subgingival margins are present. Surgical correction through crown lengthening moves margins from a subgingival position to a crestal or supragingival position, where plaque removal is more straightforward.

Lasers and closed surgical techniques have been introduced for selected anterior crown lengthening. Keratinized tissue must be adequate for a gingivectomy to be performed yet have 5 mm of keratinize tissue remaining. The bone is removed through the sulcus with hand instruments, rotary instruments, or lasers to reestablish a healthy biologic width 3 mm below the restorative margin. This novel minimally invasive approach is very technique-sensitive. The resultant root surface is rougher, and troughs are created in thicker bone. Clinically, these findings should be approached with caution, but they do not significantly alter the short-term outcomes in comparison to a TCL approach in carefully selected anterior teeth.[64,65]

BIOLOGIC SHAPING

Biologic shaping (BS) in an alternative to traditional surgical crown lengthening (Figs. 5.21–5.50). Dr. Melker coined the term BS over 35 years ago to describe an improved concept. The procedure is much more conservative to the supporting alveolar bone. It removes the existing margins and contours the root, eliminating much of the root concavities, furcations, root grooves, and enamel projections that compromise long term maintenance of gingival health. The biologic width is allowed to reestablish with minimal or no removal of supporting bone.[51–54] The restorative dentist is then able to place margins supragingival and facilitate the greatest gingival health (Table 5.5).[66–69]

BS begins with removal of all existing carious lesions, placing a solid bonded resin foundation restoration and preparing the tooth for an interim crown. The interim crown margins should be feather edge. The surgeon removes the interim restoration and reflects a partial thickness envelope flap on the buccal surface, when possible. In areas with tori or exostosis, a full thickness flap is required. The lingual flap is a full thickness flap. Buccal and lingual flaps are extended at least one tooth mesial and distal to the tooth or area in question. The tooth is examined for anatomy that will compromise future cleansability such as furcations, root grooves, enamel projections, and existing margins that violate the biologic width. The alveolar bone is examined for excess bone

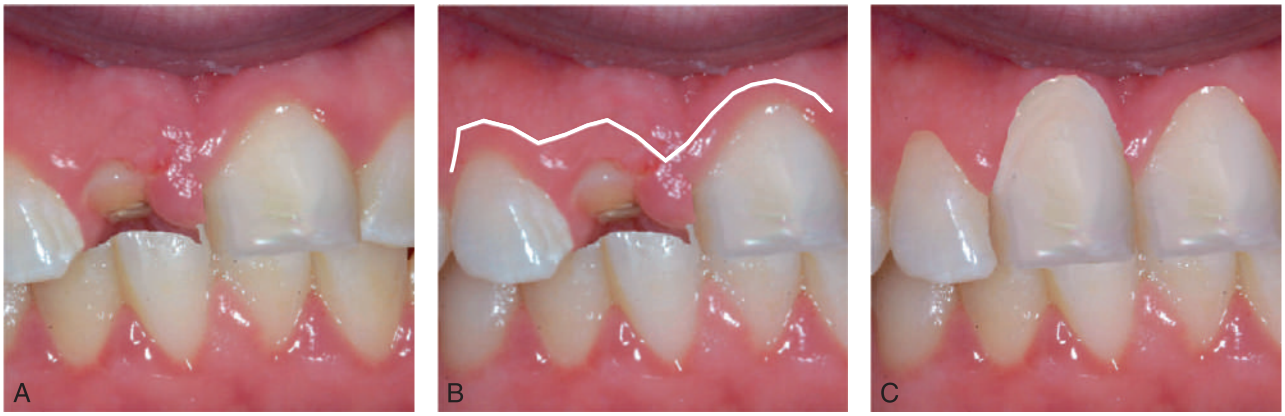

Fig. 5.20 (A) Maxillary right central incisor has fractured at the gingiva. (B) Surgical crown lengthening would necessitate removal of gingiva and bone around all three adjacent teeth (indicated by curved white line). (C) The result would be longer, uneven teeth.

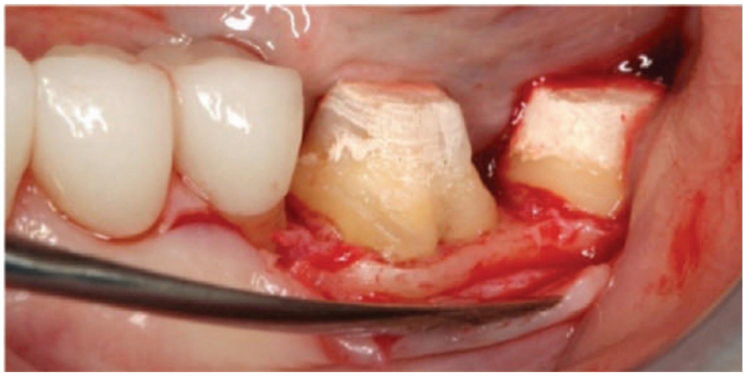

Fig. 5.21 Right mandibular first molar. The previous fixed restoration margin created a roof to the furcation exacerbating if not causing the periodontal problem. Traditional crown lengthening would have removed 2 to 3 mm of additional supporting bone and made the situation even worse.

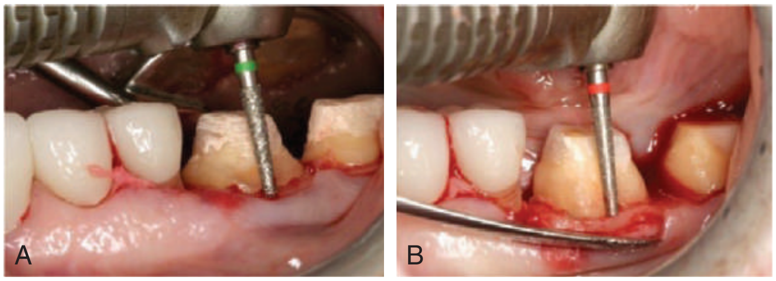

Fig. 5.22 (A) Biologic shaping (BS) removes all the existing margins AND removes roof of class I furcation, making it cleansable. A class II furcation can often be changed into a class I or better. (B) Medium and then fine grit diamond rotary instruments are used to remove all previous margins from the tooth.

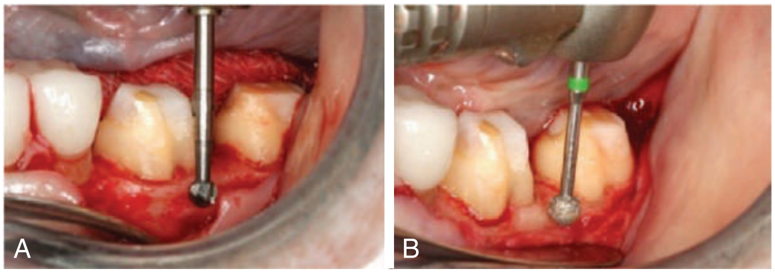

Fig. 5.23 (A) Nonsupporting bone shaped (osteoplasty) to improve gingival contours. Crown-to-root ratio is unchanged. The buccal flap is a split thickness flap and the periosteum is reflected only enough to allow access for the necessary osteoplasty. (B) The bone is shaped to allow smooth parabolic contours.

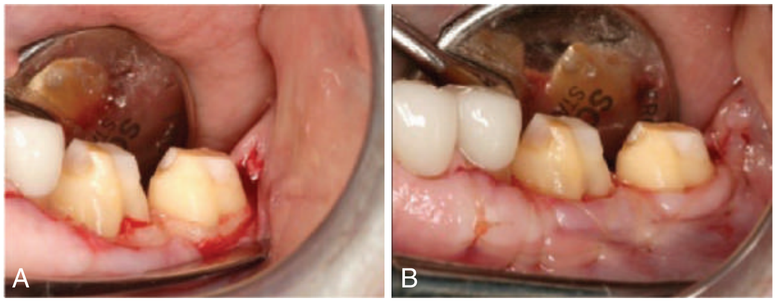

Fig. 5.24 (A) The roof of the furcation has been removed and the definitive restoration can be placed 0.5 mm supragingivally for cleansability. (B) The buccal flap split thickness leaves the periosteum intact to protect the bone, minimize postoperative pain, and allow the facial flap to be precisely sutured to the fixed periosteum just occlusally to the crestal bone.

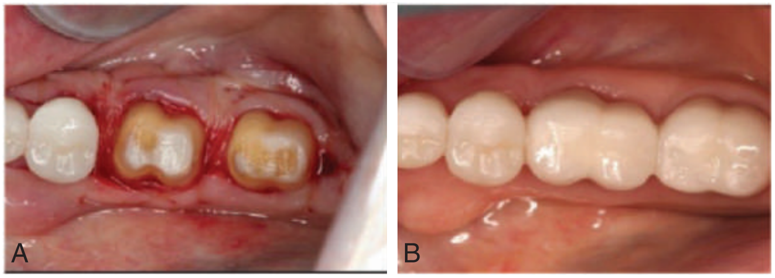

Fig. 5.25 (A) Biologic shaping is accomplished on all four sides of the tooth, leaving smooth contours that can be cleaned by the patient and dental hygienist. The interim restoration is shortened 2 mm occlusally to the sutured gingiva and recemented. This allows the biologic width to reestablish on the biologically shaped and cleaned root and additional keratinized gingiva is gained. Desensitizing and antibacterial medications are applied to the exposed dentin for 4 weeks. The dentist then relines the interim restorations 1 mm occlusally to the healing gingiva and allows an additional 8 weeks of healing before placing lite margins 0.5 mm supragingivally and making a definitive impression. (B) The contours of the definitive restoration must match the contours of the tooth.

Fig. 5.26 Biologic shaping eliminated the class 1 furcation, allowed the margin to be placed supragingivally, and maintained 100% of the supporting bone and gingiva. Note how the furcation contours are mimics in the definitive crown on the entire buccal surface.

Fig. 5.27 Buccal cusps on endodontically treated mandibular right 1st molar fractured almost at the level of the facial bone crest. Interim restoration has been placed.

Fig. 5.28 Removal of interim restoration reveals severely compromised tooth.

Fig. 5.29 Fracture extends almost to bone crest on mesial buccal root and a class 2 buccal furcation.

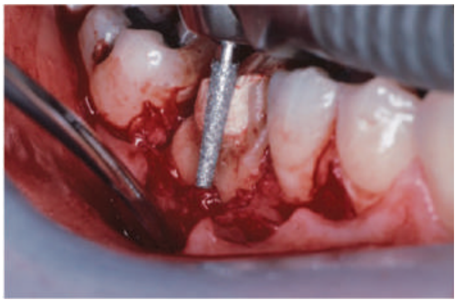

Fig. 5.30 Shaping of the root and crown started with a course grit diamond rotary instrument.

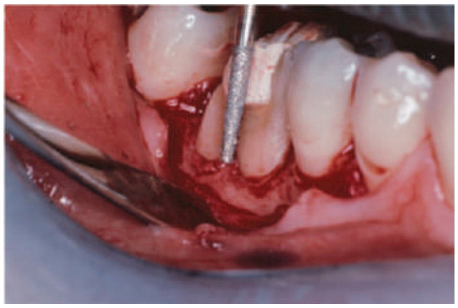

Fig. 5.31 The roof of the furcation is removed.

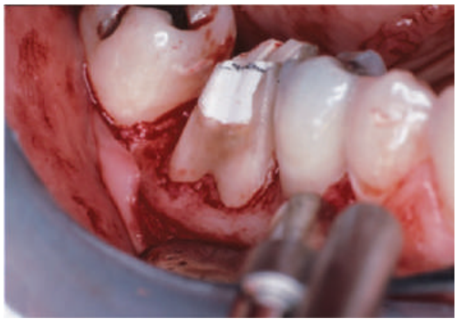

Fig. 5.32 The furcation has been totally eliminated as have all existing margins. Almost no bone has been removed.

Fig. 5.33 Margins on definitive restoration are supragingival; the gingiva has maintained its initial position. The crown contours mimic the shape of the tooth preparation. There is no horizontal probing depth into a furcation.

Fig. 5.34 The buccal sulcus depth is 1 mm with pressure firm enough to blanch the tissue.

Fig. 5.35 Occlusal view of extensively damaged teeth in the maxillary left posterior quadrant before caries removal.

Fig. 5.36 Occlusal view of extensively damaged teeth in the maxillary left posterior quadrant before caries removal.

Fig. 5.37 Removal of existing restorations and caries. Pulp exposure on the second molar required endodontic treatment.

Fig. 5.38 Minimal remaining tooth structure.

Fig. 5.39 Bonded resin foundation restoration has been placed and prepared with a feather-edge margin.

Fig. 5.40 Note the minimal ferrule.

Fig. 5.41 Caries removed, bonded resin foundation, interim restorations are cemented with polycarboxylate cement. Ready for biologic shaping.

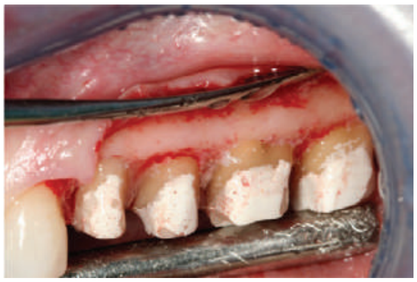

Fig. 5.42 A split thickness flap is reflected.

Fig. 5.43 Minor supporting bone removal (ostectomy), mostly reshaping the roots and osteoplasty. Scaling and root planing during surgery does not remove 100% of calculus and endotoxins, but the shaping of the entire root during biologic shaping does. The areas with bleeding are the only places supporting bone has been removed.

Fig. 5.44 The flaps have been sutured to the periosteum just occlusally to the bone crest. The biologic width was allowed to reestablish itself over the next 3 to 4 months of healing because of the supragingival margins on the interim restorations.

Fig. 5.45 The mesial root concavity on the first premolar has been eliminated, facilitating access to the area for cleaning.

Fig. 5.46 Note the convex keratinized interproximal gingiva instead of the previous non-keratinized concave gingival col.

Fig. 5.47 Chamfer margins have been placed 0.5-mm supragingivally, facilitating impression making and not compromising the periodontal health.

Fig. 5.48 Ideal gingival health and adequate tooth structure and ferrule for long term prosthetic predictability.

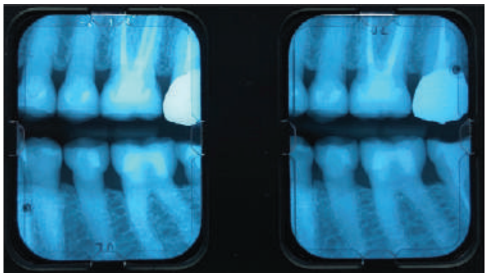

Fig. 5.49 Radiographic image. Excellent restorative margins and abundant supporting bone for long term stability.

Fig. 5.50 Note the excellent gingival health and esthetics in the definitive restorations. Traditional crown lengthening would have resulted in long crowns and exposure of the furcations compromising long term predictability.

TABLE 5.5 Comparison of Traditional Crown (TCL) Lengthening With Biologic Shaping (BS)

	Traditional Crown Lengthening	Biologic Shaping	Rational
Crown to root ratio	Increases	Maintains existing	BS often results in no supporting bone loss.
Cleansability of the sub gingival root	Makes it more difficult	Enhances cleansability	BS reshapes roots to eliminate furcations, root grooves, CEJs, existing margins
Gingival col area	Remains convex and unkeratinized	Converts to concave and keratinized	BS increases mesial-distal space between roots and the healing is similar to an edentulous ridge.
Eliminates calculus and endotoxins	Somewhat but some remain	Removes 100%	Calculus and endotoxins penetrate 0.25–0.5 mm into cementum, and 100% cannot be removed with scalers and ultrasonics. BS removes as much cementum as necessary to create a cleansable root surface.
Existing margins	Unchanged	Removes 100%	BS removes all margins on the tooth.
Keratinized tissue	Unchanged or reduced	Increases	BS places the flap just over the crestal bone and allows the biologic width to grow coronal.
Furcation	Makes them worse	Eliminates or reduces	BS opens up furcation and removes the roof, allowing future access for plaque removal
Postoperative pain	Yes	Less	The periosteum is most often never reflected from the bone.

CEJ, Cementoenamel junction.

that creates bulky contours that prevent smooth gingival contours. The surgeon then formulates a plan and shapes the root and crown to eliminate the existing margins and minimizes any contours that will affect future cleansability (see Fig. 5.21).[70] The non-supporting bone is then shaped to create smooth, parabolic architecture. Finally, if necessary, the supporting bone is shaped as conservatively as possible to create the crown length necessary for the definitive restoration. The margins of the previous restorations are completely removed during this process. The periosteal layer is not reflected from the underlying bone in most situations. The overlying gingival flap and the root are evaluated, any areas with bone dehiscences or less than 5 mm of dense connective tissue are augmented with a connective tissue graft sutured between the periosteum and the overlying gingival flap. The gingival flap is sutured at the junction of the root and the osseous crest (see Figs. 5.31 and 5.32). Exposed dentinal surfaces are treated with desensitizing medications after which the interim restorations are modified to ensure all margins are supragingival by at least 2 mm and are recemented. The restorative dentist replaces the interim restorations in 4 weeks; however, no new preparation margins are created at this time. The new interim restoration is placed 1 to 2 mm supragingivally. The surgical site is allowed to reestablish a healthy biologic width, and at approximately 4 months light chamfer margins are placed just slightly supragingivally (see Figs. 5.33 and 5.34) after which the restorations are completed (see Fig. 6.35). It is imperative that the contours of the restorations follow the contours established by the root anatomy.

BS has many advantages over conventional crown lengthening. It requires less removal of supporting bone than the more common TCL. Placement of the gingival flap at the junction of the root and alveolar bone and supragingivally interim restorations allow the healing process to develop a stable biologic width with minimal sulcus. Conventional surgical crown lengthening increases the crown/root ratio and results in a greater loss of gingiva and bone from adjacent teeth. The root anatomy of posterior teeth become much more irregular as they move apically. Conventional surgical crown lengthening removes bone but does not change the root profile. BS alters the root surface to eliminate or greatly reduce the irregularities and concavities. Normal interproximal anatomy consists of a buccal and lingual papilla connected by an un-keratinized gingival col. Bacterial invasion through this un-keratinized col is one of the etiologic factors in the development of an initial periodontal infection.[71] BS increases the mesio-distal space between adjacent teeth. As a result the gingival tissue heals in the same manner as an edentulous ridge with a convex shape that is covered with a dense connective tissue. Well executed BS should allow the patient to easily clean the tooth with a toothbrush and dental floss and provide similarly improved access to a dental hygienist's instruments.

The disadvantages of BS are few. It is a significant improvement compared with TCL but requires close coordination between highly skilled restorative and surgical team members. Hundreds of treated patients with over 35 years of survival have been documented of teeth that most dentists would have likely extracted and restored with an implant. However, with dental implants, long term maintenance issues remain a concern. Treating peri-implantitis, screw fractures or loosening, and other complications can be costly to the patient and the dental team. Our first priority should be keeping the natural tooth for as long as possible, and BS is one of the options to do so.

Surgical guides can be fabricated from a traditional hand waxed diagnostic cast or utilizing digital technology. These guides can be very helpful conveying the desired location for the gingival margin. The resolution of cone beam computed tomography is not accurate enough to reliably demonstrate the thin bone on the facial surfaces of dental roots. Reflection of a gingival flap is necessary to successfully evaluate and treat biologic width problems. A surgical guide is a tool that conveys the desired location of the gingival margin, but it is the skill and knowledge of the dentist directly visualizing the bone, root anatomy, position of the cementoenamel junction (CEJ), thickness of the connective tissue and other factors that create the final desired result.

PAPILLA

The ideal interdental gingival papilla fills the interproximal embrasure created by (1) the lateral walls of adjacent teeth, (2) coronally by the base of the interproximal contact, and (3) apically by the coronal aspect of the attachment. The clinician can change #1 and #2 with restorative dentistry, orthodontics, or both. The tip of the papilla will extend 5 mm above the level of the interproximal bone (3 mm above the attachment) when the interproximal embrasure is ideal.[72] Spear and Clooney have suggested "… viewing the papilla as a balloon of a certain volume sitting on the attachment. The balloon of tissue has a form and height dictated by the gingival embrasure of the teeth. With an embrasure that is too wide, the balloon flattens out, assumes a blunted shape, and has a shallow sulcus. If the embrasure is ideal width, the papilla assumes a pointed form, has a sulcus of 2.5 to 3.0 mm, and is healthy. If the embrasure is too narrow, the papilla may grow out to the facial and lingual, form a col, and become inflamed."[73]

This suggestion can be applied when evaluating a papilla that does not adequately fill the interproximal embrasure. First, the dentist measures the distance from the papilla tip to the bone crest. If this distance is less than 5 mm, the dentist can compress the balloon by adding restorative material to the mesial and distal tooth walls lateral to the papilla. This will push the balloon (papilla) coronally up to THE 5-mm distance from the bone crest. If the distance from the bone to the papilla is 5 mm or greater, the proximal contact must move apically to the top of the existing papilla (Fig. 5.51). When adjacent roots diverge, the proximal contact has moved coronally, and the interproximal embrasure is enlarged. Orthodontic movement to parallel the roots may improve the contact location, narrow the embrasure, and result in a taller, more pointed papilla (Fig. 5.52).

OVATE PONTICS

The extraction of a tooth entails removal of the proximal contact and half of the interproximal embrasure; as a consequence, the papilla is no longer compressed but flattens out, and esthetics are compromised. The papilla can be maintained if at the time of extraction an ovate pontic is created that will provide the proximal contact and lateral embrasure form needed to support the papilla.[74] Ovate pontics are usually inserted 2.5 mm into the extraction site. The size and shape of the ovate pontic should be comparable to the morphology of the extracted tooth. A site preservation bone grafting procedure should be performed at the time of the extraction. If bone levels remain stable, the papilla will also be stable. A well-formed ovate pontic will seal the extraction socket and aid in retaining the bone graft within the socket. After 4 weeks, the ovate pontic should be reduced to extend into the socket 1.5 mm to allow for oral hygiene (Fig. 5.53).

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

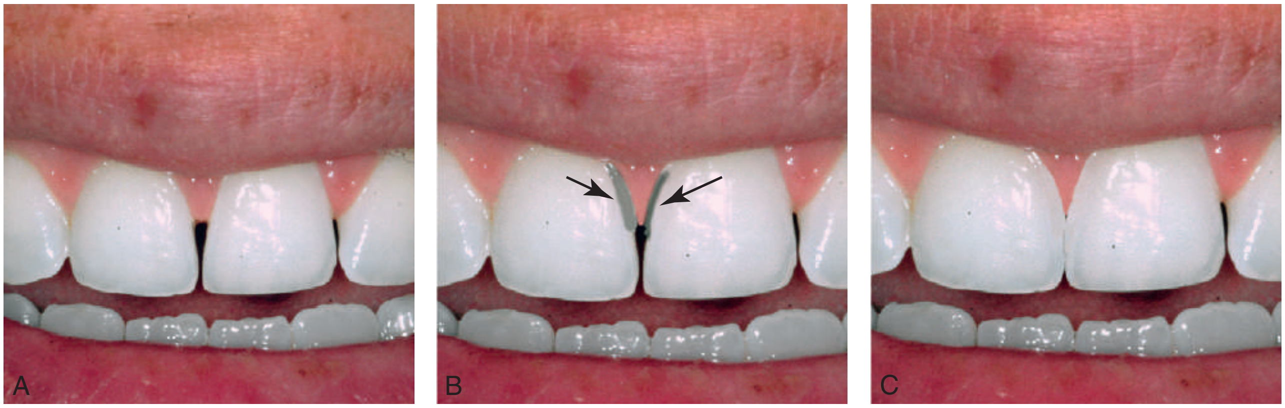

Fig. 5.51 (A) Papilla does not fill embrasure. (B) *Arrows* indicate proposed subgingival extension of laminate veneer pushing papilla laterally. (C) Laminate veneers create long incisal contact. The definitive result is that the papilla has been forced into a smaller defined shape, which creates a taller, more pointed papilla.

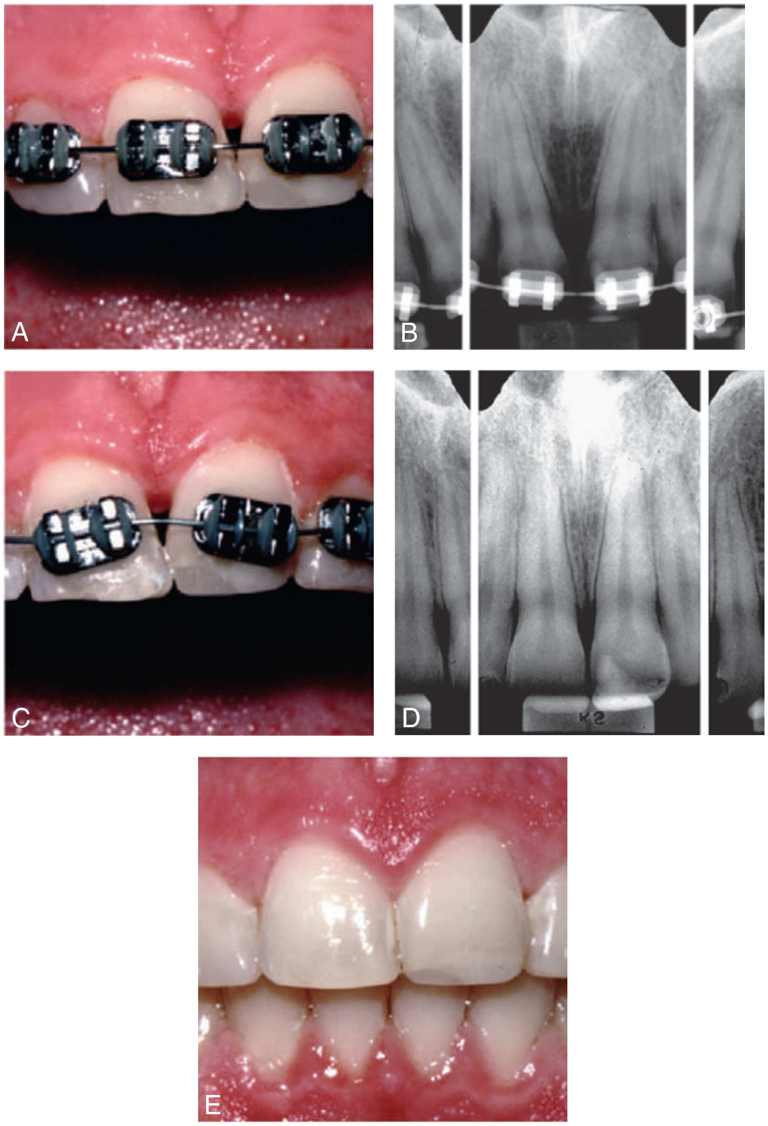

Fig. 5.52 (A) The papilla between teeth #8 and #9 does not fill the embrasure. (B) Radiograph reveals that the roots diverge, which results in a lack of pressure on the papilla. (C) Orthodontics used to reposition the roots. (D) Radiograph reveals that the roots are now correctly aligned. (E) The papilla now fills the entire embrasure. (From Newman MG, et al. *Carranza's Clinical Periodontology*. 10th ed. St. Louis: Saunders; 2006.)

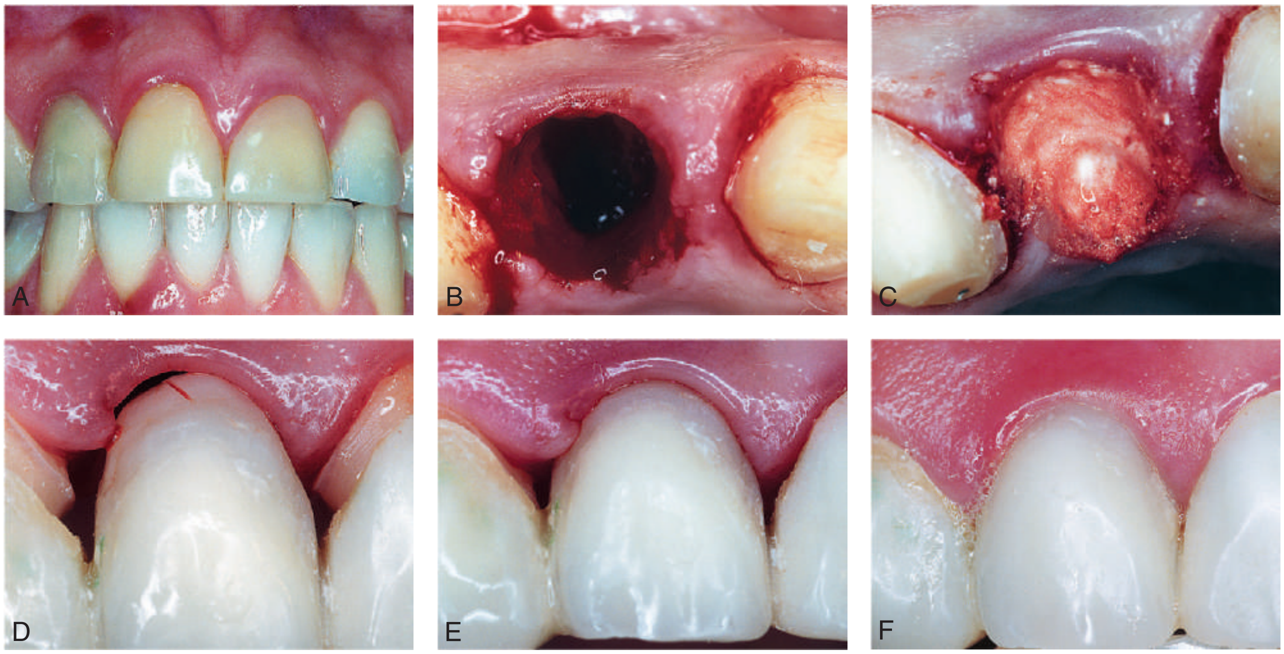

Fig. 5.53 (A) Maxillary right lateral incisor has failed despite endodontic treatment. (B) Socket after atraumatic tooth extraction. (C) Socket is filled with bone graft. (D) Interim fixed partial denture is fabricated. The ovate pontic extends 2.5 mm into the socket and makes an excellent seal of the bone graft, as well as providing lateral support for the gingival papilla. (E) Healing of extraction site after 8 weeks. (F) Definitive restoration with a well-maintained papilla. (From Newman MG, et al. *Carranza's Clinical Periodontology*. 10th ed. St. Louis: Saunders; 2006.)

of the gingival tissue between the bone and the newly created site for the ovate pontic must be at least 2 mm, lest rebound of the gingiva will occur. If the thickness is less, bone must be removed.

IMPLANT SITE MAINTENANCE AND DEVELOPMENT

Site development for dental implants in areas with insufficient bone consists of elevation of a gingival flap, placement of a bone graft, covering the bone graft with a barrier membrane, and releasing incisions so the flap can be elevated over the graft and membrane to allow tension free primary closure. Implant site development is highly technique sensitive (Fig. 5.54). The primary closure of the flap has to be maintained for 10 to 12 weeks to ensure maximum bone growth. The mobility of the gingival flap necessary to allow tension free closure results in gingival tissue that has been thinned with a compromised blood supply. The placement of a removable prosthesis to provide esthetics during the healing phase may inflict additional stress on this delicate area. Similarly, mastication over an unprotected gingival flap increases the risk for exposure of the membrane and bone graft. Short-term maintenance of teeth that have been deemed to have a poor or hopeless prognosis can allow them to serve as abutments for a fixed interim restoration that protects the gingival flap.[75,76]

EXTRACTION SEQUELAE

After a routine extraction, the average bone and gingival loss for a maxillary anterior tooth is 2.0 to 3.5 mm of vertical bone and gingival tissue, along with 1 to 2 mm of buccal and lingual bone and gingival loss. This loss will cause alterations in gingival margin levels between the prosthetic replacement tooth and the adjacent teeth. Patients with a thin biotype will develop more recession and bone loss. A thick biotype will have less bone and gingival loss.[77–80] Various bone grafts alone or in combination with barrier membranes have been employed at the time of extraction to prevent bone and gingival loss; collectively, these techniques are referred to as site preservation. These regenerative measures are partially successful and can minimize bone and gingival loss.[81–86] In the best-case scenario, a patient with a thick biotype will lose only 1 to 2 mm of vertical bone and gingiva after site preservation techniques in maxillary anterior teeth.

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

ORTHODONTIC EXTRUSION

In esthetic areas, orthodontic extrusion can minimize the risk for significant gingival changes following an extraction or correction

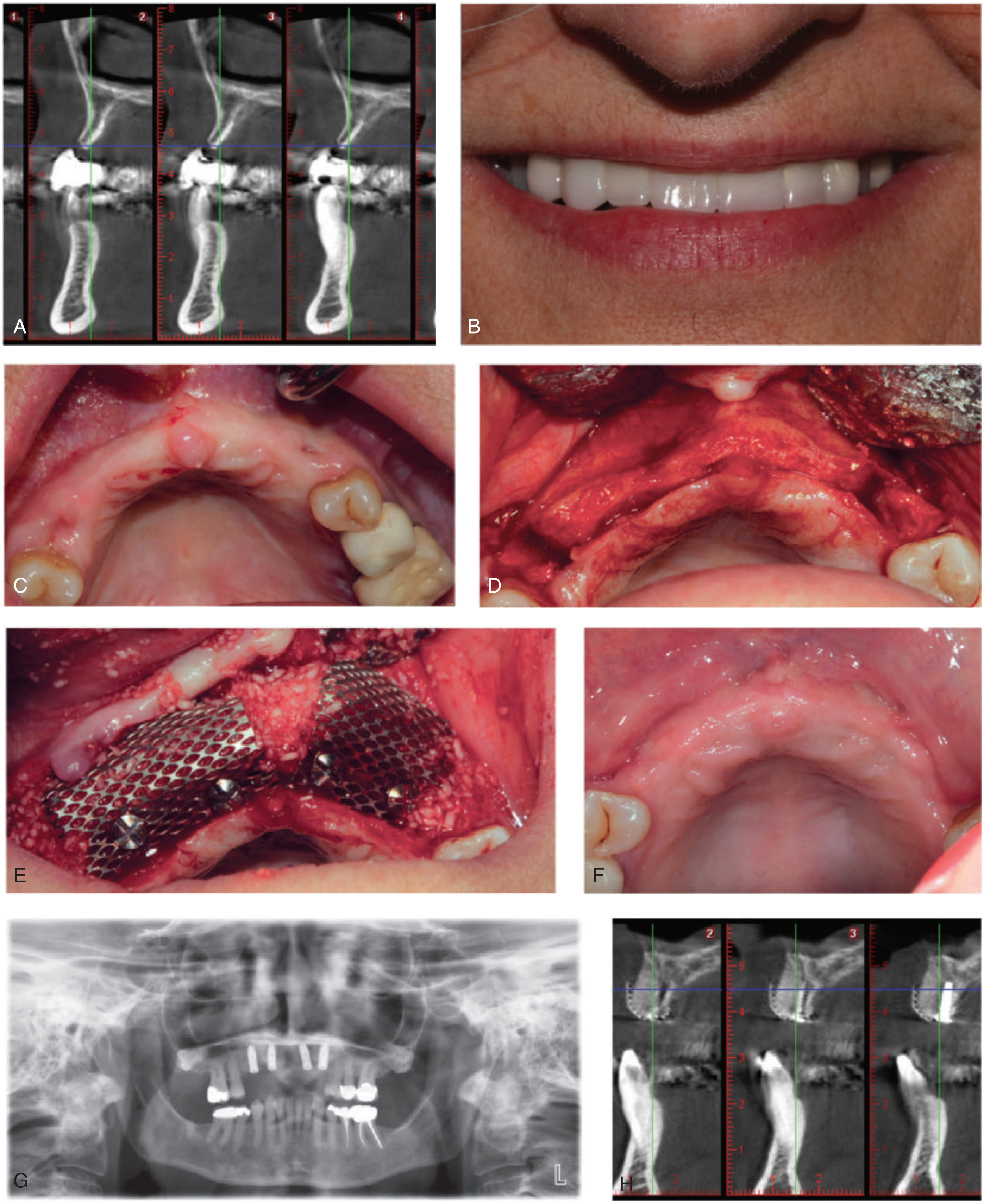

Fig. 5.54 (A) Radiographs of severely resorbed maxillary anterior ridge. (B and C) Pretreatment smile and edentulous ridge. (D) Initial full-thickness flap reflected. (E) Edentulous ridge has been decorticated, a bone graft has been placed, and two titanium membranes secured with screws provide space and stability. A resorbable membrane will be placed, and the flap will be sutured in layers. (F) Appearance 4 months after surgery. (G) Panoramic radiograph of four implants placed in the augmented ridge. (H) Radiograph of the significant bone growth in comparison with (A).

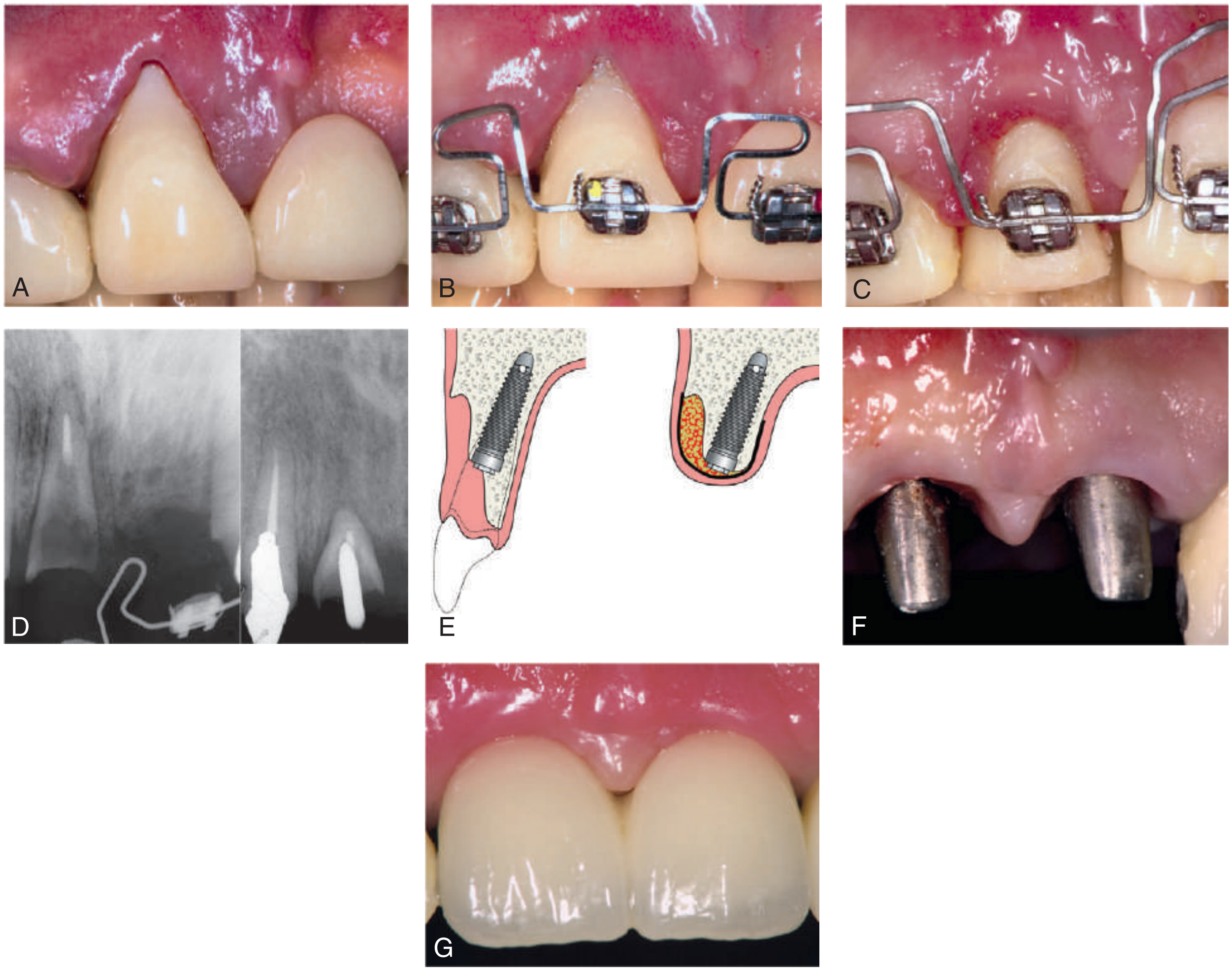

Fig. 5.55 (A) Failing maxillary right central incisor in a patient with a thin biotype and gingival recession. Extraction would create a severe esthetic challenge. (B) Orthodontic forced eruption (OFE) is initiated to move the tooth incisally and palatally. (C) Note the improved gingival contour. (D) Radiographs demonstrating almost 10 mm of OFE. (E) Illustration of bone development incisally and in width, achieved with OFE. (F) Implants placed immediately in conjunction with lateral ridge augmentation. (G) Final esthetic results that would have been very difficult to achieve without the aid of OFE. (From Watanabe T, et al. Creating labial bone for immediate implant placement: a minimally invasive approach by using orthodontic therapy in the esthetic zone. *J Prosthet Dent*. 2013;110:435.)

of a BWV.[87–89] A slow (0.5 to 2 mm per month), low-force extrusion (15 to 50 g) will bring new alveolar bone and gingiva with the tooth as it moves coronally (see Chapter 6). The tooth is extruded several millimeters beyond the adjacent teeth and stabilized for 2 months. The resulting excess gingiva and excess bone allow these tissues to approximate normal levels after extraction. An alternative approach is rapid orthodontic extrusion, in which a root is quickly moved out of the alveolus over a matter of weeks. Strong orthodontic forces are used, and a supracrestal fiberotomy (an intrasulcular incision to separate the periodontal ligament from the root surface) is performed every week to prevent the bone and gingiva from emerging with the extruding tooth. The tooth is then stabilized for 3 months, and bone and gingiva are evaluated before the definitive restoration is provided. Orthodontic extrusion can also be utilized to develop bone or expose more tooth structure for fixed prosthodontics. Whether rapidly or over a long period of time, when teeth are orthodontically erupted it is important to carefully monitor the occlusion and adjust the erupting teeth so that they have space to move and are not traumatized from occlusal forces.

Rapid orthodontic extrusion without supracrestal fiberotomy can be utilized to force eruption of the "hopeless" tooth 3 mm or more. This will move the gingiva and bone along with the tooth more coronally and loosen the periodontal ligament. As a result, the tooth will be easier to extract, 2 to 4 mm of excessive tissue and bone will undergo normally representative post extraction loss, and gingival levels will match those of the adjacent tooth. This concept of orthodontic extrusion can be taken a step further and used for implant site development in areas lacking sufficient bone, especially in a vertical direction (Fig. 5.55). Amato et al[87] utilized orthodontic extrusion to extrude 32 teeth with hopeless prognoses (mean: 6.2 mm). They were able to gain 4.0 mm of vertical bone height and 3.9 mm of vertical gingival movement. Together, with the increase in vertical gingival height, a coronal papilla movement also resulted. Light continuous pressure extrudes teeth 1 to 2 mm per month. To finalize the orthodontic extrusion, the tissues should be stabilized for 2 to 3 months before extraction, to allow the newly formed bone time to mature and mineralize.

Orthodontic movement of "hopeless" teeth for implant site development should be considered as equally efficacious as surgical implant site development. Augmentation of edentulous ridge width by approximately 3 mm is surgically predictable with particulate bone grafts and barrier membranes. Augmentation of edentulous ridge height is less feasible. The standard treatment is use of a vital block of autogenous bone.[90] Sources of autogenous bone block grafts include the ascending ramus, the chin, the hip, and the femur. Additional tissue to cover large block grafts is often harvested from the leg before the block graft itself. Orthodontics is more predictable and less invasive. Lateral augmentation of the newly developed vertical bone height from orthodontics is made more straightforward with the additional thick, keratinized gingival tissue.

SUMMARY

The periodontium that supports fixed prosthodontics is a conduit to immediate and long-term success. Preprosthetic procedures consist of periodontal supportive therapy (oral hygiene instructions, prescription rinses, and professional cleanings), surgically and orthodontically repositioning bone and free gingival margins. If a clinician were to overlook the periodontium in the initial phases of fixed prosthodontic care, complications will quickly develop before completion or immediately after therapy. Unesthetic positions of crown margins and pontics could result, as well with early dental implant failure. Maintenance is the most important factor for long-term success. Research makes it very clear that without maintenance, fixed prosthodontics will succumb to early failure.

STUDY QUESTIONS

1. Discuss and compare the 10 years' success of surgical pocket reduction surgery versus scaling and root planning.
2. Two- to three-month supportive periodontal maintenance (SPT) is effective in reducing the recurrence of periodontal disease in most patients. What other benefits occur as a result of frequent SPT?
3. Teeth with a questionable periodontal prognosis can often be maintained for a considerable time period. Please discuss how this affects the restorative treatment options.
4. Discuss the effect of thick or thin gingival biotype on the amount of anticipated gingival recession after an anterior extraction.
5. Describe the effect on crown-to-root ratio of surgical crown lengthening versus orthodontic forced eruption.
6. At the time of extraction of a maxillary central incisor, is a socket preservation bone graft sufficient to preserve the gingival papilla?
7. Biologic shaping (BS) minimizes changes to the crown to root ratio. Please discuss the reason for the minimal changes to the crown to root ratio.
8. A mandibular first molar with a buccal class 1 furcation has received BS and the roof of the furcation was eliminated. How should the future crown be modified?
9. The buccal flap reflection for BS is a split-thickness flap. What are the advantages of a split thickness flap.
10. What is the difference between osteotomy and osteoplasty?

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6

Mouth Preparation

Once a treatment plan is selected, the sequence of therapy is critical to the successful delivery of care. Mouth preparation is the process of creating the optimal foundation for the anticipated, fixed prosthodontic treatment. Each patient presents with unique needs; it is important that these are identified, and that the patient is educated to any risk factors to become active participants throughout the treatment and during future maintenance. Consequently, during mouth preparation all risk factors, periodontal disease, caries, biomechanical, and orthopedic concerns should be carefully considered, and appropriate measures should be undertaken to stabilize the dentition. This chapter sequentially describes how to address any deteriorating conditions that may be present and how to appropriately prepare the dentition for optimal fixed prosthodontics treatment.

MOUTH PREPARATION

As the scope of fixed prosthodontics continues to expand, it is increasingly clear that esthetic, biologic, and mechanical failures often result from inadequate mouth preparation and lack of patient education. Mouth preparation refers to procedures that must be accomplished before fixed prosthodontic treatment can be properly undertaken. Patient education refers to teaching patients about their own etiological risk factor(s) that contributed to their failures and training them to be motivated to have an active role in their own oral health. Long-term success is dependent on both. Patients need to understand the etiology of pathologies that are present, the importance of a maintenance plan that addresses the etiologic factors, and the importance of their engagement and motivation for their own oral health. During the mouth preparation phase of treatment, patient education begins. Rarely are implant-supported or tooth-supported prostheses provided without some initial therapy, often of a multidisciplinary nature because what causes the need for fixed prostheses also promotes other pathologic processes (caries and periodontal disease being the most common). These problems must be corrected in the early preparatory phase of treatment to stabilize the residual dentition and prevent further deterioration. Once initial treatment is completed, etiological factors are reevaluated. The success of the initial therapy must be confirmed before proceeding to the next phase of treatment. Just as a patient with periodontal disease needs routine reevaluation, a patient with a high incidence of caries should be carefully monitored throughout the mouth preparation phase for improved plaque control (Fig. 6.1) If such etiological factors have not shifted in a positive direction, the treatment plan may deserve reconsideration. Fixed prosthodontic treatment is successful only if restorations are placed in a healthy environment. Misguided attempts to try to help a patient by prematurely initiating fixed prosthodontic treatment often leads to early failure that could have been avoided. One example of such a misguided attempt is a well-intended decision to prepare a tooth for a crown, without first replacing a preexisting, defective amalgam or composite resin restoration. On preparation, the existing restorative material is dislodged, the presence of significant caries that was radiographically not readily discernible is discovered, and endodontic treatment is indicated, although its outcome appears to be somewhat unpredictable. The subsequent best-case scenario is an uncomfortable conversation with the patient, whereas a worse outcome might include tooth loss, resulting in the need for significant change to the previously developed treatment plan. In the latter scenario, patient confidence in the dentist is diminished.

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

Comprehensive treatment planning ensures that mouth preparation is undertaken in a logical and efficient sequence, aimed at bringing the teeth and their supporting structures to optimum health. Equally important is the need to educate and motivate the patient to maintain long-term dental health through never ending meticulous oral hygiene practices. As a general plan, treatment procedures should be performed in the following sequence:

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

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

- Preliminary assessment (Fig. 6.2A)
- Emergency treatment of presenting symptoms (see Fig. 6.2B)
- Oral surgery (see Fig. 6.2C)
- Caries control and replacement of existing restorations (see Fig. 6.2D)
- Endodontic treatment (see Fig. 6.2E)

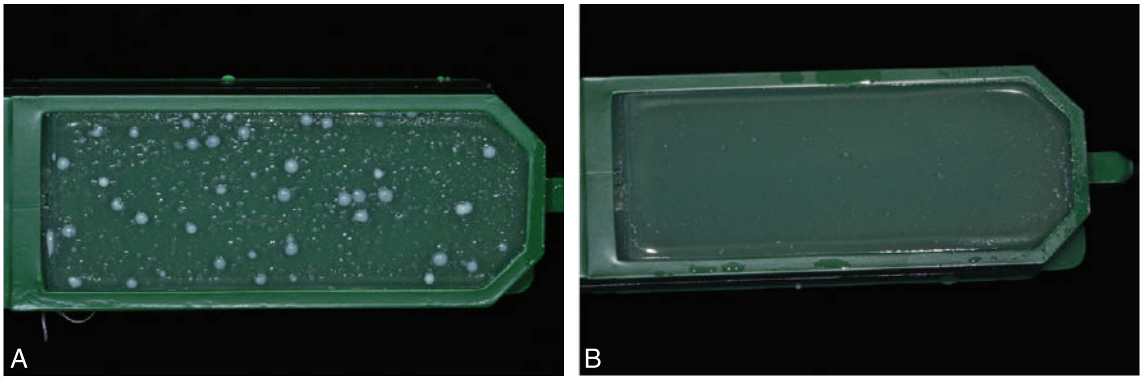

Fig. 6.1 (A) Cultured saliva grew colonies of *Streptococcus mutans*. It was determined that the patient had a high frequency of snacks throughout the day. Instructions were given to the patient to only have three meals a day. (B) Patient was highly compliant and motivated. At a following salivary test, no colonies of *Streptococcus mutans* were able to be grown.

- Definitive periodontal and implant treatment (see Fig. 6.2F)
- Orthodontic treatment
- Fixed prosthodontics (see Fig. 6.2G and H)
- Removable prosthodontics (see Fig. 6.2I)
- Follow-up care

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

ORAL SURGERY

Pathosis

During the initial examination, the dentist should recognize any hard and soft tissue abnormalities. If necessary, the patient can be referred to a surgeon for further consultation, treatment, or both. Diagnosis of pathologic conditions can be difficult; when in doubt, the practitioner should make the appropriate referral.

Hard Tissue Procedures

Tooth extraction is the most common surgical procedure involving hard tissue. To reduce overall treatment duration, it should be performed as early in treatment as possible so that other needs can be attended to during healing and osseous recontouring, after extraction. If bone augmentation is indicated to develop future implant sites, now is an appropriate time in the sequencing of therapy. However, clinicians must understand that not all bone grafts are equal. Seibert classified three different types of edentulous spaces (Fig. 6.3). A Seibert Class 1 ridge defect is deficient only in a horizontal dimension, whereas a Class 2 ridge defect is vertically inadequate with no horizontal defect. A Class 3 ridge defect has both horizontal and vertical dimensions. Generally speaking, a Seibert Class 1 ridge is more predictable to graft than a Class 2, and a Class 3 would be the most complex because it contains both a horizontal and vertical dimension (Fig. 6.4).

If teeth are treatment planned for extraction and residual ridges need augmentation for dental implants, a serial extraction technique sequence is helpful to maintain interim restorations and to not place pressure on grafts. With serial extractions, some non-restorable teeth may be recruited to temporarily support interim restorations while grafts are integrating. Once the graft has healed and the therapy is ready to proceed to the next phase of treatment, the non-restorable tooth that was supporting the interim restorations may be removed (Fig. 6.5).

Tuberosity reduction (Fig. 6.6) is also common, especially when space is inadequate to accommodate a prosthesis. Although maxillary or mandibular tori (Fig. 6.7) seldom interfere with the fabrication of a fixed partial denture, their excision may make it easier to design a removable partial denture and may improve access for oral hygiene measures.

Impacted or unerupted supernumerary teeth often should be removed to avoid potential future damage to adjacent structures. When teeth are in close proximity, a cone beam computed tomography (CBCT) scan is useful to determine the risk of creating a periodontal defect at a healthy adjacent tooth when removing the impacted one. If a periodontal defect will be created, the impacted tooth may best be left alone.

Orthognathic Surgery

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

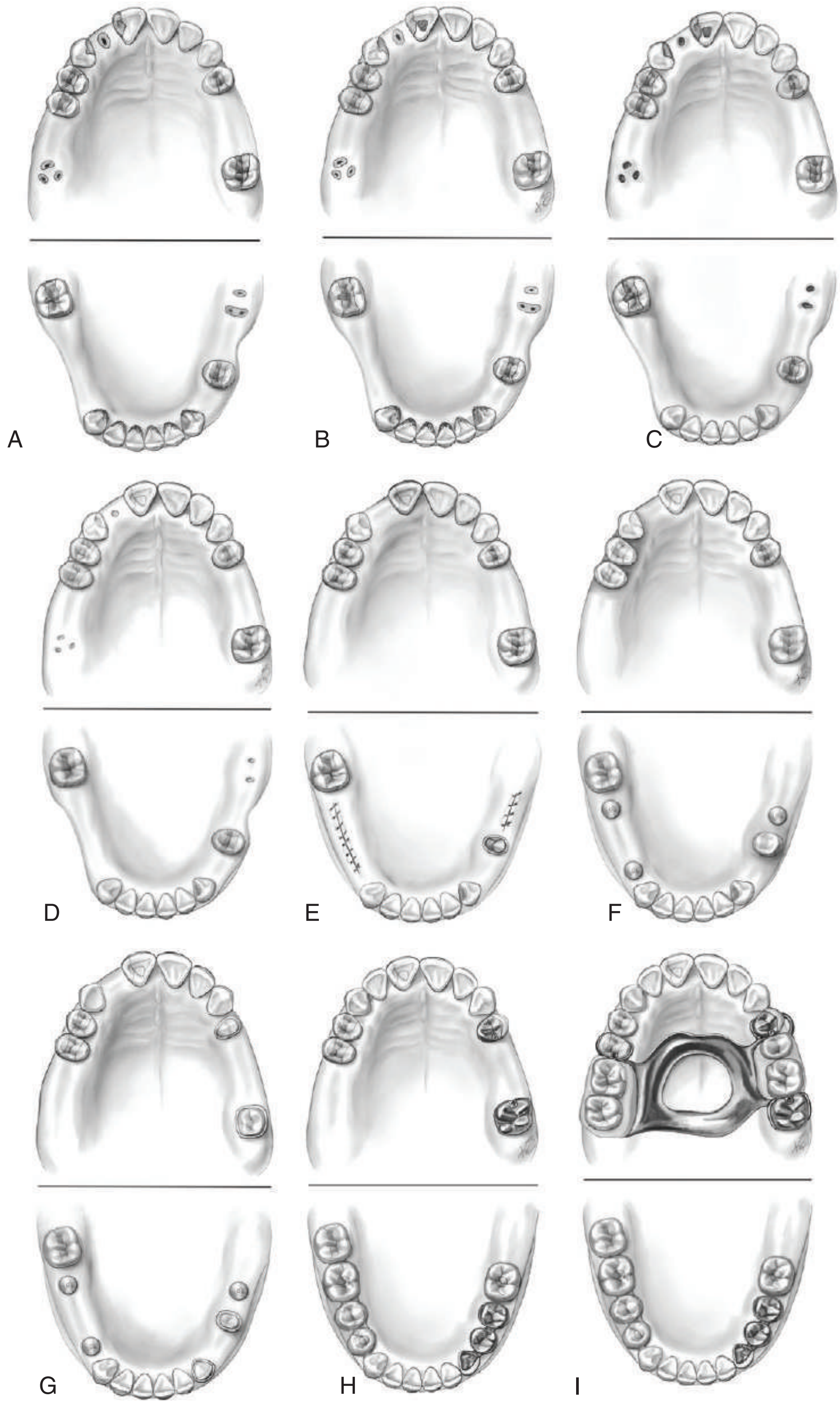

Fig. 6.2 Illustrated sequence of treatment. (A) Scenario in which pain seems to originate from the maxillary right central incisor. In addition, several teeth are missing, and retained roots, caries, calculus, and defective restorations are present. (B) Relief of the acute problem by endodontic treatment of the incisor. (C) Removal of deposits and unrestorable teeth. (D) Control of caries and replacement of defective restorations. The progress of ongoing disease has been halted. (E) Endodontic treatment. Implant placement in left and right posterior quadrants and post-and-core restoration and interim restoration are placed. (F) Definitive periodontal treatment. The now osseointegrated implants are uncovered. (G) Preparation of teeth for the definitive restoration. (H) Completed fixed restorations. Mandibular arch is treated with implant supported prostheses, and appropriate axial contours and occlusal rests have been incorporated in the maxillary arch to support a removable partial denture. (I) End of active phase of the treatment. Note that predictable management of complex prosthodontics involving fixed and removable prostheses can be facilitated by adopting the technique described in Chapter 3.

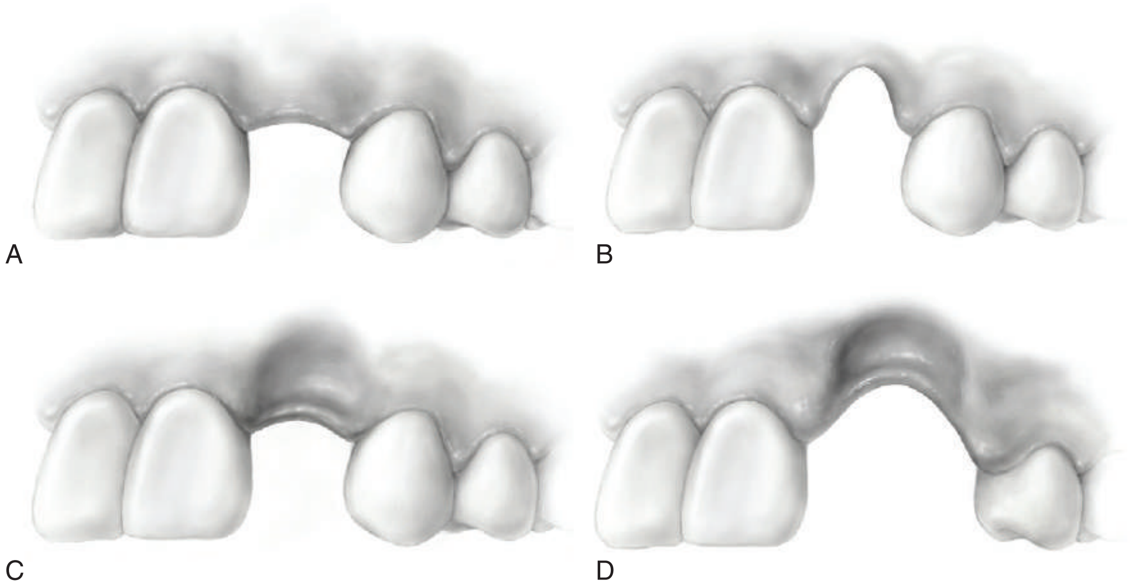

Fig. 6.3 (A) Example of missing tooth with no alveolar defect. (B) Seibert Class 1 alveolar defect has a loss of bone volume in the horizontal direction. (C) Seibert Class 2 alveolar ridge defect has a deficiency of bone volume in the vertical direction. (D) Seibert Class 3 alveolar ridge defect has both horizontal and vertical volumetric bone loss.

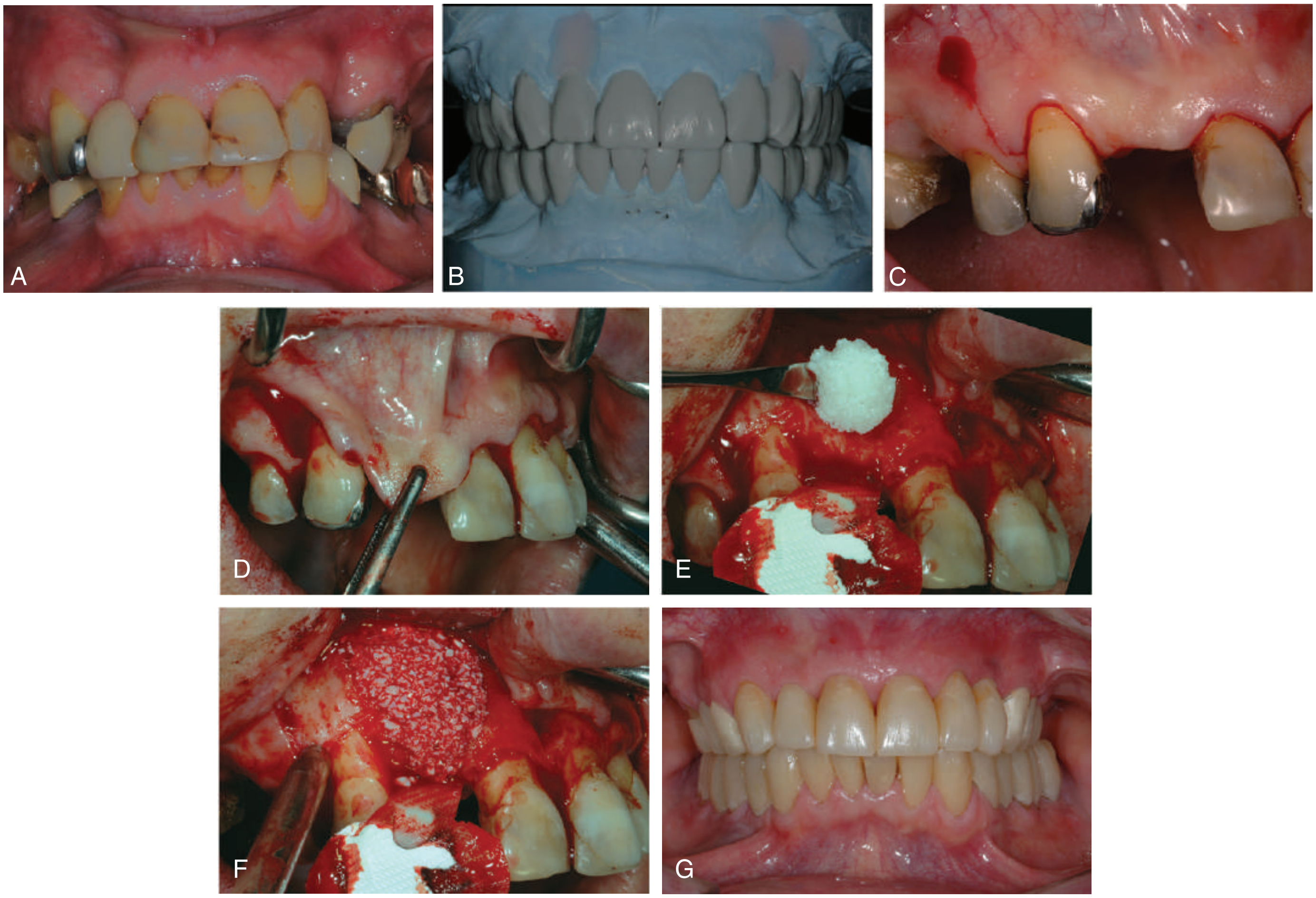

Fig. 6.4 (A) Patient initial presentation with loss of the right maxillary lateral incisor with a Seibert class 1 ridge defect and missing left maxillary canine with a Seibert class 3 defect. (B) Diagnostic waxing was done to guide the ideal ridge augmentation to support the ideal tooth positions. (C) Initial incision. (D) Releasing of the flap to minimize pressure on the future graft. (E and F) Bone graft and membrane placement. (G) Grafts healing and interim restorations designed from the diagnostic waxing inserted.

Fig. 6.5 (A) Initial patient presentation with failing fixed partial denture from maxillary right canine to left second molar. (B) The long span fixed partial denture was removed and the residual canines and left second premolar and first molar were retained to temporarily support an interim prosthesis during alveolar ridge augmentation and implant placement. Note the anterior Seibert class 3 defect. The left canine, second premolar, and first molar were not restorable and were planned for serial extraction during the therapy. (C) Ridge augmentation and dental implants placed. Interim restorations were immediately placed on the implants. (D) 1 month healing. (E and F) Definitive maxillary restorations. Maxillary right second molar and canine are individual tooth supported restorations and implant-supported fixed prosthesis from the maxillary right lateral to the left first molar location.

CARIES AND EXISTING RESTORATIONS

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

Preparation design can be more challenging for a foundation restoration than for a conventional restoration, particularly with regard to the placement of retention feature because it is important that these are not removed with the crown preparation. In general, when a crown is needed, the dentist should plan to replace any existing restorations. Once existing restorations and caries are removed, small defects, resulting from less extensive lesions, can often be incorporated in the design of a restoration or can be blocked out with cement (Fig. 6.8). The latter is

Fig. 6.6 Tuberosity reduction was indicated for this patient to accommodate a removable partial denture. (Courtesy Dr. J. Bergamini.)

Fig. 6.7 (A) Mandibular torus necessitating surgical reduction before the fabrication of a removable partial denture. (B) Buccal torus that was interfering with oral hygiene.

recommended on axial walls, where an undercut would otherwise result. If a small defect is present on the occlusal surface, it may be better to incorporate it into the definitive restoration, as long as all future line angles are rounded. If the geometry of

Fig. 6.8 Small defects *(arrow)* that would create undercuts are best blocked out intraorally with cement or resin.

the defect cannot be rounded without drastic removal of tooth structure, however, it is best to block it out. The difficulty, of course, is anticipating such future considerations during this preparatory phase of treatment. Predictability is even more challenging when an existing crown or fixed partial denture must be replaced. In those patients, the extent of damage is visible after the defective restoration has been removed. Detailed communication with the patient, in advance of such treatments, is of paramount importance.

FOUNDATION RESTORATIONS

A foundation restoration, or core, is used to build a damaged tooth to either ideal anatomic form before the tooth is prepared for a crown or ideal preparation form before cementing an interim restoration. Anatomic contour foundations may have to serve for an extended time before fabrication of the definitive prosthesis and should provide the patient with adequate function. They can also be used to establish a new vertical dimension to evaluate function, esthetics, and speech before determining the definitive treatment (Fig. 6.9). Foundation restorations should be contoured and finished to facilitate oral hygiene. Subsequent tooth preparation is greatly simplified if the tooth is built up to ideal contour, permitting preparation as if the tooth were intact. Depth grooves can be used to enable precise evaluation of occlusal and axial reduction (see Chapter 8), and preparation design will be consistent from tooth to tooth. Alternatively, a foundation restoration can be shaped to mimic the definitive crown preparation (Fig. 6.10). However, then an interim restoration will have to be used to create the final contours and function of the prepared tooth. Long-term interim restorations have a high risk of cement washout and subsequent secondary caries. As a result, dental patients with interim restorations that are in use over long periods of time, waiting for surgical healing or orthodontics, need to be on a monthly interim restoration maintenance plan. Monthly interim restoration maintenance is time consuming and costly for all parties. Whenever possible, an anatomic contour core restoration is preferred over a tooth with a core buildup and a cemented interim restoration, since many variables may necessitate postponing cementation of the definitive restoration. For

Fig. 6.9 (A) Diagnostic waxing creates a new occlusal plane for a patient. (B) Posterior implant supported interim restorations show the change between the existing occlusal plane and the new proposed one. (C) A thermoplastic mold of the diagnostic waxing is transferred to the mouth to build up the natural teeth with composite resin to the new occlusal plane. (D) Anatomic contour composite resin foundation restorations. (E) Reevaluation of the dentofacial analysis with interim restorations built at the new occlusal plane.

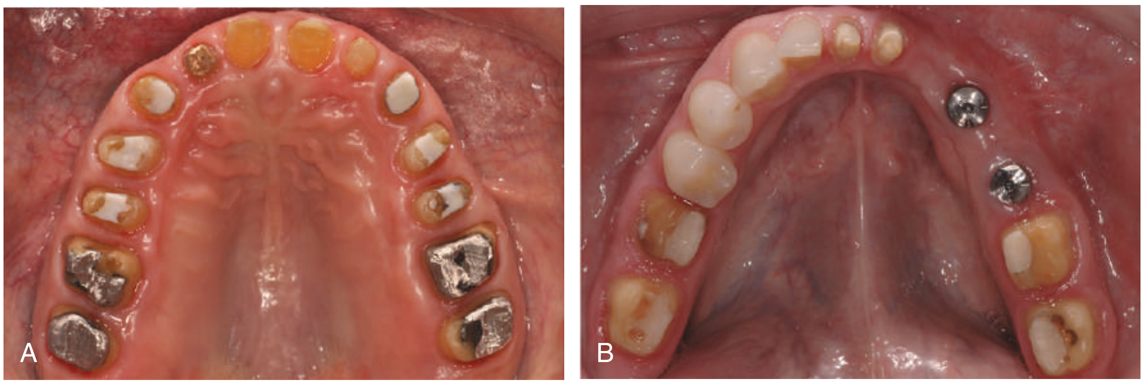

Fig. 6.10 (A and B) Examples of composite resin and amalgam foundation restorations incorporated into the definitive tooth preparations.

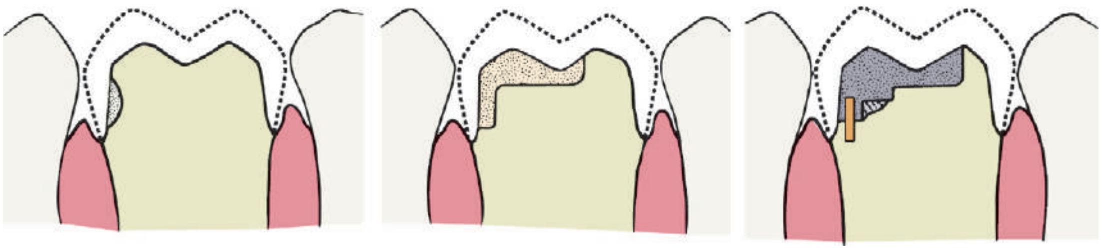

Fig. 6.11 The placement of a foundation restoration depends on the extent of damage to the tooth and should always be designed with the definitive restoration in mind. (A) Cement. This is suitable when damage is minimal. (B) Composite resin. Suitable for restoring larger defects. (C) Pin-retained amalgam. Suitable for extensively damaged teeth. A retentive well is often used instead of a pin.

Fig. 6.12 Composite resin used as a foundation material prior to complete crown preparations. (Courtesy Dr. A. Zonnenberg.)

example, delayed hard or soft tissue healing or the need for unanticipated endodontic treatment of another tooth preparation can easily impact treatment sequence and time.

Selection Criteria

Selection of the correct foundation material depends on the extent of tooth destruction, the overall treatment plan, and the operator's preference (Fig. 6.11). The effect of subsequent tooth preparation, for the restoration on the retention and resistance of the foundation material, must be carefully considered. Retention features, such as grooves, wells, or pinholes, should be placed sufficiently pulpally to allow for adequate reduction for the definitive restoration, without preparing away any retentive features of the core. During subsequent tooth preparation, adhesive retention may be helpful in preventing loss of the foundation.

Composite Resin

Composite resin exhibits many advantages. It does not require condensation as amalgam, it polymerizes rapidly, and it comes in many colors. Tooth-colored core material works well with translucent ceramic restorations because less opaque ceramics need to be used. Composite resins (Fig. 6.12) are much stronger than glass ionomers, a difference that is correlated with the higher diametral tensile strength of the composite resin.[4] They are strong enough for larger cores. However, the current materials have disadvantages, specifically their absorption of moisture and thermal expansion. These factors may contribute to the somewhat unpredictable longevity of the resin-dentin bond, which has been shown to decline as a function of time in simulated aging experiments.[5] Formulations are available that release fluoride, which may provide an anticariogenic benefit.[6] Bonding is achieved with a dentinal bonding agent or through etching a glass ionomer liner. Neither method alone develops the bond strengths needed to withstand high masticatory forces, and conventional undercut retention is also needed (Fig. 6.13). In general, the enamel bond is easier to accomplish and remains stronger over time than the bond to dentin.[7] However, many teeth that require core restorations have lost substantial amounts of enamel. Continued resin polymerization and its inherent thermal expansion coefficient, however, may lead to microleakage of the crown. Many dentists prefer to use a special colored core material, rather than conventional tooth-colored composite resin as a foundation because it allows them to more easily discern the composite resin-tooth junction; a benefit that is especially helpful in difficult to see subgingival finish lines in the posterior quadrants. Advantages and disadvantages of the available foundation materials are summarized in Table 6.1.

Dental Amalgam

The American Dental Association (ADA) states that amalgam is safe, affordable, and durable. Although amalgam is not used as much as before, for many it remains a material of choice for large posterior foundation restorations. It has good resistance to microleakage and is therefore recommended when the crown preparation will not extend more than 1 mm beyond the foundation-tooth junction.[8] It can be shaped to ideal restoration form and serves well as a long-term interim restoration. Its strength is superior to that of glass ionomers, and retention can readily be provided by undercuts, pins, or slots. Adhesive bonding systems, such as those based on 4-methacryloxyethyl trimellitic anhydride (4-META), are also available[9–12] and may further reduce leakage of the restoration.[13,14] Additional retention may be provided with the use of polymeric beads, supplied with the Amalgambond system.[15]

Amalgam requires an absolutely rigid matrix for proper condensation; otherwise, the foundation will break. Achieving proximal contact is straightforward because the material is condensable. Matrix placement can be demanding when a tooth with little remaining coronal tissue is restored. Amalgam has a longer setting time than resin-based foundation materials. This

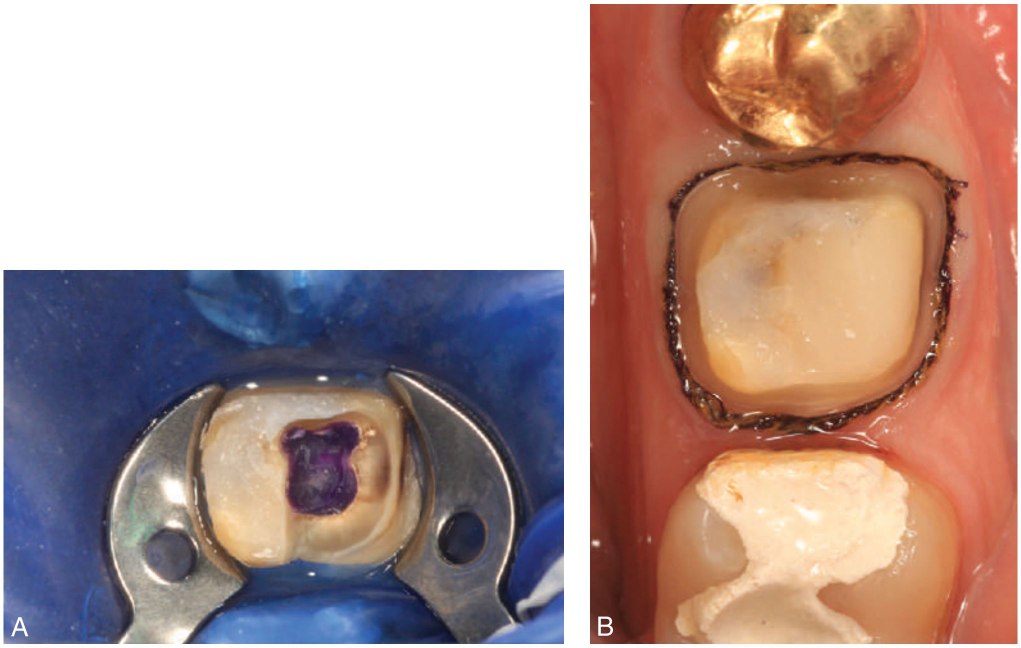

Fig. 6.13 (A) Endodontically treated molar with purple colored composite resin sealing off the root canal. (B) Definitive tooth preparation with composite resin foundation restoration.

TABLE 6.1 Foundation Restoration Materials

Material	Advantages	Disadvantages	Recommended Use	Precautions
Composite resin	Rapid setting Ease of use Bonding Tooth colored Anatomic contour buildup	Thermal expansion Setting contraction Microleakage	Most foundations	Moisture control
Glass ionomer	Rapid setting Adhesion Fluoride	Low strength Moisture sensitive[a]	Smaller lesions	Moisture control
Amalgam	Good strength Intermediate restoration	Preparation delay Condensation Corrosion No bonding[b]	Large foundations	Well-supported matrix

[a]Resin-modified formulations are less sensitive.
[b]Bonding can be achieved with 4-methacryloxyethyl trimellitic anhydride (4-META) products.

normally delays crown preparation until a subsequent patient visit. When this presents a problem, a rapid-setting, high-copper, spherical alloy may be chosen. With an electric high speed set at 10,000 to 15,000 rpm and a large diamond rotary instrument, large amalgam cores can be prepared immediately after condensation (Fig. 6.14). If an air-driven handpiece is used, 30 minutes of setting time should lapse before attempting to prepare a crown. Spherical amalgams are advantageous for foundation restorations because they have greater early strength than other amalgam formulations; thus, fracture soon after placement is less of a concern.[16]

The degrees of bacterial adhesion and viability are different on different dental biomaterials.[17] It is hypothesized that biofilm colonization on dental materials degrades its surface finish and enhances adhesion of bacterial plaque, which may increase risk for secondary caries.[18] In vivo, amalgam has been shown to have a thicker but less viable biofilm than the biofilms on composite resin and glass ionomers.[17]

Resin-Modified Glass Ionomer Cement

This is a suitable choice to block out a small lesion, but because of its inherent weakness, it is not recommended for larger core restorations. The material sets rapidly, enabling crown preparation with minimal delay. When placed correctly, glass ionomer adheres to dentin, although conventional undercut retention may be needed to supplement this. It is important to select a material with adequate radiopacity. A formulation that is less radio-opaque than dentin should not be used as a foundation

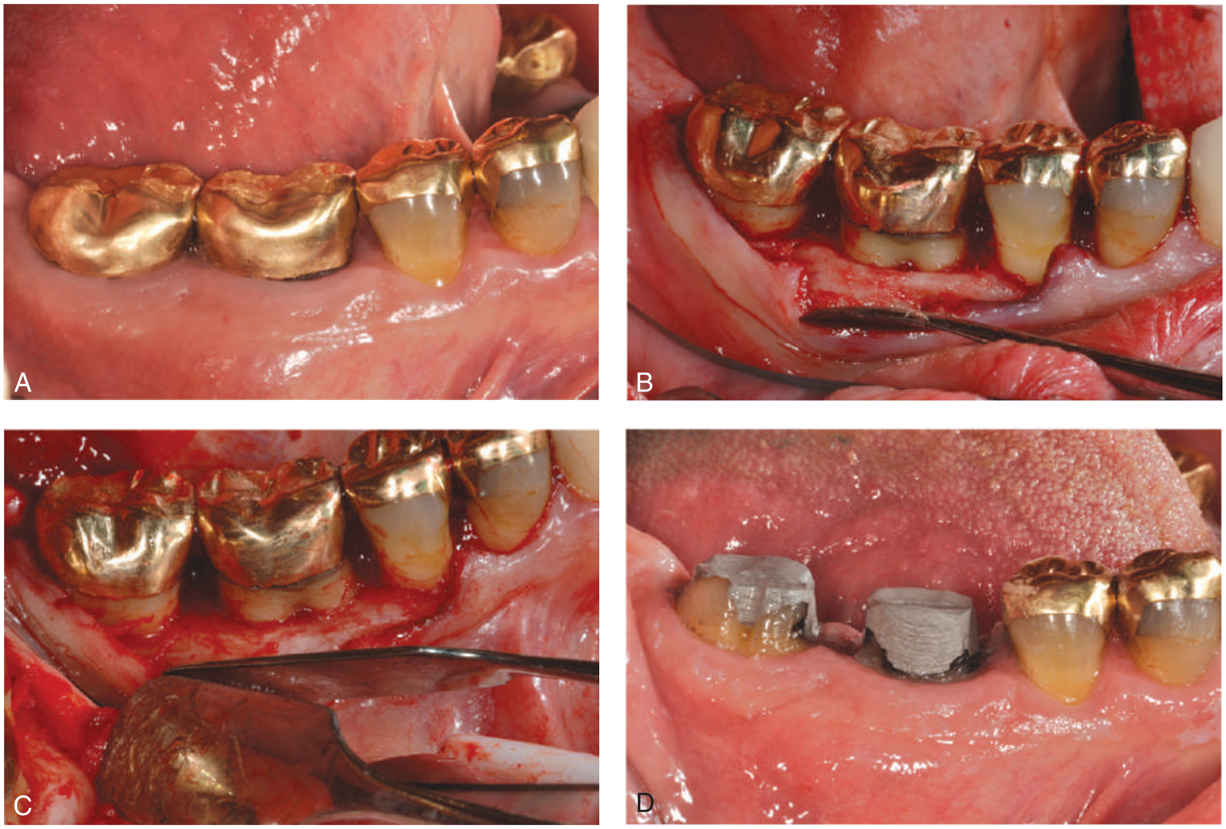

Fig. 6.14 (A) Initial presentation failing gold crowns and deep pocketing around the first molar. (B) Pre-osseous view of the alveolar ridge and bony defect around the first molar. (C) Post-osseous view after crown lengthening and smoothing of the bony contours. (D) Amalgam cores prepared the day of condensation with an electric high speed and diamond rotary instrument at a low rpm.

because its later radiographic appearance may suggest recurrent caries.[19] The presence of fluoride in resin-modified glass ionomers may help prevent recurrent caries. The chief disadvantage of glass ionomers is their comparatively low strength; thus, for longer term restoration of more extensive lesions, this material is inferior to amalgam or composite resin.[20,21]

Step-by-Step Procedures

Composite Resin Core

1. Isolate the tooth. Dental dam isolation is strongly recommended for moisture control, infection control, and optimum visibility. Placement follows techniques developed for conventional operative dentistry, although with extensively compromised teeth, placing the dental dam can be challenging. On occasion, cotton roll isolation must suffice.
2. Design the tooth preparation for the foundation restoration with the geometry of the intended crown preparation in mind. Ensure that future tooth preparation will not eliminate retention of the foundation. The preparation may differ somewhat from that for a conventional filling. The step-by-step guide highlights these differences.
3. Limit the extent of the outline form. In contrast to conventional preparations, which are extended to remove residual unsupported enamel or deep occlusal fissures, a more conservative outline is recommended for foundation restorations because the unsupported enamel will eventually be removed during crown preparation. Although minimizing foundation preparation outline form can help conserve supporting tooth structure, the foundation should be adequately extended for the detection of any carious lesions (Fig. 6.15A).
4. Retain unsupported enamel if convenient. For a conventional tooth preparation, unsupported enamel must always be removed; otherwise, such enamel may fracture during function and leave a deficient margin. However, for a foundation restoration, the unsupported enamel may be preserved, provided that the enamel-dentin junction is caries free. Preserving unsupported enamel may facilitate matrix placement and simplify contouring (see Fig. 6.15B).
5. Remove any carious dentin carefully and thoroughly with a hand excavator or a large round bur in a low-speed handpiece. The excavation of caries is performed in a circular, outer-to-inward method. The dentinoenamel junction is cleaned before the pulpal area to reduce the risk of contamination. Discolored, hard dentin can be left on the pulpal wall, but caries-affected areas at the enamel-dentin junction must be removed completely. Use of a caries detection agent helps reveal such areas. If pulpal exposure occurs during preparation, whether carious or mechanical, either endodontic treatment or tooth removal is necessary. A direct pulp cap is not a good choice when a fixed partial denture is planned; however, if endodontic treatment is selected and the pulp cannot be extirpated immediately, a suitable interim restoration should be placed.
6. Create optimum bonding and resistance form through maximizing the surface area. Good resistance to masticatory

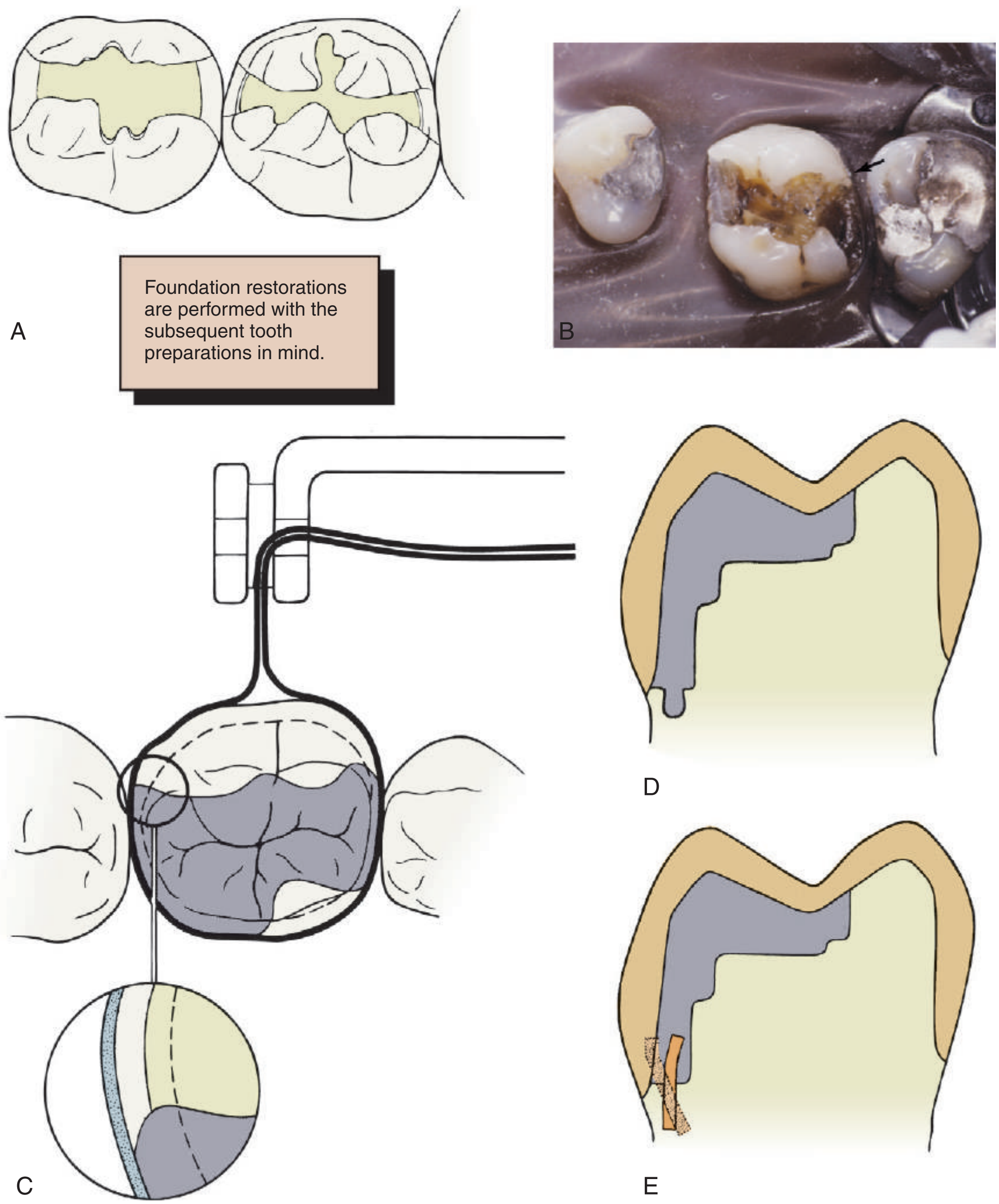

Fig. 6.15 The principles of preparation design for an amalgam foundation restoration differ slightly from those for a conventional extensive amalgam restoration. (A) The outline form of a foundation need not include fissures or proximal or occlusal contacts if caries can be removed completely. (B) Unsupported enamel *(arrow)* can sometimes be left when a foundation restoration is prepared. It may facilitate matrix placement and is removed when the crown is prepared. (C) Acute cavosurface margins are acceptable for a foundation restoration but not for a definitive amalgam. (D) Resistance form is improved by preparing the tooth in a series of steps perpendicular to the direction of occlusal force. (E) When pin retention is used, pinholes should be drilled slightly pulpally and at an angle to the root surface (solid line), in comparison with the way they are placed for a conventional extensive amalgam restoration (dotted outline). This ensures that foundation is retained after crown preparation.

forces is as crucial for a foundation as for a conventional restoration. Whenever possible, the tooth preparation should be limited to diseased tooth structure; however, to ensure that the foundation restoration has adequate retention, the preparation, if necessary, is augmented by wells, slots, or pins. Proper placement of retention features, in combination with bonding procedures, are essential to successful foundation restorations. The mechanical retentive features can be incorporated into the design in such a manner that they assist the bonding and will not be eliminated during crown preparation (see Fig. 6.15D and E).

These procedures can be a particular challenge with the extensive reduction necessary for a complete crown restoration. In comparison to pins, slots and wells create less residual stress in the dentin and thus reduce the risk of pulp exposure or damage.[22–27] They should be placed pulpally to the intended crown margin, at a depth of about 1 mm, with a small tungsten carbide bur. Careful placement of the primer, adhesive, and composite resin into the slots ensures improved restoration retention.

Pin location is dictated by root furcations and the size of the pulp chamber. In general, pins should be placed further pulpally than when conventional extensive pin retained restorations are provided; to prevent infringement on the pulp, they should be positioned at a slight angle to the long axis of the tooth.

Placement. The adhesive interface between the composite resin core and the tooth's dentin is vital to the longevity and durability of the restoration. Whether an etch-and-rinse or a self-etch technique is chosen is largely a matter of clinical preference. Although a statistically significant difference does not exist between the two techniques, the etch-and rinse technique appears to be slightly stronger.[28] Generally speaking, a multi-step adhesive system produces a higher bond strength to dentin than a one-step adhesive system.[29] As a result, a three-step, total-etch dentin bonding technique is still recommended.[30] Both light-polymerized and dual-polymerized composite resin materials are available. The cores can be bulk-filled or layered, depending on the selected composite resin system. Light-polymerized composite resin materials have the convenience of an extended working time, but concern exists about the adequacy of polymerization in deep areas. Since flowable composite resin has been shown to have a higher microtensile bond strength than a universal resin and bulk-fill resin, a flowable composite resin liner may be advisable.[29] The flowable composite resin also flows into small undercuts and irregularities and thus supplement some mechanical retention. A Mylar matrix is used to confine the material and provide good adaptation. Alternatively, a thermoplastic external surface form, made from a diagnostic setup, can be used to build each tooth up to ideal anatomic form.

Contouring and Finishing

Composite resin core materials are easily prepared with conventional diamond rotary instruments, although a light touch is needed to avoid gouging the surface. Contouring follows conventional practice if the foundation is to serve for any significant period. Such foundations should also be polished to facilitate plaque control. If the foundation is to be prepared shortly after placement, a more rudimentary occlusal contour is acceptable. However, occlusal form should be adequate to provide proper tooth stability. Moreover, all margins should be contoured properly because any residual excess will lead to plaque retention and soft tissue irritation, making subsequent preparation and especially margin placement more difficult.

ENDODONTIC TREATMENT

Assessment

During the initial data collection, attention must be directed toward potential endodontic needs of the patient. The clinical examination should include vitality testing of all teeth in the dental arch. This may be done with an aerosol cryogen spray, an "ice pencil" (conveniently made by filling an anesthetic needle cap with water and freezing), a heated gutta percha, or an electric pulp tester. Thermal testing is considered more useful because it may indicate the degree of pulpal inflammation, whereas electric testing reveals only whether a pulp is nonvital or vital. Tenderness to percussion should also be noted. Any abnormal sensitivity, soft tissue swellings, fistulous tracts, or discolored teeth should prompt suspicion of pulpal involvement.

Patients who have definite symptoms seldom present problems in diagnosis because pain is generally their chief complaint. When pulpal health is in doubt, however, patients should be examined radiographically during the mouth preparation phase, and the images should be carefully inspected for signs of periradicular pathosis (a radiolucency or widening of the periodontal ligament space). When the endodontic prognosis of a tooth is in doubt, radiographic findings (Fig. 6.16) should always be evaluated in reference to the results of percussion vitality and load testing.

Treatment

As a general rule, conventional (or orthograde), rather than surgical (or retrograde) endodontic treatment, should be performed if possible. This is not only because additional trauma results from the surgical approach but also because apicoectomy adversely affects the crown-to-root ratio and thus the periodontal support for the planned prosthesis. If an existing post prevents access to a recurrent periapical lesion, the post can usually be removed. Fiber composite posts are the easiest to remove, and the use of ultrasonic vibration is helpful in breaking the

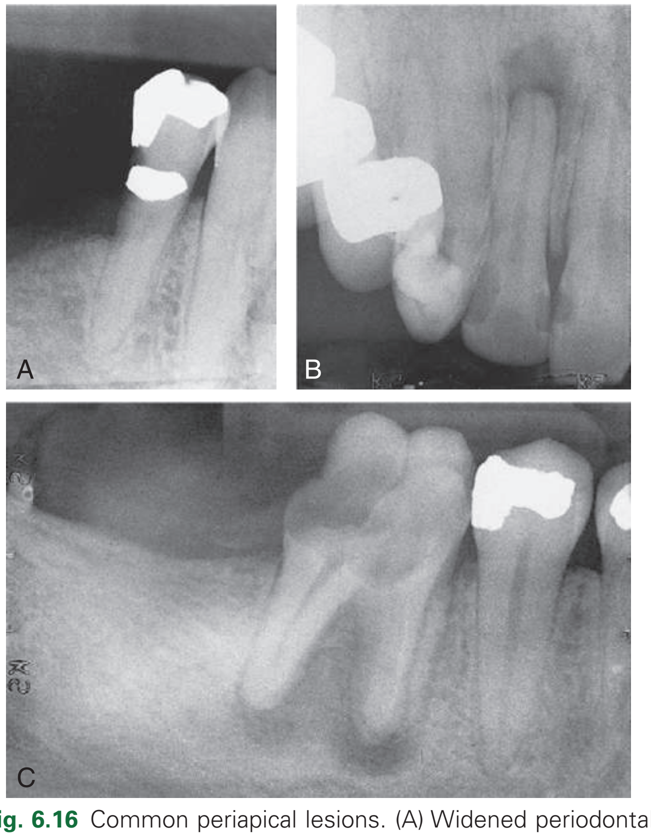

Fig. 6.16 Common periapical lesions. (A) Widened periodontal ligament space. (B and C) Large radiolucencies (established granulomas or cysts). (Courtesy Dr. G. Taylor.)

cement seal of a metal post (a Masserann kit has also shown some success with this; see Chapter 12). When a post-and-core restoration is needed in an endodontically treated tooth, 3 to 5 mm of apical seal should be retained (see Chapter 12).

When attempting to significantly recontour teeth with crowns, elective endodontic treatment may be required when there are moderate to severe horizontal and/or vertical problems with tooth alignment. Orthodontics to correct tooth malalignment is the preferred treatment and will reduce preparation encroachment on the pulp.

PERIODONTAL TREATMENT

Robert F. Baima • Rick K. Biethman

Unless a patient's existing periodontal disease has been properly diagnosed and treated, fixed prosthodontic treatment is doomed to fail. A careful evaluation of the periodontal health of the patient's dentition is prerequisite to the stabilization phase of treatment. Only once periodontal health has been re-established does it become feasible to arrive at a definitive fixed prosthodontic treatment plan. During each examination, probing depths, attachment levels, extents of mobility, crown-to-root ratios, furcal involvements, tissue health, the presence of calculus, and the efficacy of plaque control measures by the patient are noted (see Chapter 1). The periodontal treatments presented in Chapter 5 form the basis for an effective approach to management of chronic periodontal disease. In addition, specific periodontal procedures may be indicated to enhance the functional and esthetic outcomes of comprehensive fixed restorative dentistry. The following introductory discussion is augmented by more detailed descriptions of the various procedures in Chapter 5.

Gingival Tissue

The amount of gingiva necessary for long-term periodontal health is open to debate.[31,32] In a healthy mouth, subjected to minimal stress, a total lack of keratinized tissue may be acceptable.[33] In a mouth requiring comprehensive fixed prosthodontics, the stress levels are no longer minimal. For a tooth or implant to be treated with a restoration extending into the gingival sulcus, a band of gingiva (keratinized tissue) is recommended. Gingival recession can lead to mucogingival defects that are unstable when attempting to place crown margin. Miller's classification system identifies three types of gingival defects (Fig. 6.17). Although some clinicians say Miller's classification system is not robust enough for their practice, it is a simple method to quickly describe most gingival defects to professional colleagues. Where a mucogingival defect is present, or in areas of localized gingival recession, a graft or other gingival augmentation procedure should be considered.[34,35] Intervention must include eliminating causes, reeducating the patient in proper oral hygiene practices as needed, and proceeding with surgical procedures to reestablish a stable and maintainable periodontal status.

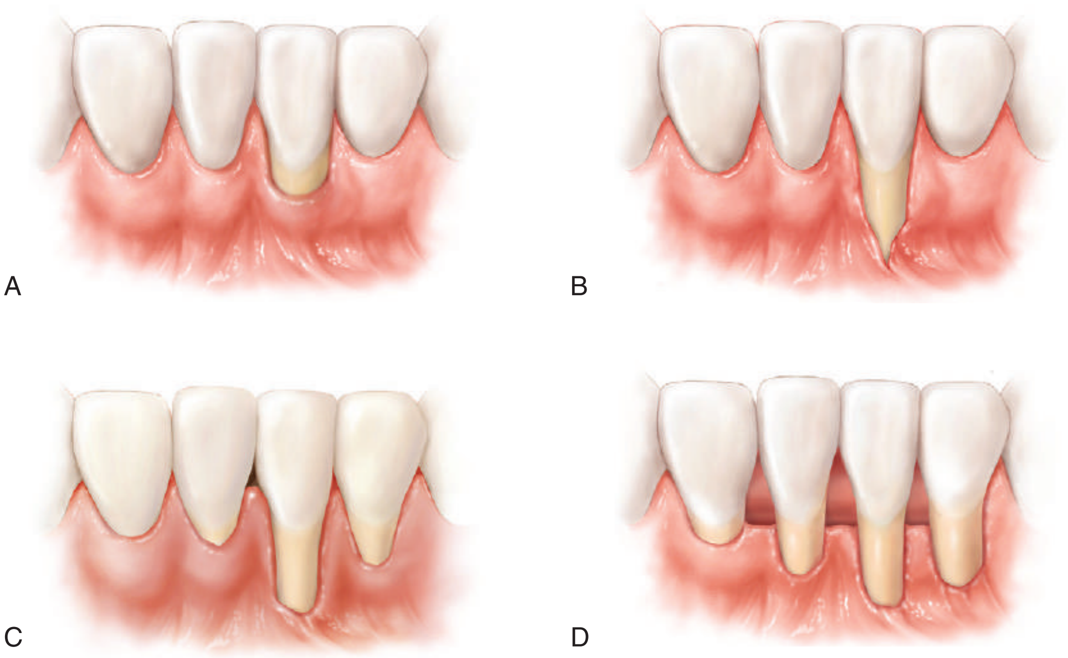

Fig. 6.17 Miller classification. (A) Class I Marginal tissue recession which does not extend to mucogingival junction (MGJ) and is not associated with alveolar bone loss in the interdental area. Complete root coverage is obtainable. (B) Class II Marginal tissue recession which extends to or beyond the MGJ and is not associated with alveolar bone loss in the interdental area. Complete root coverage is obtainable. (C) Class III Marginal tissue recession which extends to or beyond the MGJ and is associated with alveolar bone loss in the interdental area. Partial root coverage is obtainable. (D) Class IV Marginal tissue recession which extends to or beyond the MGJ and is associated with gross alveolar bone loss in the interdental area with exposure of more than one proximal root surface. No root coverage.

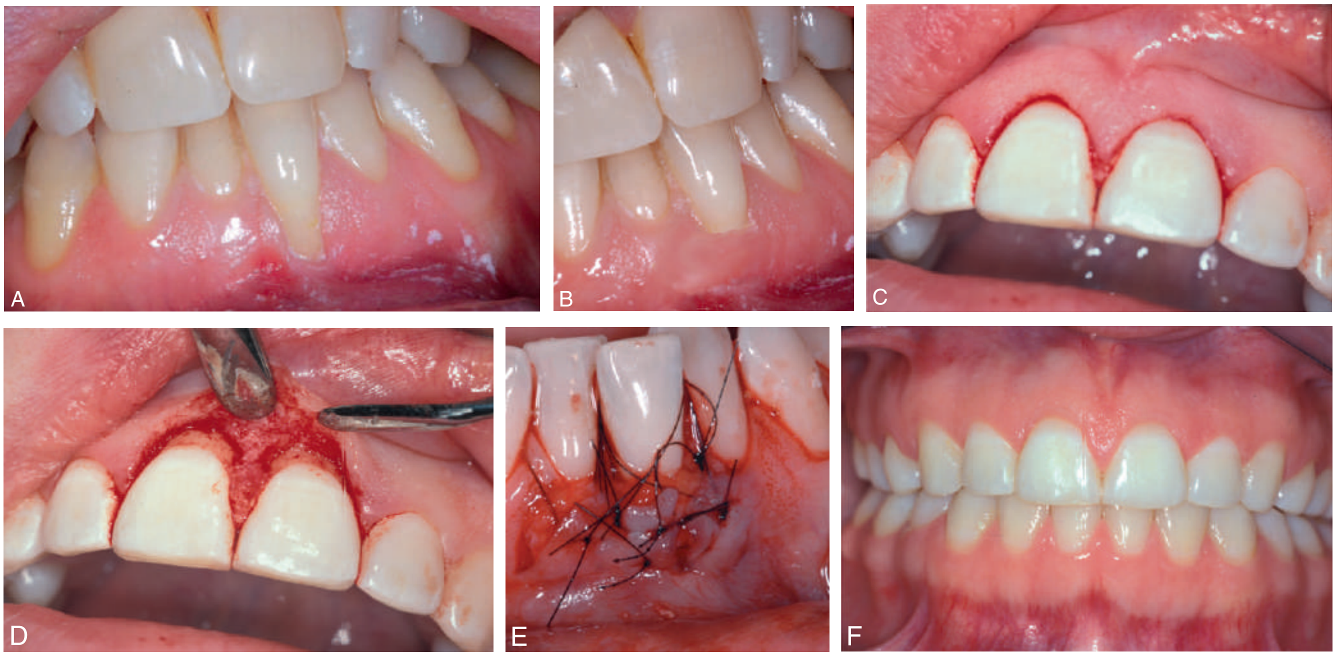

Fig. 6.18 Laterally positioned pedicle graft. (A and B) Localized recession around the left mandibular central incisor. The lateral incisor has an adequate band (width) of keratinized tissue, and so it is suitable as a donor site. (C) Bed preparation of the recipient site. An incision is made obliquely toward the site. (D) Releasing incision at the distal of the donor site. The graft is rotated into position over the recipient site. (E) Flap sutured in position. A free autogenous gingival graft may be used to cover the donor site. (F) The healed graft. There is almost always some loss of attachment (average, 1 mm) at the donor site.

Mucosal Reparative Therapy

Details of treatment depend on the specific pathologic processes present. Mucosal reparative therapy is indicated to increase the width of the band of gingiva through surgical grafting. Grafting techniques are described as follows.

The laterally positioned pedicle graft[36,37] (Fig. 6.18) is used for an area of recession or lack of gingiva on a single tooth, when amounts of gingiva in adjacent teeth or edentulous spaces are adequate. The pedicle graft is the most predictable treatment because of maintenance of the blood supply to the pedicle. It was first described in 1956.

A free autogenous gingival graft (Fig. 6.19) can be used to increase the width of gingiva in areas where necessary. The donor site most commonly used is the hard palate, although any area of keratinized tissues, such as an edentulous ridge or the retromolar pad, may be suitable. Healing requires approximately 6 weeks,[38–41] at which time the donor site and the grafted site should appear normal. Multiple teeth can be treated at the same time with the free gingival graft. This technique was the standard from 1963 to 1990.[42–44] It is still used today in nonesthetic situations in which the quality and quantity of keratinized tissue is paramount.

A coronally positioned (advanced) pedicle graft[45,46] (Fig. 6.20) is used when a single tooth or multiple teeth exhibit gingival recession and sensitivity. If the width of the gingiva is inadequate, a free gingival graft may be placed to increase it before the coronal positioning.

Since 1990, the most common gingival augmentation technique is the connective tissue graft (Fig. 6.21). This technique involves the use of a subepithelial connective tissue graft, harvested from the palate in a split-thickness manner, which allows the wound to be closed after removal of the graft. This approach minimizes patient discomfort at the donor site, and the color match is improved (Fig. 6.22). Connective tissue grafts can be combined with pedicle grafts and tunneling procedures to improve blood supply and survivability. Connective tissue grafts can be utilized to cover exposed roots and non-carious cervical lesion, to augment deficient ridges, and to attempt to rebuild papillas.[47–53]

Crown-Lengthening Procedures

Surgical crown lengthening (Fig. 6.23) may be indicated when the clinical crown is too short to provide adequate retention, without the restoration impinging on the normal soft-tissue attachment (biologic width, see Chapter 5).[a,54–57] Crown lengthening may improve the appearance of multiple short teeth. In some patients, an apparently unsalvageable tooth with extensive subgingival caries, a subgingival fracture, or root perforation resulting from endodontics can be successfully restored after crown lengthening. Surgical crown lengthening increases the crown-to-root ratio and results in a loss of gingiva and bone from adjacent teeth. A pretreatment decision must be made about whether the tooth should be removed or restored.

Crown lengthening may be accomplished either surgically or with combined orthodontic-periodontic[54–58] techniques, depending on the patient and the dental situation.

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[a] The term *biologic width* refers to the combined connective tissue-epithelial attachment from the crest of the alveolar bone to the base of the gingival sulcus.[34]

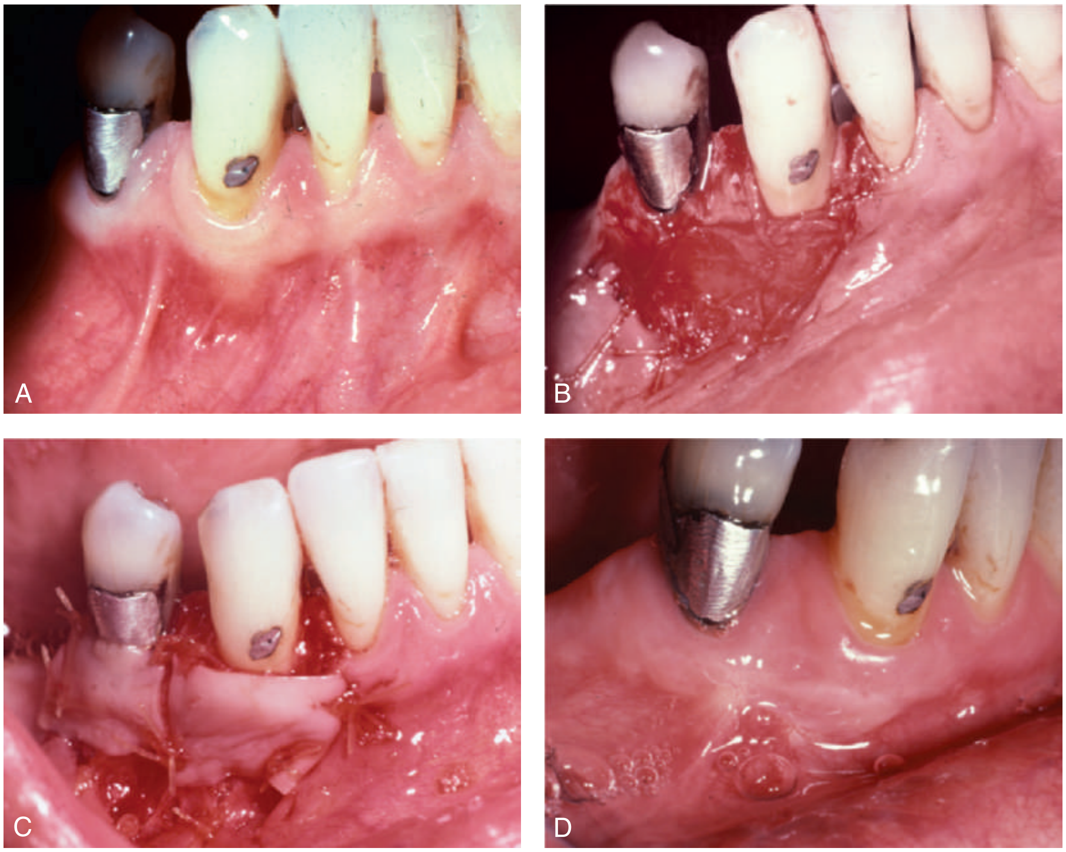

Fig. 6.19 Free autogenous gingival graft. (A) Lack of adequate keratinized gingiva around a planned abutment tooth. (B) The recipient site is prepared. (C) The graft is sutured into place. Some apical adjustment is needed around the premolar before application of the surgical dressing. (D) The healed graft. (Compare the width of attached keratinized gingiva here with that in A.) The defective restoration can be treated at this stage.

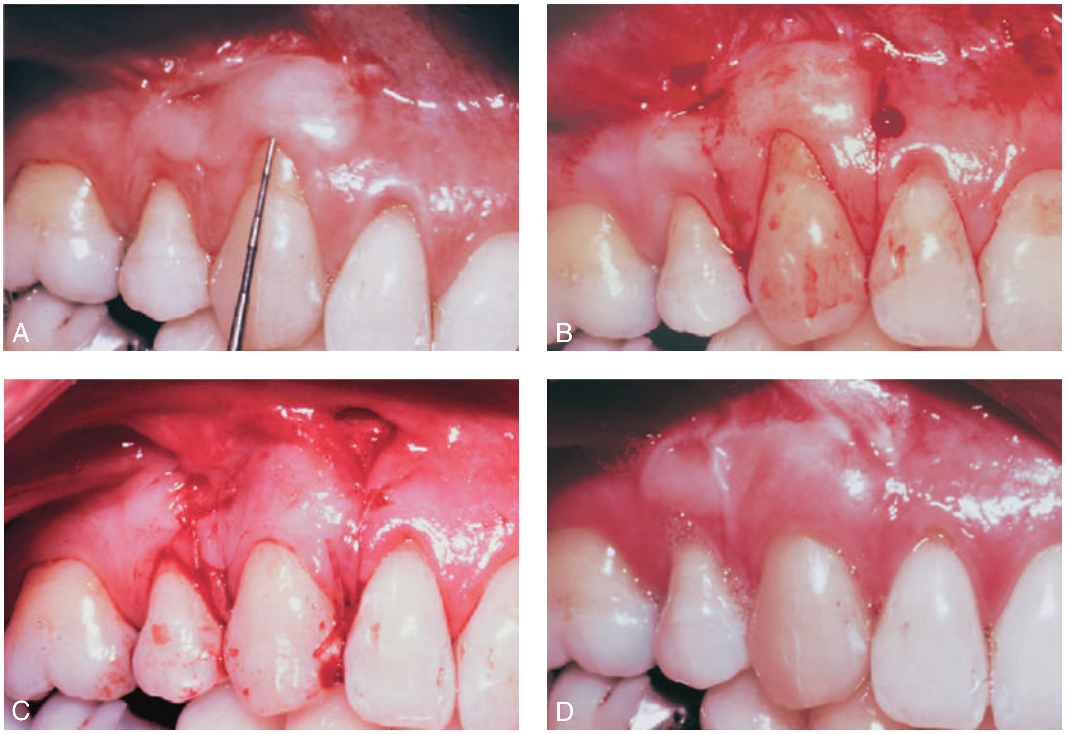

Fig. 6.20 Coronally positioned pedicle graft. (A) The position of the free gingival margin after autogenous graft placement. There is approximately 4 mm of recession. (B) Incisions for the pedicle. Divergence of the incisions ensures an adequate blood supply because the base of the flap is broad. (C) The pedicle is coronally positioned and sutured snugly in place at the cementoenamel junction with horizontal and suspension sutures. (D) The healed graft. (Courtesy Dr. S.B. Ross.)

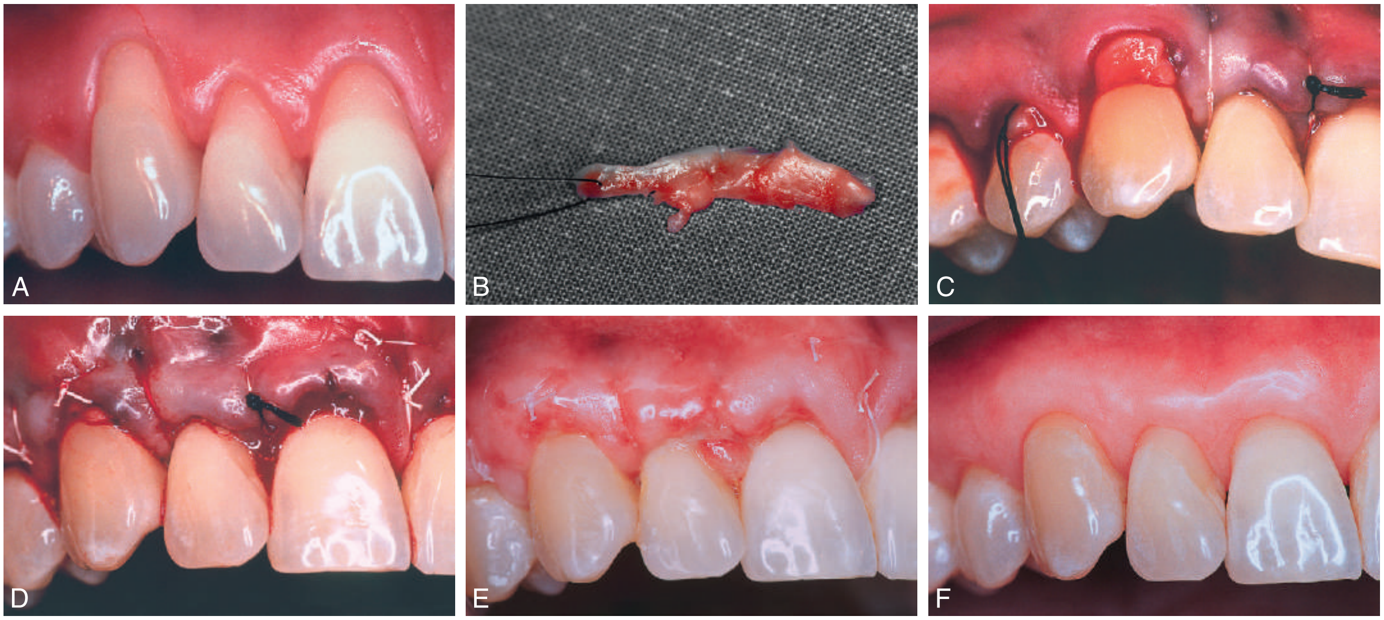

Fig. 6.21 Pouch and tunnel technique for root coverage. (A) Preoperative view. Note gingival recession. (B) Donor connective tissue from palate. (C) Donor tissue placed in pouch and tunnel. (D) Facial gingiva is sutured coronally to cover donor tissue. (E) Postoperative healing at 2 weeks. (F) Healing at 3 months. Note root coverage and thick marginal gingiva. (Courtesy Dr. Robert R. Azzi.)

Fig. 6.22 (A) Patient initial presentation with Miller class 1 gingival recession on 8 and 9 and Seibert class 3 ridge defects in the lateral incisor areas. (B) Connective tissue grafts sutured in place. (C) Definitive ceramic restorations inserted after healing.

Surgical Crown Lengthening

It is sometimes possible to achieve an effective increase in crown length by gingivectomy or removal of gingiva by electrosurgery alone (see Fig. 6.23), although osseous recontouring is most often needed to prevent encroachment of the prosthesis on the biologic width. For these procedures, a full-thickness mucoperiosteal flap is reflected, and the osseous resection creates 3.5 to 4.0 mm of space between the osseous crest and the margin of the existing restoration or carious lesion (see Fig. 6.14).[50,59] In these instances, however, the following factors should be considered:

1. Esthetics: When surgical crown lengthening (Fig. 6.24) is indicated, it may be difficult to achieve a harmonious

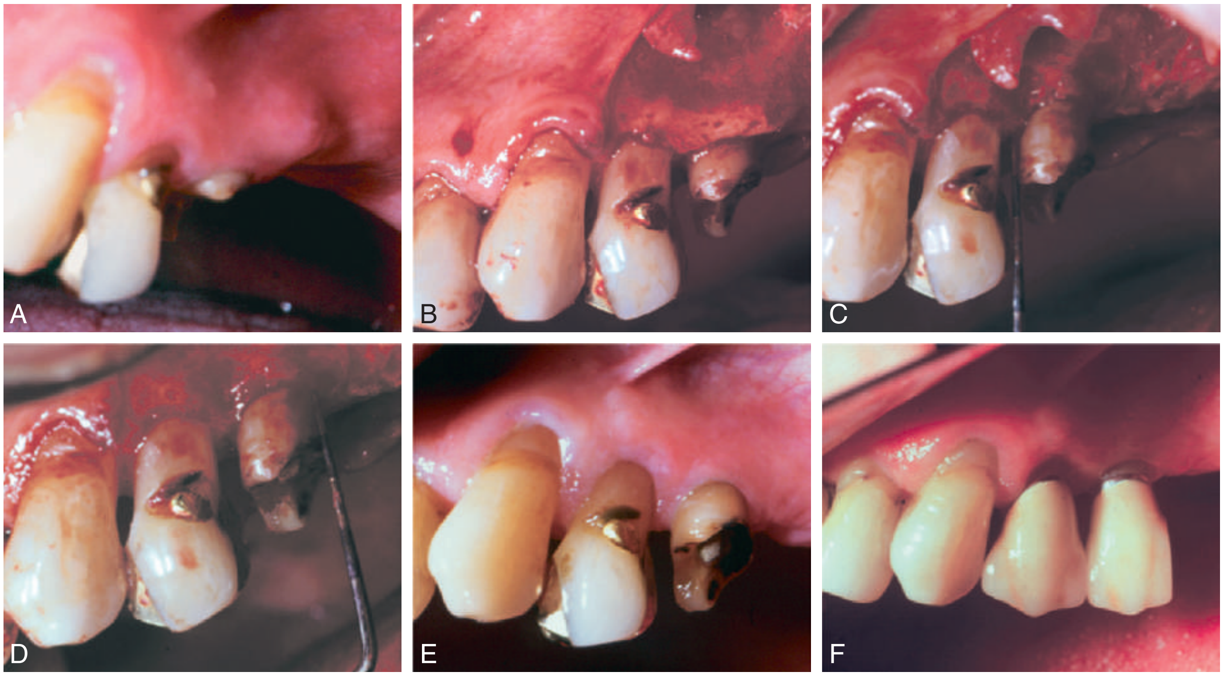

Fig. 6.23 Surgical crown lengthening. (A) Fractured and carious second premolar. (B) Reflection of a flap and removal of granulation tissue. (C) Bone removed on the mesial aspect to increase the distance to the fracture site to 3.5mm. (D) Distally, the bone is removed so that there will be 3.5mm from the caries to the alveolar crest. (E) Healing after the surgical crown lengthening. (F) Definitive crown restoration after cementation, before restoration of the sextant with a removable partial denture.

transition from the tissue around the lengthened tooth to that around adjacent teeth. Alternatives include orthodontic extrusion or removal and replacement with a prosthesis. If surgery is undertaken, most of the osseous reduction should be on the lingual or palatal side, where there is usually no esthetic problem, with blending on the labial or buccal side only as necessary.

2. Root length within bone: If osseous support is limited, it may be better to remove the tooth and replace it with a prosthesis than to have the patient undergo surgery on a tooth with a doubtful prognosis.
3. Effect on adjacent teeth: Often a fracture or defect is of such depth that it cannot be eliminated without severely endangering the adjacent teeth. In these instances, removal or orthodontic extrusion may be preferable.
4. Root furcation exposure in a posterior tooth: Posterior teeth with long root trunks are ideal for crown lengthening, without furcation involvement. If a through and through (Class 3) furcation would be created, the tooth should be removed.
5. Mobility: Postsurgical mobility of a tooth with small or conical roots is of concern. If such a tooth cannot support itself or cannot be supported by the adjacent teeth, then removal may be necessary.
6. Extent of the defect: The severity and complications of any fracture, root caries, or cervical wear must be carefully evaluated during the treatment planning phase.
7. Root perforation: This is uncommon, but if it occurs during endodontic therapy, its location determines whether to remove, orthodontically extrude, or lengthen the tooth surgically.[60]
8. Thickness of the soft tissue: In some instances, thick gingival tissue may prompt a regrowth of tissue in a coronal direction. An increased removal of osseous support may be needed at the time of crown lengthening surgery to negate this potential problem.[61]

Restoration of a tooth that has undergone surgical crown lengthening is commonly initiated 4 to 6 weeks after the surgical procedure. A clinical study[62] demonstrated that the biologic width and the position of the free margin of the gingiva exhibited minimal change between 3 and 6 months after surgery. Therefore, it may be advisable to provisionally restore the tooth in question, either before or immediately after surgical crown lengthening, and subsequently fabricate the definitive restoration after 3 to 6 months.

Although surgical crown lengthening may not be a panacea for fractured, perforated, or badly decayed teeth, it can help solve difficult or complex restorative problems when used with proper clinical judgment.

Maintenance and Reconstruction of the Interdental Papilla

The loss of the interproximal papilla, especially in the maxillary anterior area, is of concern to the restorative dentist, the periodontist, and the patient. One study found that during a maximal smile, 91% of the men and women displayed interdental papillae.[63] Multiple techniques have been used, with and without the use of guided tissue or bone regeneration, to maintain and reconstruct the interdental papilla (Figs. 6.25–6.27).[64–70] The results of these procedures have not been predictable or reproducible. The reconstruction of a papilla is dependent on

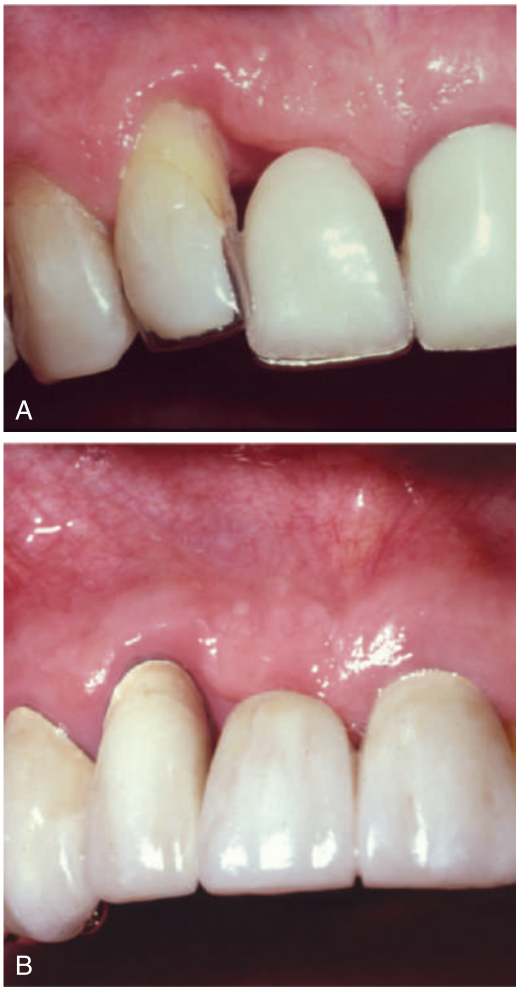

Fig. 6.24 Esthetic problems can occur after surgical crown lengthening of an anterior tooth. (A) Lateral incisor is lengthened to include a mesial periodontal defect. (B) Esthetics would have been better if the distal aspect had been included and the gingival contour gradually sloped.

multiple factors, such as the amount of attachment loss in the area, the blood supply available for the newly created papilla,[71] and the distance from the contact area to the crest of the interproximal bone.[72] The majority of the techniques used for reconstruction of the interdental papilla are combinations of either surgical, orthodontics, or restorative dentistry. Therefore, the treatment plan involves careful coordination and planning of the different disciplines. It is more predictable to preserve an existing papilla than to regenerate a lost papilla. As a result, the removal of an anterior tooth should always be reevaluated to make sure that it is the best plan for the patients.

▪ ▪ ▪

Implant-Supported Fixed Prostheses

Treatment plan options for the partially edentulous patient can be endless. Since the advent of dental implants, the placement of implant-supported prostheses has become a routine part of general dentistry. At the treatment planning stage, the clinician should pose one question: "If only one implant could be used, where would it be most beneficial?" The success of this procedure requires meticulous patient selection and skillful execution of the selected technique (Fig. 6.28). Achieving good function, while satisfying all other patient expectations, can prove especially challenging in the esthetic zone. A team approach to treatment is strongly recommended, with close cooperation between specialists (see Chapter 13).

ORTHODONTIC TREATMENT

Minor orthodontic tooth movement[73–77] can significantly enhance the prognosis of subsequent restorative treatment. Orthodontics can improve periodontal defects, level gingival contours, optimize tooth proportions, and idealize axial alignment for conservative crown preparations. Non-restorable teeth can have rapid root extrusion to gain a ferrule effect so they can be predictably restored. Alternatively, teeth can be slowly

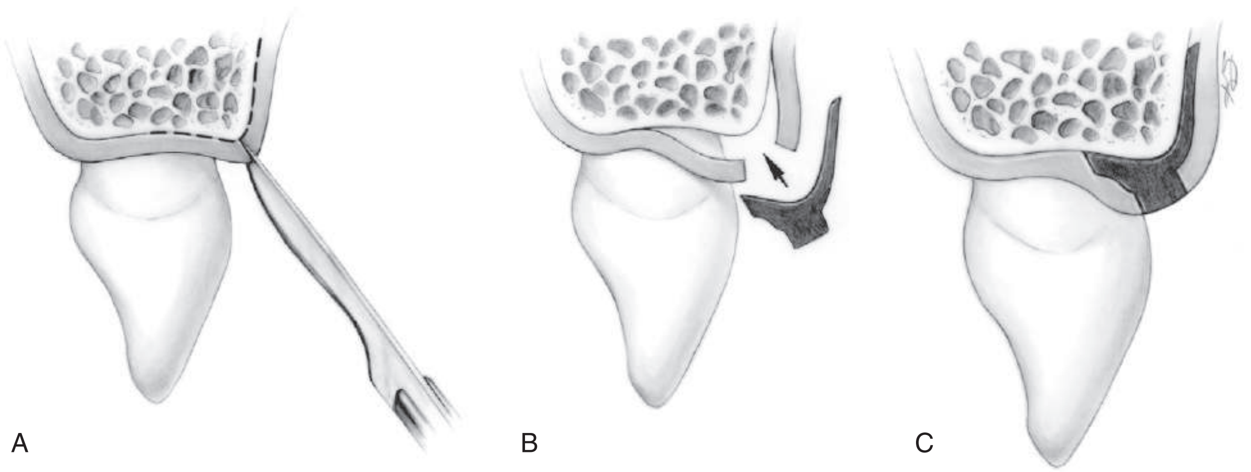

Fig. 6.25 Technique for surgical reproduction of the interdental papilla. (A) Intrasulcular and buccal incisions are placed in the interdental papilla; the existing papilla is left attached to the palatal flap. (B) Split-thickness flap is elevated buccally and palatally *(arrow)*. Connective tissue graft is prepared for placement under the buccal and palatal flaps. (C) Buccal and palatal flaps are sutured after connective tissue from the retromolar area is placed under the flap. (From Azzi R, Etienne D, Carranza F. Surgical reconstruction of the interdental papilla. *Int J Periodontics Restorative Dent*. 1998;18:467.)

erupted or intruded to ideally position-free gingival margins. Tooth movement can also help direct occlusal forces more favorably, parallel to the long axes of the teeth, and often leads to substantial conservation of tooth structure (see Fig. 7.17B and C), in as much as teeth can be prepared with more ideal preparation geometry. Orthodontic therapy is probably the most economical and wise therapeutic choice a patient can make.

Assessment

Clinical examination should focus on tooth malpositioning in both horizontal and vertical dimensions. Abnormal tooth relationships, such as anterior or posterior reverse articulation, should alert the dentist to the possible need for orthodontic treatment. Specifically, attempts to correct abnormal tooth relationships or the contours of malpositioned teeth with fixed

Fig. 6.26 Computer imaging technology used to envision esthetic changes resulting from treatment with laminate veneers. The resulting papilla compression from increased proximal contact length will result in improved esthetics. The image is manipulated using photo editing software such as Adobe Photoshop. (A) Premodification. (B) After simulated diastema closure.

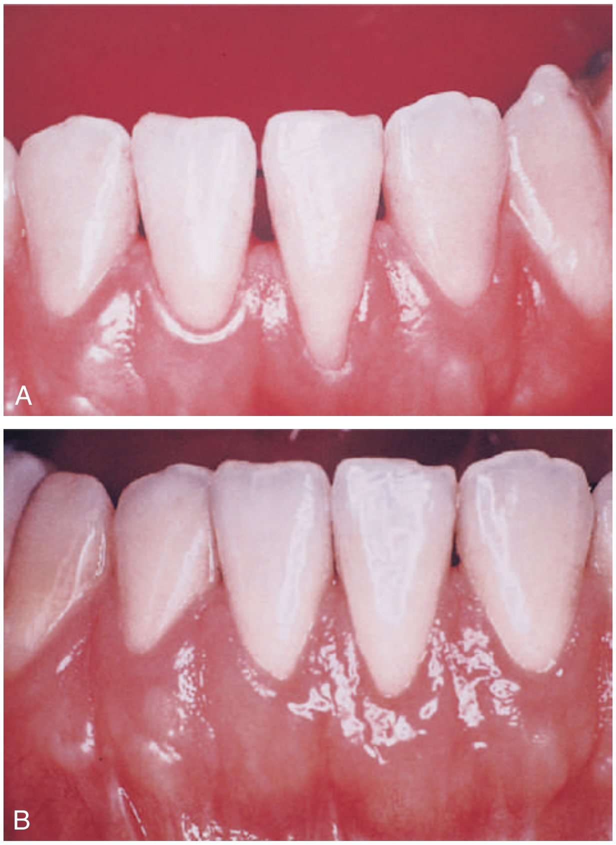

Fig. 6.27 Reconstruction of the interdental papilla. (A) Preoperative view of papillary deficiency in the interproximal area of the mandibular central incisors. (B) Results of papillary graft and final tissue contour. (From Azzi R, Etienne D, Carranza F. Surgical reconstruction of the interdental papilla. *Int J Periodontics Restorative Dent*. 1998;18:467.)

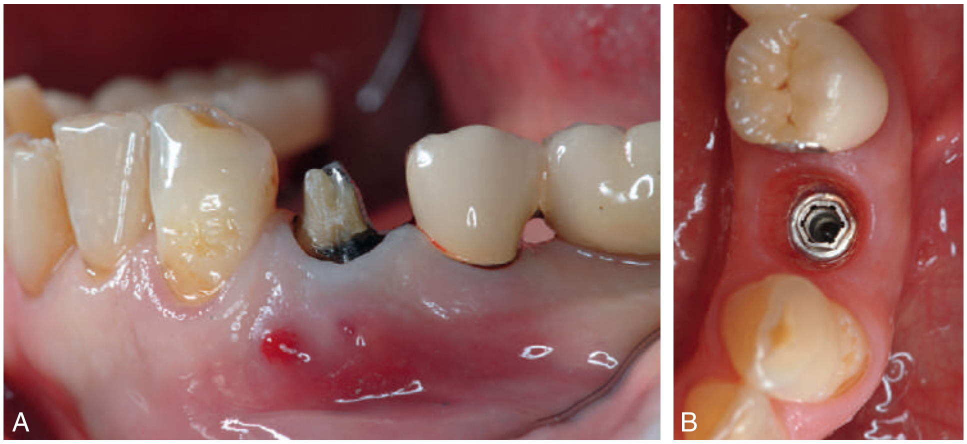

Fig. 6.28 (A) Failure of mandibular premolar, necessitating its atraumatic removal. (B) After proper surgical management, healthy tissues surround this osseointegrated implant.

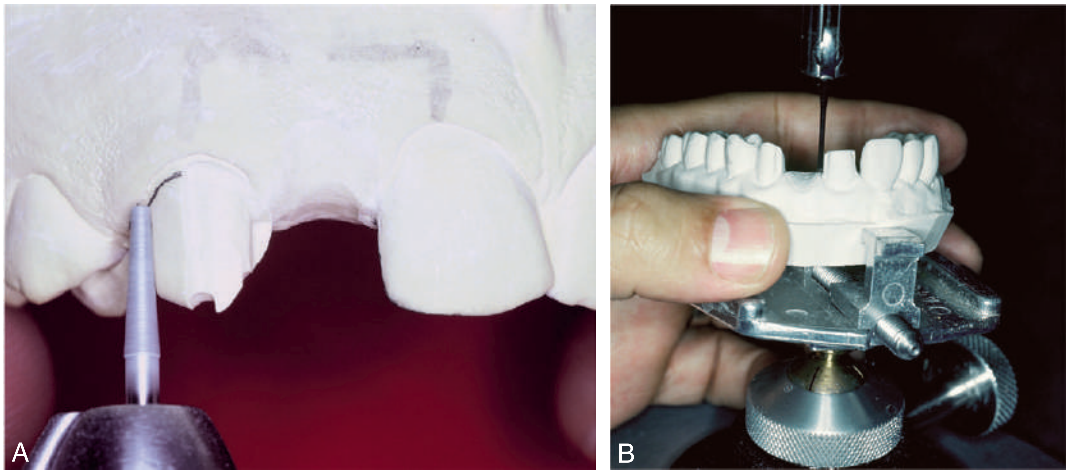

Fig. 6.29 Use of diagnostic preparations (A) and a dental surveyor (B) in assessing the need for orthodontic treatment before fixed prosthodontics.

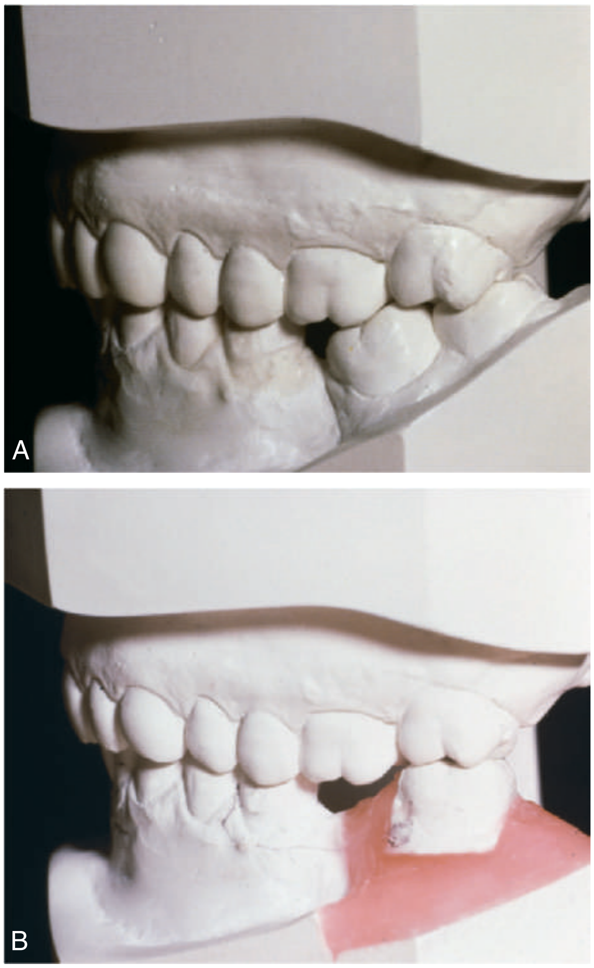

Fig. 6.30 Diagnostic cast sectioning (A and B) for determination of desired orthodontic tooth movement. (Courtesy Dr. P. Ngan.)

Fig. 6.31 Computer imaging technology can assist in treatment planning and communicating the envisioned esthetic changes to the patient. (A) Before modification (B) After simulated diastema closure.

prosthodontic treatment alone are rarely successful; orthodontic realignment, as part of the mouth preparation, is preferred and far more likely to lead to a successful result. Before orthodontics is started, active diseases should be controlled.

The need for orthodontic referral and treatment is determined through a careful analysis of articulated diagnostic casts, whose usefulness can be enhanced with a dental surveyor (Fig. 6.29). One helpful procedure[78] is to section a duplicate cast (Fig. 6.30) and reassemble it according to the proposed orthodontic modifications. This facilitates assessing the feasibility of any minor tooth movement (e.g., closing diastemas, uprighting molars, aligning tilted teeth) and is especially valuable in explaining the treatment proposal to the patient. Diagnostic preparations and waxing procedures, made on such altered casts, often clearly illustrate the benefits of minor tooth movement. Many dentists use computer imaging technology to optimize esthetic treatment planning and improve patient communication (Fig. 6.31).[79–82]

Treatment in the Vertical Dimension

In general practice, it is often possible to perform minor tooth movement before fixed prosthodontic treatment, without referral to an orthodontist. However, a specialist should be consulted if treatment is more complex than straightforward tipping, uprighting, or rapid extrusion of an abutment tooth.

A non-restorable, single, rooted tooth with good periodontal attachment can gain more coronal tooth structure through rapid orthodontic extrusion. For rapid extrusion of a single anterior tooth, bonded brackets can be used with a multistrand elastic wire ligated in place to achieve the desired tooth movement. Rapid extrusion is done with a relatively strong force to erupt the tooth out of its periodontal attachment to achieve more available tooth structure (Fig. 6.32). In contrast, if the

Fig. 6.32 (A) Patient presents with a high smile line and failed anterior fixed partial denture. (B) The prosthesis is loose and secondary caries is detected on the lateral incisor. The missing right central incisor has a horizontal defect in the residual ridge. (C) Radiographs determine that the lateral incisor has gross caries and is non-restorable in its current condition. (D and E) After grafting and implant placement in the left central incisor location, orthodontics was used to rapidly extrude the right lateral incisor to gain new tooth structure to ensure a ferrule effect. (F and G) Gingival and ridge defects were improved and individual ceramic restorations inserted.

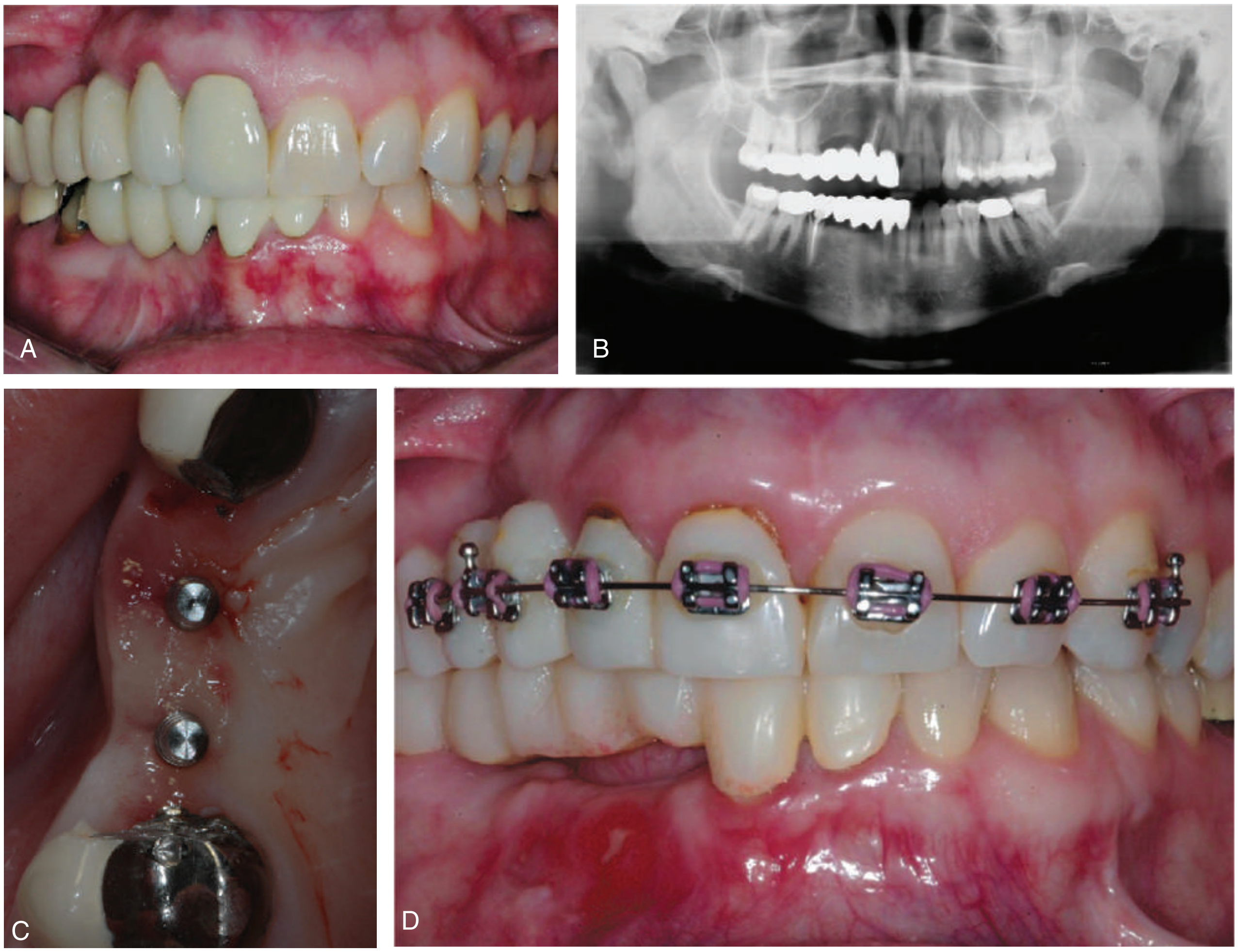

Fig. 6.33 (A) Clinical presentation of a failed tooth supported fixed partial dentures, on the right maxilla and mandible. Patient wanted to improve the gingival symmetry and tooth proportions between the maxillary anterior teeth. (B) Radiograph of failed maxillary and mandibular prostheses. (C) The maxillary fixed partial denture was sectioned and temporary implants was placed to provide orthodontic anchorage. (D) Interim restorations were inserted and the right maxillary lateral and central incisors were orthodontically extruded to bring the free gingival margins incisally and improve the anterior tooth proportions.

periodontal attachment is required to come with the tooth, a more complex slow controlled force is indicated. Extrusion of 0.5 mm per month will allow the periodontal attachment to reassemble as the tooth is slowly erupted. In estimating the time of treatment for developing more incisal migration of the periodontal attachment, one can plan for 2 months for every 1 mm of gingiva gain and an additional 6 months for retention (Fig. 6.33). When any anterior tooth is moved, however, the amount of labial bone should be carefully evaluated and determined to be adequate before treatment. In contrast to extrusion of teeth, orthodontics can also intrude teeth to improve aberrant gingival margins (Fig. 6.34) and gain prosthetic space (Fig. 6.35). Orthodontic mechanics that reposition free gingival margins are complex and require a high level of training.

Treatment in the Horizontal Dimension

Anterior teeth can be proclined or retroclined to optimize the tooth position for facial support and occlusion. Orthodontic treatment should also be considered when restorations are planned to correct a diastema. Often esthetics can be dramatically improved by distributing the space of a midline diastema around all the anterior teeth (Fig. 6.36A–C). A diagnostic waxing procedure will help determine the optimum tooth position. Uprighting a mesially tilted molar can be accomplished with a coil spring (see Fig. 6.36D–G), but the tooth should first be reshaped so that it is not in occlusal contact. A neglected crown preparation can be salvaged with a straightforward orthodontic appliance (Fig. 6.37). All orthodontic movement requires adequate anchorage to avoid inadvertent movement of other teeth.

DEFINITIVE OCCLUSAL TREATMENT AND OCCLUSAL RESHAPING

According to current research, occlusion has a limited impact on the development of disorders of the temporomandibular joints and associated musculature.[83] Previously, it was widely accepted that the etiology of temporomandibular disorders fit in a mechanical-based gnathological occlusal phenomenon,

Fig. 6.34 (A) Patient has excessive gingival display with aberrant free gingival margins. (B) Frontal view in maximal intercuspation. (C) Diagnostic arrangement with improved symmetry of the free gingival margins. A flexible translucent ruler was laid over the diagnostic arrangement and the intended gingival contours were traced. (D) The same tracing was overlaid on the orthodontically intruded teeth to aid in determining if the teeth had been intruded into the correct positions. (E) Clinical view of the intruded anterior teeth without the tracing overlay. (F) Definitive restorations restore the tooth contours and proportions while reducing the excessive gingival display.

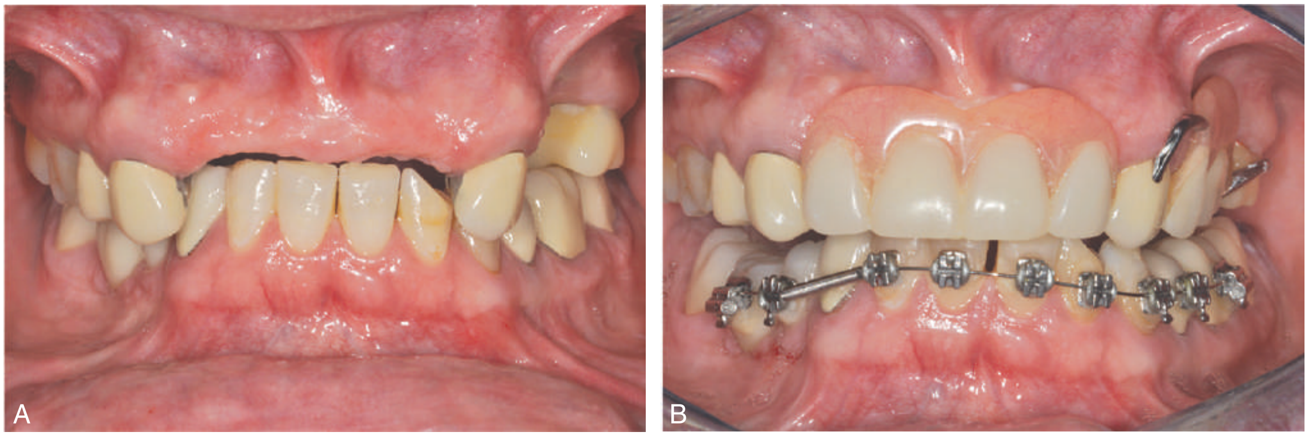

Fig. 6.35 (A) Clinical presentation of a skeletal class 2 mandible The patient declined jaw surgery. The mandibular incisors had erupted into the maxillary alveolar ridge, preventing sufficient space for a removable partial denture. (B) Orthodontics was used to intrude the mandibular anterior teeth to gain space for a maxillary removable partial denture.

Fig. 6.36 Orthodontic tooth movement as an adjunct to fixed prosthodontics. (A–C) Minor tooth movement before correction of a diastema. (D–G) A mesially tilted molar uprighted with a coil spring before the provision of a fixed partial denture. (D to G, Courtesy Dr. P. Ngan.)

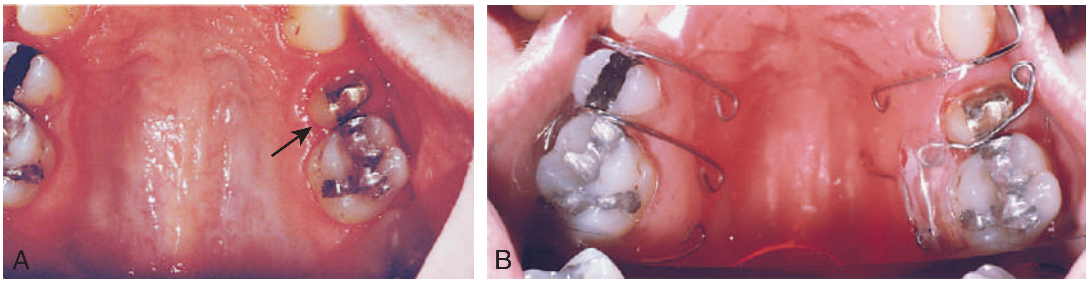

Fig. 6.37 (A) The maxillary premolar *(arrow)* was prepared for a metal-ceramic crown but the interim restoration was inadequate. Unfortunately, the patient did not return when the interim restoration became dislodged. The tooth had moved distally and was in contact with the first molar, making crown placement impossible. (B) A removable appliance was used to reposition the tooth before impression making. (Courtesy Dr. P. Ngan.)

where teeth would be irreversibly reshaped to conform to a single occlusal philosophy.[84] Today, clinical evidence contraindicates occlusal reshaping to resolve temporomandibular disorders.[84] Contemporary thinking has gradually transformed into a chronic pain biopsychosocial disease model.[85] Notwithstanding, iatrogenic occlusal problems that have led to development of pathologic processes should be diagnosed and alleviated, before definitive fixed prosthodontic treatment is undertaken. If clinical data are inconclusive, this diagnosis can often be achieved with an occlusal guard as a noninvasive, reversible means.[86]

SUMMARY

Planning a logical treatment sequence should precede any fixed prosthodontic intervention. Treatment of unstable, deteriorating conditions such as caries and replacement of faulty restorations must be completed first. Such mouth preparation is normally multidisciplinary. It incorporates oral surgery; operative dentistry; and endodontic, periodontic, orthodontic, or occlusal therapies, or a combination of these. Comprehensive mouth preparation is particularly important for fixed prosthodontics, which, like all dental disciplines, is enhanced by meticulous preparatory treatment.

STUDY QUESTIONS

1. Discuss in detail the recommended sequence of preparatory treatment procedures before initiation of definitive fixed prosthodontic treatment.
2. Discuss the advantages, disadvantages, indications, and any applicable precautions for the various foundation restoration materials.
3. Discuss methods to classify gingival and ridge defects.
4. Discuss three types of periodontal grafting procedures, their indications, and their limitations.
5. What are the indications for tooth movement before fixed prosthodontic treatment is initiated? With anterior teeth, what must be evaluated before treatment is started?
6. What are the indications and contraindications for comprehensive occlusal reshaping?

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7

Principles of Tooth Preparation

Demineralized tooth structure can be remineralized. Instead of diamond-cutting instruments to prepare diseased teeth, the use of fluorides and optimization of oral environments have become a cornerstone of clinical dental care.[1] Although extremely helpful to arrest disease in progress and from a preventive perspective, at a macroscopic level, however, teeth cannot regenerate missing anatomical parts. Today, more than ever before, clinicians face the dilemma to choose between remineralization of a carious lesion or embarking on restorative intervention. Caries monitoring can prove to have high risks if a patient is non-compliant or the disease process is refractory. Restorative intervention, however, results in removal of not only diseased tooth structure but some healthy tooth structure as well. The dentist needs to educate the patient in the decision process because it is not solely solved by preparing a tooth. The health of a tooth is dependent on a lifelong balance between demineralization with remineralization of enamel, dentin, and cementum along with maintenance of any subsequent restoration.

Once enamel and dentin are lost as a result of caries, trauma, erosion, wear, congenital factors, or iatrogenically, restorative materials are all that are currently available to reestablish form and function. With rare exceptions, teeth require preparation to receive restorations, and these preparations must be based on fundamental principles from which basic criteria can be developed to help predict the success of prosthodontic treatment. Careful attention to every detail is imperative during tooth preparation. Tooth preparations can receive direct or indirect restorations. Direct restorations are created intraorally with plastic materials such as composite resin, glass ionomer, or dental amalgam. Indirect restorations are fabricated extraorally. This chapter focuses on tooth preparations for indirect restorations. A good preparation for an indirect restoration facilitates subsequent techniques (e.g., interim restoration fabrication, soft tissue management, digital scans, impression making, along with virtual or analog fabrication of dies and casts, waxing) while ensuring the best possible prognosis.

INDICATIONS AND CONTRAINDICATIONS FOR INDIRECT RESTORATIONS

The following are common indications and contraindications for the various treatment options:

Indications for indirect restorations:

- Missing cusp(s)
- Gross caries causing an unsupported cusp
- Protection of posterior endodontically treated teeth[2,3]
- Caries associated with a preexisting indirect restoration causing weakened cusps
- Worn teeth with moderate to severe dentin exposure
- Cracked teeth (to encircle the tooth)
- Complete crowns are indicated on teeth with five affected surfaces

Contraindications for indirect restorations:

- Patients with uncontrolled high caries risk
- To remove sound tooth structure that could be preserved with a direct restoration or be remineralized
- Patients with temporomandibular disorder (TMD) symptoms (e.g., pain) should first have such concerns addressed prior to tooth preparation
- Teeth with a poor or guarded prognosis (e.g., if the loss of a tooth is anticipated within five or so years due to periodontal disease)

Once the decision has been made to intervene restoratively, the next question is if the restoration will be adhesively or cohesively retained. Through adhesive dentistry, prosthetic reconstructions can be performed with conservative techniques using porcelain laminate veneers, and partial-coverage restorations bonded to enamel. With cohesive dentistry, partial-coverage restorations, inlays, and complete crowns can also be performed conservatively but those rely on opposing axial walls of certain geometric shapes within the tooth preparation to deliver mechanical retention. The dentist needs to select the best approach suitable for the specific tooth and situation. To aid in the decision process, the principles of tooth preparation may be divided into three broad categories that encompass both methods:

1. Biologic considerations, which affect the health of the oral tissues
2. Restoration/tooth interface considerations, how the prosthetic materials are connected to living hard tissues affecting the integrity and durability of the restoration (mechanical retention vs. adhesion)
3. Esthetic considerations, which affect the appearance of the patient

Successful tooth preparation and subsequent restoration depend on simultaneous consideration of all these factors. Improvement in one area often adversely affects another area, and striving for perfection in one may lead to failure in another. For example, consider two restorative options for an endodontically treated maxillary central incisor with gross proximal caries and severe intrinsic staining. A complete crown or a porcelain laminate veneer supplemented with a composite restoration to restore the endodontic access hole could be treatment planned. In the tooth preparation for a porcelain laminate veneer (see Chapter 11), sufficient thickness of ceramic is necessary to mask the discolored tooth. However, if too much tooth structure is removed, less enamel will be available for bonding and the ceramic will have to rely on less predictable dentin bonding (restoration/tooth interface). In contrast, if such stained enamel is preserved for bonding but the ceramic is made thicker to mask the discolored tooth structure, an overcontoured veneer may not promote periodontal health (biological considerations). Furthermore, if the stained enamel is preserved and the veneer is not overcontoured, the ceramist is forced to use more opaque ceramic which could limit the lifelike appearance of the restoration (esthetic consideration).

If a metal-ceramic crown is planned (see Chapter 24), the metal coping will mask discolored tooth structure (esthetic consideration). However, sufficient thickness of porcelain is necessary for a lifelike appearance. Furthermore, if too much tooth structure is removed to accommodate a greater thickness of porcelain for esthetic reasons, the pulp may be encroached upon (biological consideration) and the tooth unduly weakened (restoration-tooth interface and biological considerations). In-depth knowledge and understanding of the various criteria are prerequisite to the development of a treatment plan, communication with a dental patient, and satisfactory tooth preparation skills. Accomplishment of optimum tooth preparation (Fig. 7.1) invariably challenges the dentist to find the best combination of compromises among applicable biologic, restoration/tooth interface, and esthetic considerations.

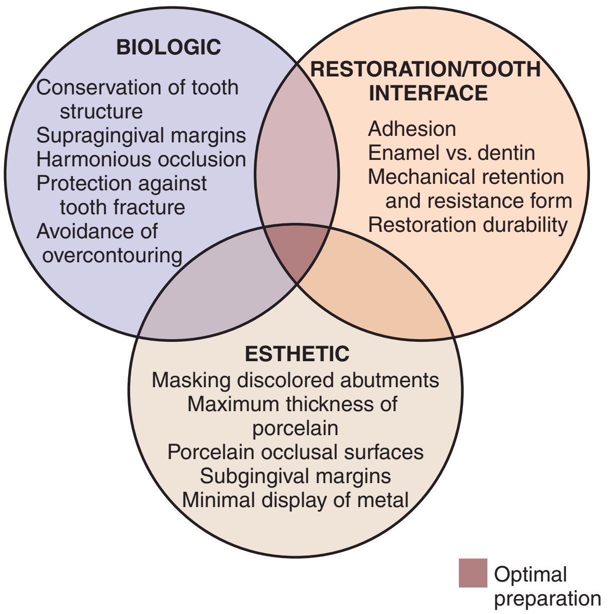


Fig. 7.1 The optimum preparation enables the fabrication of a restoration that satisfies biological, esthetic, and tooth/restoration interface requirements.

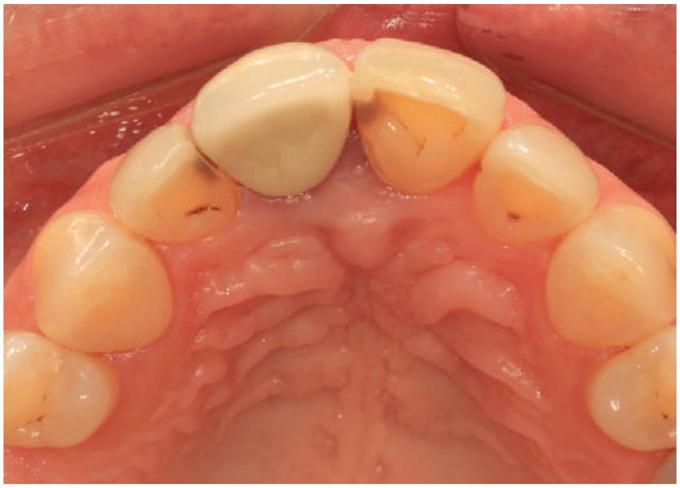


Fig. 7.2 Patient received a crown on her maxillary central incisor at a young age due to trauma. Note that the only caries she has are on the proximal areas of the teeth adjacent to the existing crown.

BIOLOGIC CONSIDERATIONS

Surgical procedures involving living tissues must be performed carefully to avoid unnecessary damage. The adjacent teeth, soft tissues, and the pulp of the tooth being prepared are easily damaged during tooth preparation. If poor preparation leads to inadequate marginal fit or deficient crown contour, plaque control around fixed restorations becomes more difficult. This, in turn, impedes the long-term maintenance of dental health.

Prevention of Damage During Tooth Preparation

Adjacent Teeth

Iatrogenic damage to an adjacent tooth is a common error in dentistry. Even if a damaged proximal contact area is carefully reshaped and polished, it remains more susceptible to dental caries than the original undamaged tooth surface (Fig. 7.2), presumably because the original surface enamel contains higher fluoride concentrations and the polished layer is more prone to plaque retention.[4] Sound tooth preparation technique avoids and prevents damage to adjacent proximal surfaces.

A metal matrix band placed around the adjacent tooth for protection may be helpful; however, the thin band can be perforated and the underlying enamel still damaged. The preferred method is to use the proximal enamel of the tooth that is being prepared for protection of the adjacent structures. Teeth are 1.5 to 2 mm wider at the contact area than at the cementoenamel junction. Therefore, a thin, tapered diamond or tungsten carbide rotary instrument can be passed through the proximal contact area (Fig. 7.3) while leaving a slight "lip" or "fin" of enamel without resulting in excessive tooth reduction or necessitating undesirable angulation of the rotary instrument. The latter situation, tipping the diamond unnecessarily away from the adjacent proximal surface, is a common clinical error.

Soft Tissues

Placing preparation finish lines subgingivally takes great planning and care lest the periodontal soft tissues becomes red, inflamed, or recede (see Chapter 5). Naturally, a poor periodontal response at the gingival margin of a crown can adversely impact the esthetic result.

Damage to the soft tissues of the tongue and cheeks can be prevented by careful retraction with an aspirator tip, mouth mirror (Fig. 7.4), or flanged saliva ejector. Great care is needed to protect the tongue when the lingual surfaces of mandibular molars are being prepared.

Pulp

Great care is also needed to prevent pulpal injuries during fixed prosthodontic procedures, especially when significant amounts of tooth structure are being removed. Pulpal degeneration that occurs many years after tooth preparation has been documented.[5] Extreme temperatures, chemical irritation, or microorganisms can cause an irreversible pulpitis,[6] particularly when they occur on freshly sectioned dentinal tubules. Prevention of pulpal damage necessitates selection of techniques and materials that reduce the risk of injury while teeth are prepared.[7]

Tooth preparations must account for the geometry of the pulp chamber. Pulp size can be evaluated on a radiograph and decreases with age. Up to about age 50, it decreases more so occlusocervically than faciolingually. Average pulp dimensions have been related to coronal contour[8] and are presented in Table 7.1 and Fig. 7.5. Literature reports 5.7% to 33.8% of teeth prepared for a compete crown or fixed partial denture (FPD) retainers succumb to pulpal degeneration and require endodontics.[9–12] Vital pulp survival in teeth restored with single metal-ceramic crowns was more favorable than teeth prepared for FPD retainers.[12] Pulp tissue in maxillary anterior teeth prepared for metal-ceramic FPD has a higher risk of necrosis than for any other tooth type.[12] This is not a contradiction for crowns or FPDs but illustrates the importance of

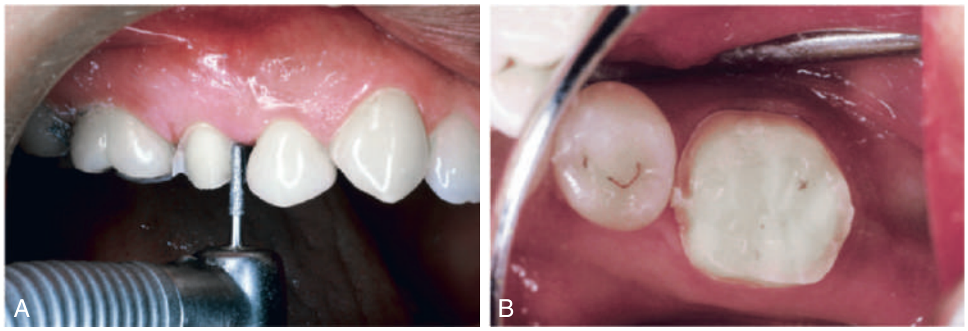


Fig. 7.3 Damage to adjacent teeth is prevented by positioning the diamond so that a thin "lip" of enamel is retained between the rotary instrument and the adjacent tooth during reduction of the proximal surface. (A) Note that the orientation of the diamond parallels the long axis of this premolar. (B) Proximal reduction almost complete. Note that enamel was maintained mesial to the path of the diamond as the reduction progressed.

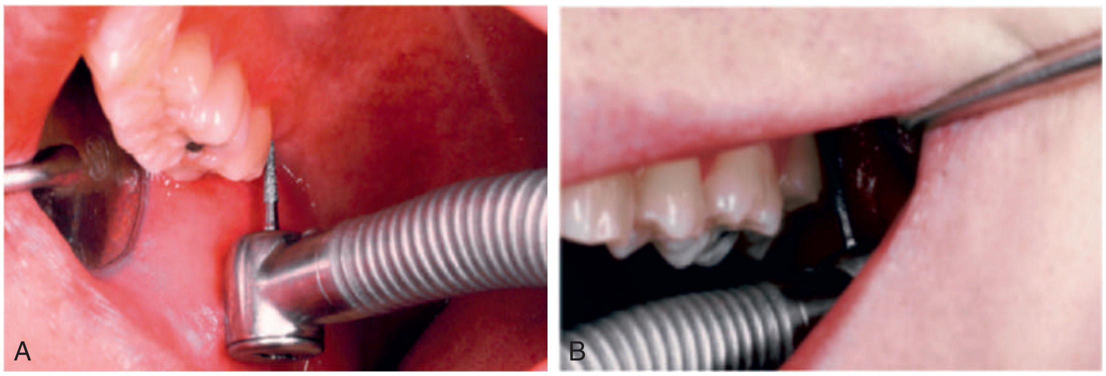


Fig. 7.4 Soft tissue protection. Mouth mirror is used to protect the tongue during tooth preparation (A) and to displace the cheek and reduce the risk of injury (B).

TABLE 7.1 **Dimensions of Pulp and the Coronal Contour**

	LENGTH (MILLIMETERS)								
Age Range (Years)	**Coronal Length**	**Incisal to MPH**	**Incisal to DPH**	**Mesial Surface to MPH**	**Distal Surface to DPH**	**Labial Surface to MPH**	**Labial Surface to DPH**	**Palatal Surface to MPH**	**Palatal Surface to DPH**
Maxillary Central Incisor									
10–19	12.1	4.7	4.8	1.7	2.1	1.8	1.8	1.4	1.3
20–29	11.5	4.8	5.1	2.2	2.3	1.9	1.9	1.4	1.2
30–39	11.2	5.3	5.5	2.1	2.5	2.3	2.4	2.1	2.0
40–49	10.8	6.3	6.2	2.5	2.9	2.0	2.1	2.0	1.8
50–59	12.3	6.3	6.2	2.6	2.6	2.8	2.3	2.2	2.1
Mean ±SD	11.58 ± 0.34	5.5 ± 0.25	5.6 ± 0.28	2.2 ± 0.16	2.5 ± 0.14	2.2 ± 0.12	2.1 ± 0.12	1.8 ± 0.16	1.7 ± 0.19
Range	9.70–14.00	4.0–6.2	4.0–6.2	1.2–3.3	1.4–3.5	1.5–2.9	1.5–2.9	1.0–2.9	1.1–2.9
Maxillary Lateral Incisor									
10–19	10.1	3.9	4.3	2.4	2.6	2.0	2.1	1.3	1.3
20–29	10.2	4.8	5.2	2.5	3.2	2.4	2.4	1.9	1.9
30–39	–	–	–	–	–	–	–	–	–
40–49	–	–	–	–	–	–	–	–	–
50–59	–	–	–	–	–	–	–	–	–
Mean ± SD	–	–	–	–	–	–	–	–	–
Range	–	–	–	–	–	–	–	–	–

	LENGTH (MILLIMETERS)					
Age Range (Years)	**Coronal**	**Incisal to PH**	**Mesial Surface to PH**	**Distal Surface to PH**	**Labial Surface to PH**	**Palatal Surface to PH**
Maxillary Canine						
10–19	10.7	4.4	3.4	4.0	2.7	2.3
20–29	10.6	4.6	3.3	3.7	3.1	2.6
30–39	10.5	4.8	3.0	4.0	2.9	2.5
40–49	9.5	4.8	3.0	3.6	2.8	2.8
50–59	9.5	5.4	2.8	3.4	2.9	3.0
Mean ± SD	10.23 ± 0.26	4.8 ± 0.20	3.1 ± 0.13	3.7 ± 0.12	2.9 ± 0.11	2.6 ± 0.15
Range	8.29–12.7	3.8–7.2	2.3–3.6	2.9–4.8	2.5–3.5	1.9–3.7

DPH, Distal pulp horn; *MPH*, mesial pulp horn; *PH*, pulp horn; —, data unavailable.
From Ohashi Y. Research related to anterior abutment teeth of fixed partial denture. *Shikagakuho*. 1968;68:726.

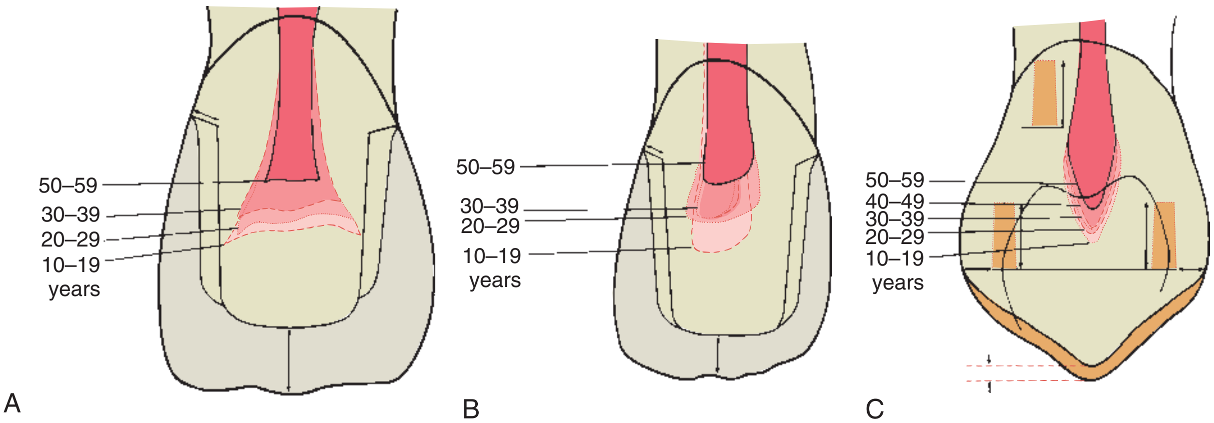


Fig. 7.5 Illustrations of the relationship between tooth preparation and pulp chamber size. The dashed lines represent pulp chamber structure at various ages. (A) Maxillary central incisor with a metal-ceramic crown preparation. (B) Maxillary lateral incisor with a metal-ceramic crown preparation. (C) Maxillary canine with a pinledge preparation. (Redrawn from Ohashi Y. Research related to anterior abutment teeth of fixed partial denture. *Shikagakuho.* 1968;68:726.)

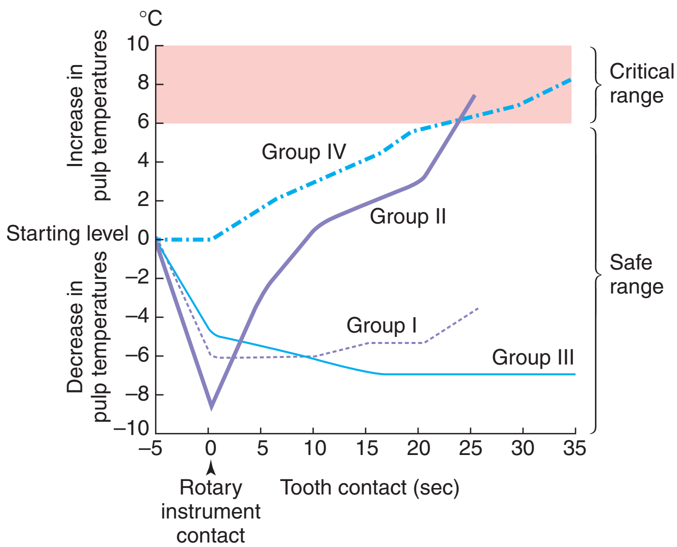


Fig. 7.6 Pulpal temperature rise during tooth preparation. *Group I*, air turbine, water cooled. *Group II*, air turbine, dry. *Group III*, low speed, water cooled. *Group IV*, low speed, dry. (Redrawn from Zach L, Cohen G. Pulp response to externally applied heat. *Oral Surg Oral Med Oral Pathol.* 1965;19:515.)

careful case selection, meticulous delivery of patient care, and constant improvement of one's clinical skills.

Causes of Injury

Temperature. Considerable heat is generated by friction between a rotary instrument and the surface being prepared (Fig. 7.6). Excessive pressure, higher rotational speeds, temperature and flow rate of water coolant[13] along with the type, shape, and condition of the cutting instrument (Fig. 7.7) may all increase the generated heat.[13,14] When using a high-speed handpiece, a feather-light, intermittent touch (approximately 100 g) allows efficient removal of tooth material with minimal heat generation.[15] Nevertheless, even with the lightest touch, the tooth overheats unless a water spray is used. The spray must be accurately directed at the area of contact between tooth and rotary instrument. It also washes away debris, which is important because rotary instrument clogging reduces cutting efficiency (Fig. 7.8).[16] Irrigation also prevents dentin desiccation (which may cause severe pulpal irritation).[5,17] Debris accumulation has been shown to vary with rotary instrument shape. Shoulder- and chamfer-shaped diamonds may accumulate less debris. Debris is not readily removed after 5 minutes of ultrasonic cleaning.[18] During tooth preparation, rotary instrument performance is largely dependent on the dentist's execution of the specific clinical procedure and less on handpiece design and characteristics.[19]

Electric handpieces have adjustable rpms. Generally, gross tooth reduction and shaping is done with 200,000 rpm using water coolant. If the spray prevents adequate visibility, as may be the case when a margin is being finished, rotations can be reduced to 17,000 rpm with reduced water spray. Alternatively, hand instrumentation can be used as the safest option. Relying on air cooling alone with a high-speed handpiece is hazardous because a tooth can easily overheat and the pulp is easily damaged.[20]

Particular care is needed when preparing grooves or pinholes because coolant cannot reach the cutting edge of the rotary instrument. To prevent heat buildup, these retention features should ideally be prepared at low rotational speed or with a high-speed handpiece with a feather-light intermittent touch.

Chemical action

Biomaterials in tissue engineering. The chemical action of certain dental materials (bases, restorative resins, solvents, and luting agents) can cause pulpal damage,[21] particularly when applied to freshly cut dentin. Resin-based sealers increase crown retention when luted with resin, modified-resin, and resin-modified glass-ionomer cements.[22,23] However, adhesive systems can be cytotoxic and affect the viability of odontoblastic cells.[24,25] Compounds may be released from dental adhesive cements that are known carcinogens.[24,25]

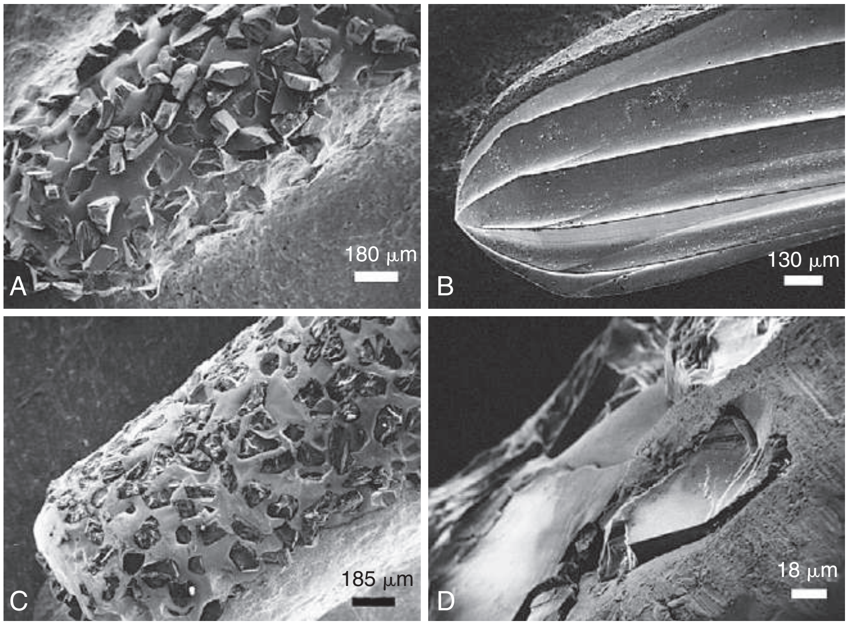


Fig. 7.7 Scanning electron micrographs of rotary instruments. (A) Unused diamond rotary instrument. (B) Unused tungsten carbide bur. (C) Worn diamond rotary instrument. (D) Diamond rotary instrument particles that have fractured at the level of the binder. (Courtesy Dr. J.L. Sandrik.)

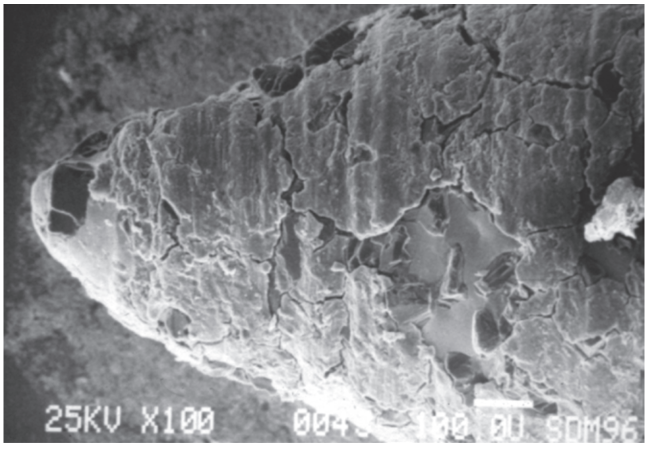


Fig. 7.8 Clogging on the tapered tip of a diamond after one molar tooth preparation reduces cutting efficiency.

Matrix metalloproteinases (MMPs) are known to exist within the dentin collagen hybrid bond layer.[26] MMPs are a group of enzymes that modulate biological cellular mechanisms through multiple signaling pathways in normal physiological processes as well as cancer invasion, metastasis, and inflammatory diseases.[27,28] MMPs degrade physical barriers as in extracellular matrix proteins such as the collagen in the dentin-resin hybrid layer. When dentin is etched, MMPs are released by pulpal odontoblast cells to the dentinal tubules.[26] Since it is difficult for an adhesive to infiltrate the full depth of the conditioned dentin, deep collagen is not protected from MMPs.[29] In the laboratory through transmission electron microscopy, it has been observed that the number of dentin collagen fibrils within the hybrid layer of the resin-dentin bonded interface significantly decreases within 44 months of water storage.[30] Hydrolytic degradation of the hybrid layer is symptomatic by water tree propagation, also known as nanoleakage.[31]

Dental agents applied to etched dentin are capable of inhibiting MMP.[32] Treating prepared dentin with 5% glutaraldehyde has been used successfully to decrease dentinal hypersensitivity. It has no effect on the retention of crowns.[33] However, it is capable of preserving resin-dentin bond by cross-linking collagen in the hybrid layer and MMPs.[34] By itself, glutaraldehyde is not harmful to odontoblast-like cells. However, when mixed with hydroxyethylmetacrylate (HEMA), the compound material is cytotoxic.[34] Chlorhexidine, carbodiimine, and proanthocyanidin when applied to acid-etched dentin have also been successfully used to significantly reduce MMP activity.[32]

MMP inhibitor research looks promising in that the dentin treatments will improve the long-term durability of the hybrid layer by making it less prone to degradation. Future clinical research is indicated to evaluate MMP inhibitor challenges with nanoleakage, recurrent caries, postoperative sensitivity, cytotoxicity, cell vitality, and integrity of the prosthesis.

Bacterial action. Vital dentin seems to resist infection.[35] However, pulpal damage under restorations has been attributed[36,37] to bacteria that either were left behind or gained access to the dentin because of microleakage.[38] Bacteria have been detected in the interface between clinically acceptable crowns and failed root canals.[39] This indicates that the fitting surface of a crown to a tooth is a potential pathway for bacterial leading to endodontic complications.[40]

The colonization and adhesion of bacteria in oral biofilms have been associated with secondary caries[41,42] and gingival inflammation.[43] The roughness of a crown cement margin has also been suggested to influence plaque accumulation.[44] It has been demonstrated that monolithic ceramics with a glazed surface have a greater roughness than a polished one and will tend to accumulate more biofilm.[45] When oral biofilmes attach to a resin-dentin margin, the acidity of the bacteria can weaken the bonded interface.[46] When an adhesive resin cement is used, it is recommended to polish the margin area after curing.[44]

Many dental materials, including glass ionomers, zirconia-reinforced glass-ionomer, and zinc phosphate cement, have an antibacterial effect.[47,48] Many dentists use an antimicrobial agent, such as chlorhexidine gluconate disinfecting solution after tooth preparation and before cementation to clean the abutment, although clinical trials do not show an improvement in postoperative sensitivity,[49] retention, or failure rates when used for direct composite resin restorations.[50,51]

A general clinical recommendation in fixed prosthodontics is that all carious dentin be removed before placement of a restoration that will serve as a foundation for a comprehensive reconstruction. In general, for teeth that will subsequently receive indirect restorations, direct pulp caps are contraindicated because subsequent failure of the pulp cap is likely to jeopardize costly prosthodontic treatment.

Conservation of Tooth Structure

One of the basic tenets of restorative dentistry is to conserve as much tooth structure as possible while preparation design remains consistent with the adhesive or mechanical principles and coupled to esthetic and outcomes in tooth preparation. Tissue preservation reduces the harmful pulpal effects of the various procedures and materials used. Remaining dentin thickness has been shown[52] to be inversely proportional to pulpal response, and tooth preparation in close proximity to the pulp should be avoided. Dowden[53] argued that any damage to the odontoblastic processes would adversely affect the cell nucleus at the dentin-pulp interface, no matter how far from the nucleus it occurred. Thus, in assessing a possible adverse pulpal response, the amount of residual dentin must be taken into consideration; particular care must be exercised when vital teeth are prepared for complete-coverage restorations (Fig. 7.9).

Tooth structure is conserved through adherence to the following guidelines:

1. Use of partial-coverage rather than complete-coverage restorations (Fig. 7.10)[54]
2. Use adhesive bonding techniques to preserve enamel for bonding instead of preparing multiple axial walls (Fig. 7.11)

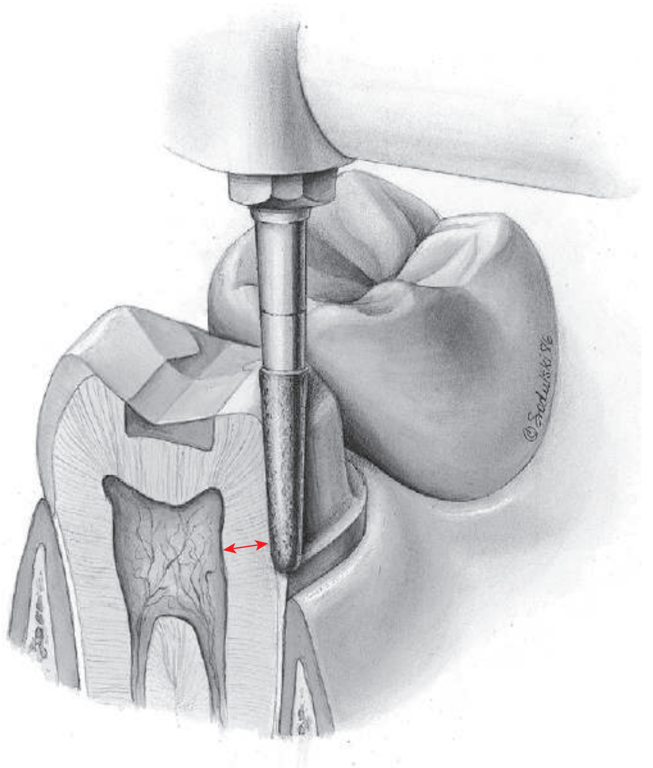


Fig. 7.9 A considerable amount of care is needed when a tooth is prepared for a complete crown, because of the extensive nature of the reduction with many dentinal tubules sectioned. Each tubule communicates directly with the dental pulp. Maximal dentin thickness should be maintained *(arrow)*.

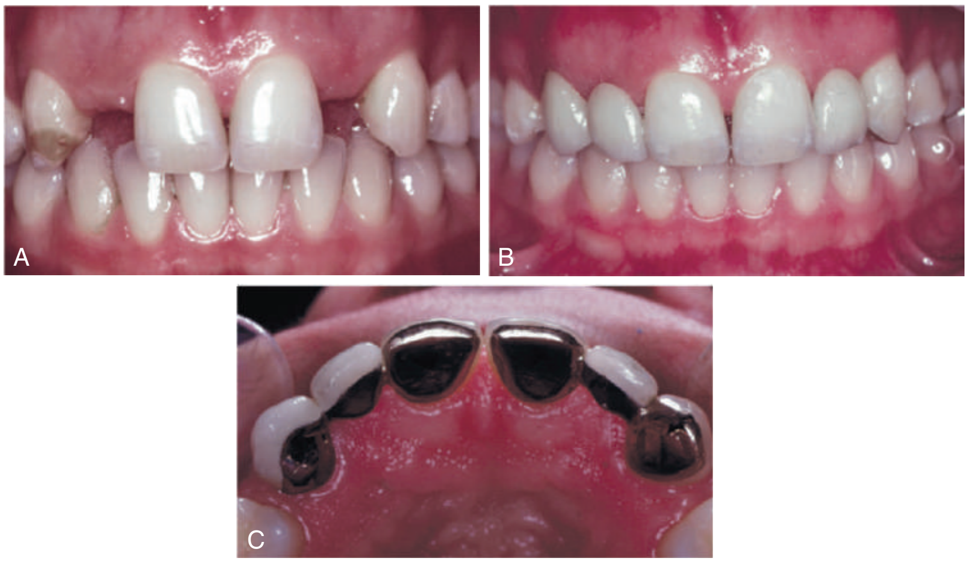


Fig. 7.10 Conservation of tooth structure by using partial-coverage restorations. In this patient, they are used as fixed partial denture abutments to replace congenitally missing lateral incisors.

Fig. 7.11 (A) Initial presentation, occlusal gold restoration with a crack in the tooth structure running mesial-distal-buccal. (B) Existing restoration and distal caries removed. After the buccal cusp had been reduced, it was decided to extend the preparation over the lingual cusp because of the mesial crack on the mesial margin ridge. (C) Definitive tooth preparation for a partial-coverage bonded ceramic restoration with cuspal coverage. (D) Cemented lithium disilicate partial-coverage restoration.

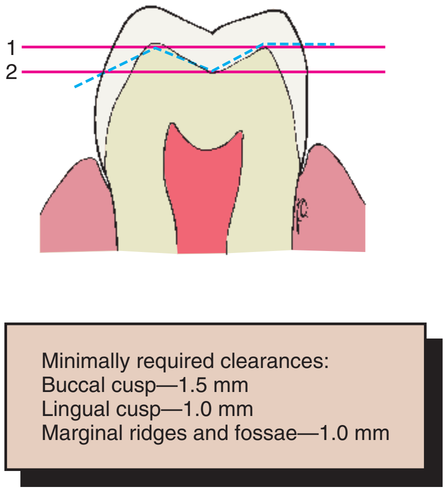


Fig. 7.12 An anatomically prepared occlusal surface results in adequate clearance without excessive tooth reduction. A flat occlusal preparation will result in either insufficient clearance *(1)* or an excessive amount of reduction *(2)*.

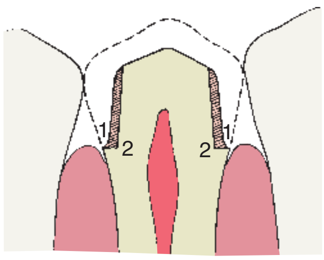


Fig. 7.13 A shoulder margin *(2)* is indicated when esthetic restorations are planned to achieve sufficient material thickness for a lifelike appearance, but it is much less conservative than a chamfer margin *(1)*.

3. Preparation of the occlusal surface so that reduction follows the anatomic planes and produces uniform thickness in the restoration (Fig. 7.12)
4. Selection of a margin geometry that is conservative and yet compatible with the other principles of tooth preparation (Figs. 7.13 and 7.14)
5. Avoidance of unnecessary apical extension of the preparation (Fig. 7.15), which would result in loss of additional tooth structure
6. When a complete crown is indicated: Preparation of teeth with the minimum practical convergence angle (taper) between axial walls (Fig. 7.16)
7. When a complete crown is indicated: Preparation of the axial surfaces so that a maximal thickness of residual tooth structure surrounding pulpal tissues is retained; if feasible, teeth may be orthodontically repositioned (Fig. 7.17; see Figs. 3.8 and 3.9), allowing less axial convergence than necessary when tooth alignment is less than optimal to accommodate preparations for fixed dental prosthetic retainers

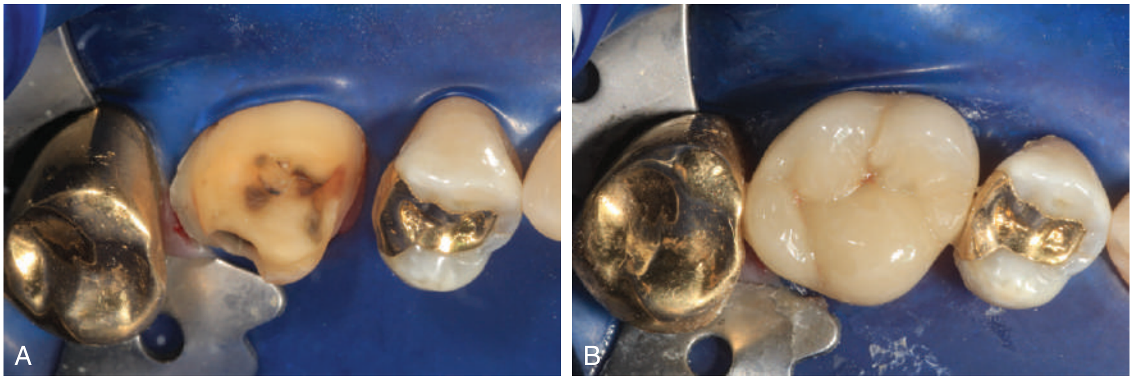


Fig. 7.14 (A) Example of a tooth preparation that fit the clinical needs of the tooth. Note the different finish line designs with smooth flowing rounded lines around the tooth in order to conserve sound tooth structure. (B) Bonded lithium disilicate restoration.

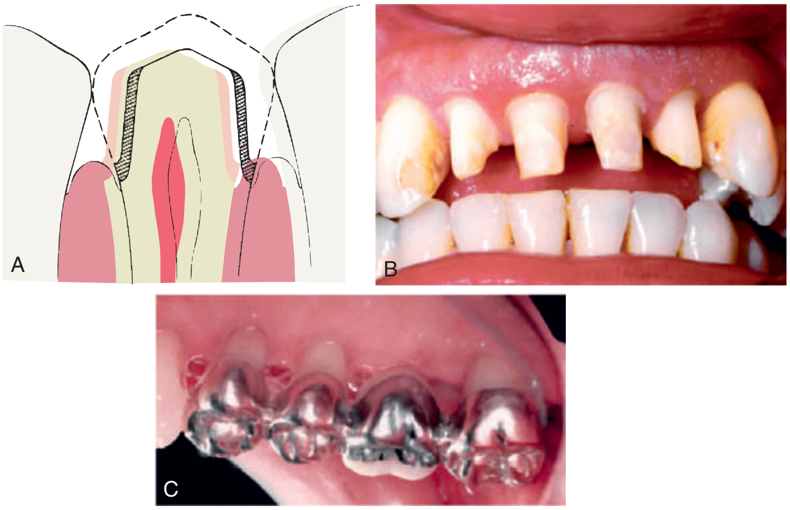


Fig. 7.15 (A) Apical extension of the preparation can necessitate additional tooth reduction because coronal diameter becomes smaller. (B) Preparations for periodontally involved teeth may necessitate considerable reduction if the margins are to be placed subgingivally for esthetic reasons. (C) Supragingival margins are preferred where applicable.

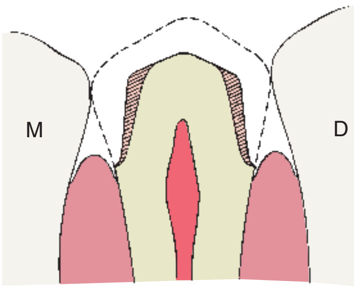


Fig. 7.16 Excessive taper results in considerable loss of tooth structure *(cross-hatched area)*.

Considerations Affecting Future Dental Health

Current techniques in tooth preparation and materials used for fixed reconstructions are compatible with healthy periodontium when patients are educated and motivated in self-performed oral hygiene.[55,56] The primary etiological factor for periodontitis is bacterial biofilm. However, improper tooth preparation may have adverse effects on long-term dental health. For example, insufficient axial reduction inevitably results in overcontoured restorations that hamper plaque control. This may cause periodontal disease[57] or dental caries in patients without good oral hygiene and a pathogenic oral biofilm. Alternatively, inadequate occlusal reduction may result in poor form and subsequent occlusal dysfunction. Poor choice of margin location, such as in the area of occlusal contact, may lead to chipping of ceramic, or enamel.[58]

Axial Reduction

Crown contours have been long debated with little scientific evidence. Gingival inflammation is commonly associated with crowns and fixed dental prosthetic abutments that have excessive axial contours, probably because it is more difficult for the patient to maintain plaque control around the gingival margin (Fig. 7.18).[59] Successful preparations provide a balance between sufficient space for the development of anatomically correct axial contours and conservation of tooth structure to preserve a durable abutment. The junction between the restoration and the tooth must be smooth and free of any ledges or abrupt changes in direction.

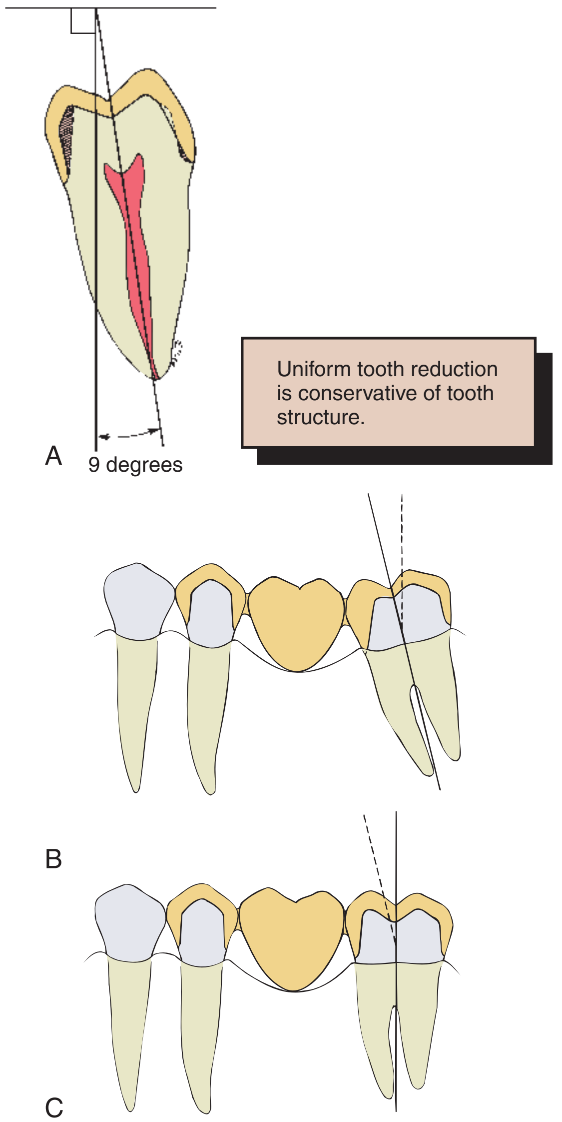


Fig. 7.17 To conserve tooth structure, the preparation of axial walls should be as uniform as possible. (A) The path of placement should coincide with the long axis of the tooth, which for a mandibular molar is typically inclined 9 to 14 degrees lingually. Preparing such a tooth with a path of placement that is perpendicular to the occlusal plane of the mandibular arch is a common clinical error that results in additional unnecessary removal of tooth structure *(cross-hatched area)*. (B) Malaligned teeth, such as a mesially tipped molar, necessitate additional removal of tissue on the mesial aspect of the molar abutment to achieve compatible paths of placement for a planned fixed partial denture. (C) If the molar abutment is orthodontically uprighted before tooth preparation, crown preparation can be more conservative.

In most circumstances, a crown should duplicate the profile of the original natural tooth that it is restoring.[60,61] Natural anterior teeth have facial mean subgingival emergence angles of 9.93 ± 5.68 degrees to the long axis of the tooth and 14.34 ± 8.44 degrees at the lingual.[62] As the contours migrate supragingivally, they slightly increase on the facial and lingual 11.13 ± 7.92 degrees and 15.58 ± 9.16 degrees respectively.[62] If an error is made, a slightly undercontoured, flat restoration is better because it is easier to keep free of plaque; however, increasing proximal contour on anterior crowns to maintain the interproximal papilla[63] (see Chapter 5) may be beneficial from an esthetic perspective. A general guideline is to match the contours of the contralateral tooth. Following this guideline, one would need to impress the complete arch so that these contours are communicated to the laboratory. Sufficient tooth structure must be removed to allow the development of correctly formed axial contours (Fig. 7.19), particularly in the interproximal and furcation areas of posterior teeth, where periodontal disease often progresses with serious consequences.

Margin Placement

Whenever possible, the margin of the preparation should be supragingival. Restorative margins placed within the periodontal sulcus are known as subgingival margins. Subgingival margins of indirect restorations have been identified as a factor in gingival inflammation, bleeding on probing, and recession of the periodontium (see Chapter 5).[64–70] Supragingival margins are easier to prepare accurately without trauma to the soft tissues and facilitate impression making or optical capture. They can usually also be situated on hard enamel, whereas subgingival margins are often on dentin or cementum.

Advantages of supragingival margins include the following:

1. Improved bonding with no crevicular seepage
2. Preservation of cervical tooth structure maintains structural integrity of the abutment
3. A dental dam could be used if indicated
4. They can be easily finished without associated soft tissue trauma.
5. They are more easily kept plaque free.
6. Impressions are more easily made, with less potential for soft tissue damage.
7. Restorations can be easily evaluated at the time of placement and at recall appointments.
8. Elevation of the restorative margin eliminates potential risks of chronic periodontal complications contributed by restorative dentistry.

Subgingival margins (Fig. 7.20), however, are indicated if any of the following conditions are present:

1. Dental caries, cervical erosion, or restorations extend subgingivally, and a crown-lengthening procedure (see Chapter 6) is contraindicated.
2. The proximal contact area extends apically to the level of the gingival crest.
3. Additional retention, resistance, or both are needed (see Restoration/Tooth Interface Considerations section later in the chapter).
4. The margin of an esthetic restoration is to be hidden behind the labiogingival crest.
5. Root sensitivity cannot be controlled by more conservative procedures, such as the application of dentin bonding agents or connective tissue grafts to cover exposed root structure.

Axial contour modification is indicated: for example, to provide an undercut to provide retention for a removable partial denture clasp (see Chapter 21). To start the emergence profile

Fig. 7.18 (A) Unhealthy gingival tissue as a result of overcontoured restorations. (B) The tooth preparations are underreduced. (C) Once the restorations are recontoured, gingival health returns.

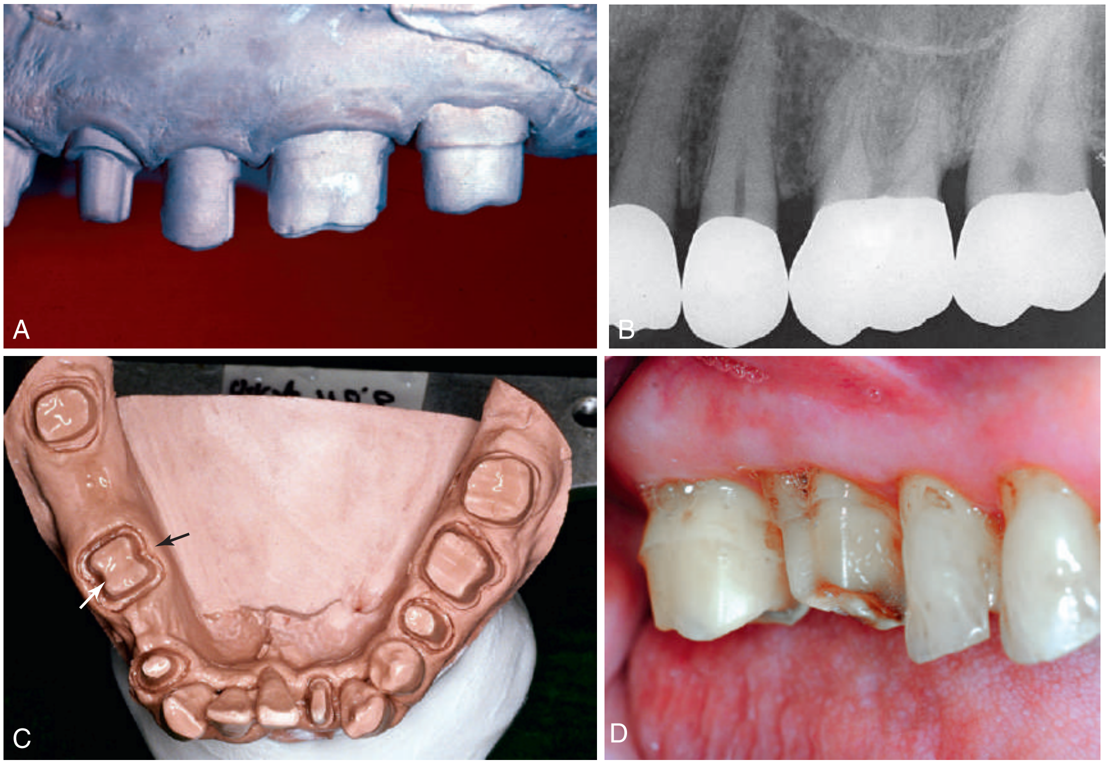


Fig. 7.19 (A and B) Tooth preparations with adequate axial reduction allow the development of properly contoured embrasures. Tissue is conserved through the use of partial-coverage and supragingival margins where possible. (C) Preparing furcation areas adequately is important *(arrows);* otherwise, the restoration is excessively contoured, which makes plaque control difficult. (D) Note the additional preparation of the buccal axial wall of the first molar to allow for improved access for plaque control in the furcation area.

Fig. 7.20 Examples of situations in which subgingival margins are indicated. (A) To include an existing restoration. (B) To extend apical to the proximal contact (adequate proximal clearance). (C and D) To hide the metal collar of metal-ceramic crowns.

of a crown more apical to close gingival black triangles Average dimensions for clinical crown height and sulcus depth in young healthy adults are provided in Fig. 7.21.

Margin Adaptation

The interface between a restoration and the tooth is always a potential site for recurrent caries because of dissolution of the luting agent and inherent surface roughness. The more precisely the restoration is adapted to the tooth, the lower is the risk for recurrent caries or periodontal disease.[71] Although a precise number for acceptable marginal gap width is not known, opinion papers have established a range from 40 to 120 μm.[72] A skilled technician can routinely make castings that fit to within 10 μm[73] and porcelain margins that fit to within 50 μm,[74] provided that the tooth was properly prepared. A well-designed preparation has a smooth and even margin. Rough, irregular, or "stepped" junctions between tooth and restoration greatly increase overall margin length and substantially reduce the adaptation accuracy of the restoration (Fig. 7.22).[75,76] The clinical significance of preparing smooth margins cannot be overemphasized. Time spent obtaining smooth margins makes the subsequent steps of tissue displacement, impression making, laboratory communication, die formation, waxing, and finishing much easier and ultimately results in longer-lasting restorations. Smooth, accurately placed preparation finish lines are particularly important when restorations are fabricated with a computer-aided design and computer-aided manufacturing (CAD-CAM) process.[77] Preparations need to consider the shape and diameter of the burs that mill the ceramic restorations. Preparations with sharp line angles result in restorations with over-milled intaglio surfaces. Over milling naturally leads to large internal cement gaps.

Margin Geometry

The cross-sectional configuration of the margin has been the subject of much analysis and debate.[78–85] Different shapes have been described and advocated (Table 7.2).[86,87] For evaluation, the following guidelines for margin design should be considered:

1. Ease of preparation without overextension or unsupported enamel at the cavosurface line angle
2. Ease of identification in the optical scan or impression and on the (virtual) die
3. A distinct boundary to which the virtual design or wax pattern can be terminated and finished
4. Sufficient bulk of material (to enable restoration strength at all phases of fabrication and durability for patient service)
5. Conservation of tooth structure (assuming the above criteria are met)

Proposed margin designs are presented in Table 7.3.

The feather edge margin design creates a vertical sleeve effect between the tooth and restorations with no horizontal shelf (Fig. 7.23A). Although extremely conservative to tooth structure, feather edge margins have been limited in clinical use because of their challenges with either providing adequate material bulk or creating an overcontoured emergence profile in the restored tooth. These margin designs were frequently used before the development of elastomeric impression materials. Historically, their main advantage was that they facilitated impression making with rigid modeling compounds in copper bands (a technique rarely used today). They were useful for that purpose because there was no ledge on which a band could catch. Restorations with feather margins are difficult from a laboratory technician viewpoint as well. Overcontoured restorations often result because conservative axial reduction may lead to insufficient space to make restorations of adequate thickness within the confines of correct anatomic form.

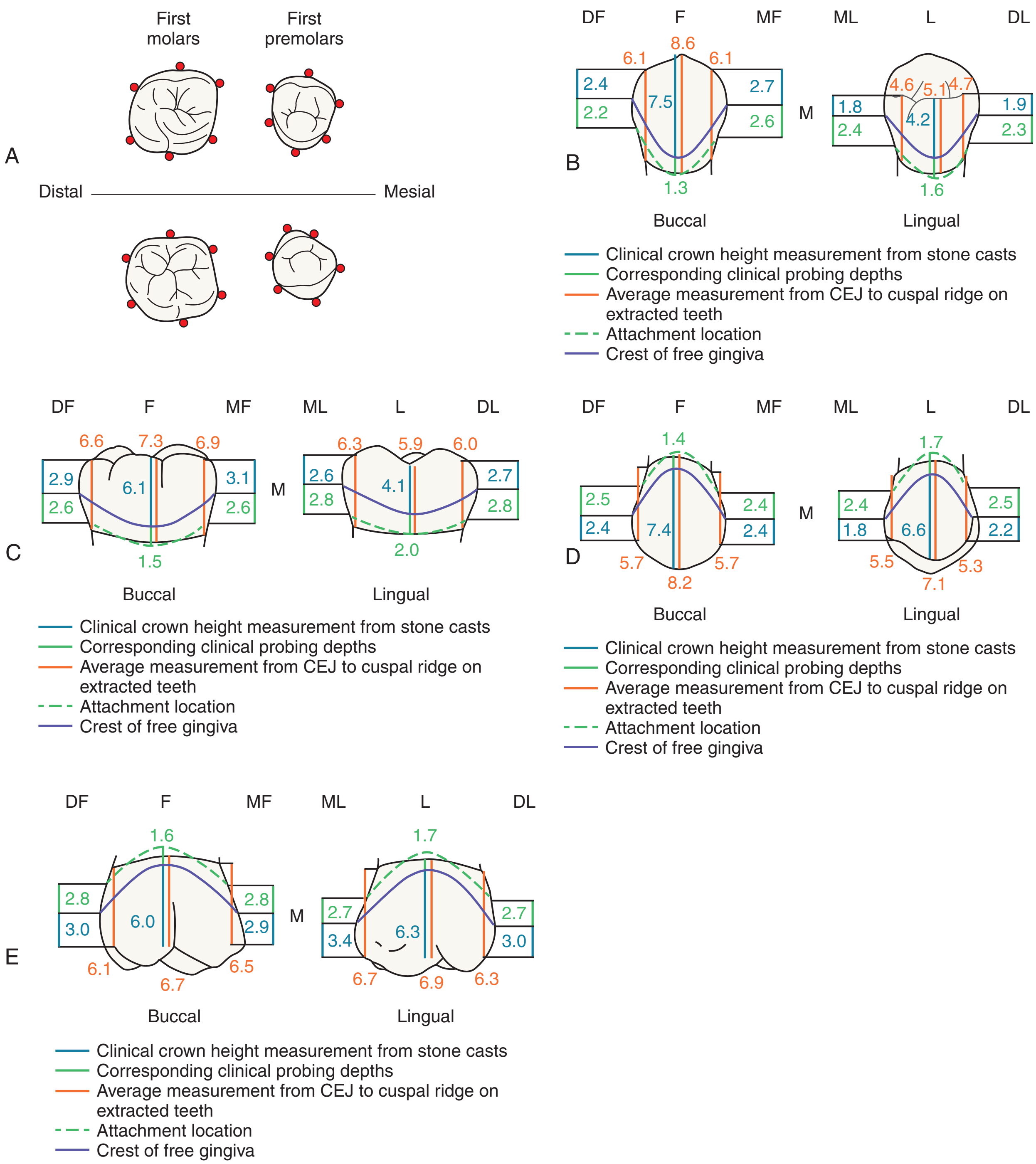


Fig. 7.21 Average normal dimensions for clinical crown height and sulcus depth in young healthy adults. (A) Occlusal view of measurement locations. (B) Mandibular first premolars. (C) Mandibular first molars. (D) Maxillary first premolars. (E) Maxillary first molars. *CEJ*, Cementoenamel junction; *DF*, distofacial; *DL*, distolingual; *F*, facial; *L*, lingual; *M*, mesial; *MF*, mesiofacial; *ML*, mesiolingual. (Data from Land MF. Unpublished data.)

When a cast restoration is planned, the technician can handle the wax pattern without distortion only by increasing its bulk beyond the original contours. For milled restorations, in most esthetic materials, minimal thickness requirements approaching 1 mm apply. However, margins of current mechanically improved ceramics like zirconia and lithium disilicate are durable at 0.5 mm thickness when luted with resin cements.[88–90] A 4-year randomized clinical trial on single monolithic zirconia crowns evaluated feather edge and chamfer finish lines. In the trial, the two geometric finish lines had no significant difference in clinical survival and success rates.[91] However, zirconia crowns with feather margins had a higher probability of bleeding on probing than the chamfer design. A 9-year retrospective study looked at lithium disilicate single crowns also with feather margins. The 9-year data showed a low clinical failure rate of 1.8%.[92] A variation of the feather edge, the biologically oriented

TABLE 7.2 Margins Produced by Various Types of Rotary Instruments

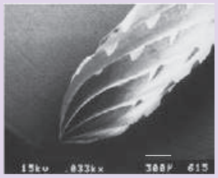
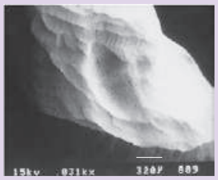
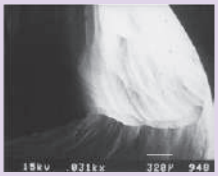
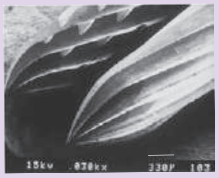
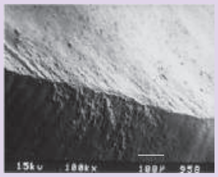
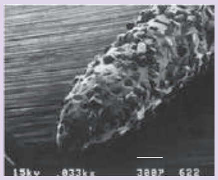
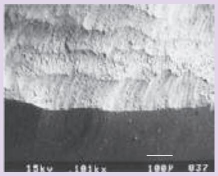
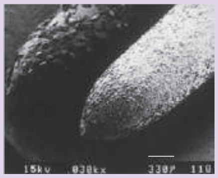
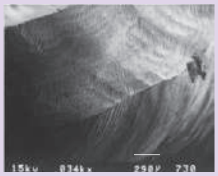
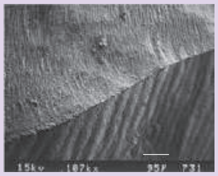
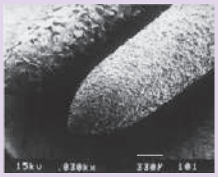
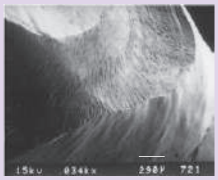
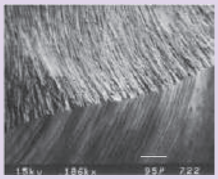
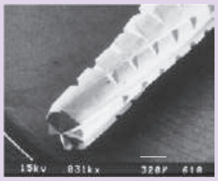
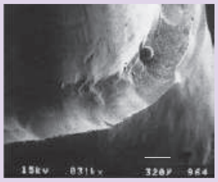
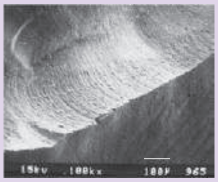
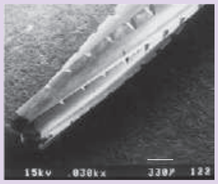
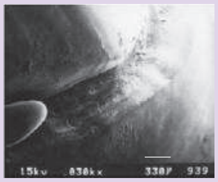
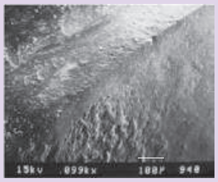
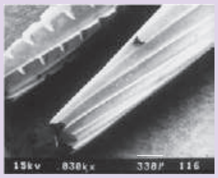
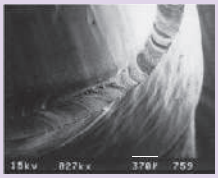
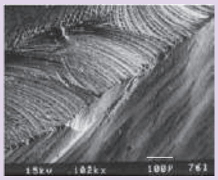
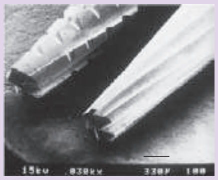
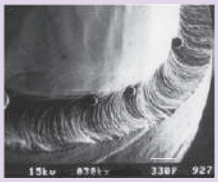
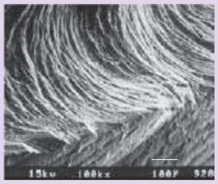
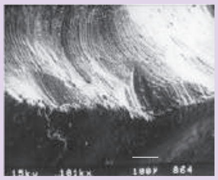
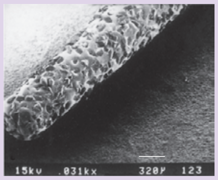
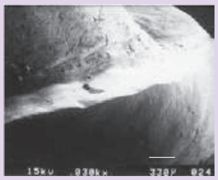
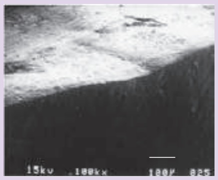
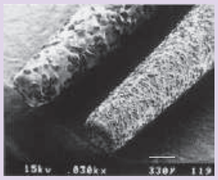
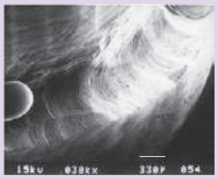
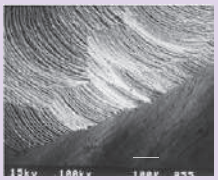
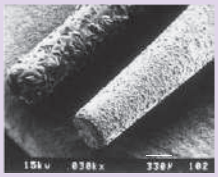
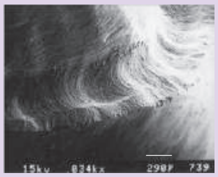
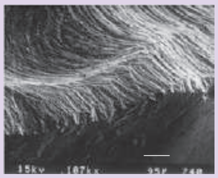
Rotary Instrument Appearance	Low Magnification of the Prepared Margin	High Magnification of the Prepared Margin
Chamfer Margins		
Chamfer tungsten carbide (high speed) 		
Chamfer tungsten carbide (high speed) Finishing tungsten carbide (high speed) 		
Chamfer tungsten carbide (high speed) Finishing tungsten carbide (low speed) 		
Chamfer coarse diamond (high speed) 		
Chamfer coarse diamond (high speed) Fine diamond (high speed) 		
Chamfer coarse diamond (high speed) Chamfer fine diamond (low speed) 		
Shoulder Margins		
Cross-cut fissure (high speed) 		

TABLE 7.2 Margins Produced by Various Types of Rotary Instruments—Cont'd

Rotary Instrument Appearance	Low Magnification of the Prepared Margin	High Magnification of the Prepared Margin
Cross-cut fissure (high speed) and hoe 		
Cross-cut fissure tungsten carbide (high speed) Finishing tungsten carbide (high speed) 		
Cross-cut fissure tungsten carbide (high speed) Finishing tungsten carbide (low speed) 		
Flat-end coarse diamond (high speed) 		
Flat-end coarse diamond (high speed) and hoe 		
Flat-end coarse diamond (high speed) Fine-grit diamond (high speed) 		
Flat-end coarse diamond (high speed) Fine-grit diamond (low speed) 		

Courtesy Dr. H. Lin.

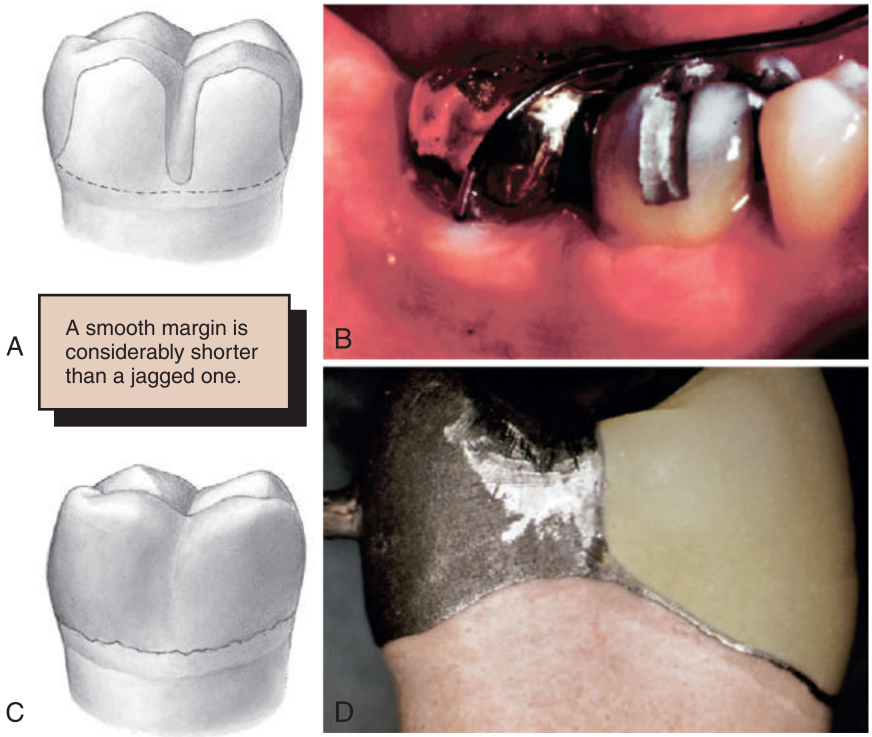


Fig. 7.22 (A and B) Poor preparation design, leading to increased margin length. (C) A rough, irregular margin makes the fabrication of an accurately fitted restoration almost impossible. (D) An accurately fitting margin is possible only if it is prepared smoothly.

TABLE 7.3 Advantages and Disadvantages of Different Margin Designs

Margin Design	Advantages	Disadvantages	Indications
Feather edge	Conservative of tooth structure	Does not provide sufficient bulk	Bonded ceramic restorations
Chisel edge	Conservative of tooth structure	Location of margin difficult to control	Occasionally on tilted teeth
Beveled	Removes unsupported enamel, allows finishing of metal	Extends preparation into sulcus if used on apical margin	Facial margin of maxillary partial-coverage restorations and inlay/onlay margins
Chamfer	Distinct margin, adequate bulk, easier to control	Care needed to avoid unsupported lip of enamel	Cast metal restorations, lingual margin of metal-ceramic crowns, porcelain laminate veneers, ceramic restorations
Shoulder	Bulk of restorative material	Less conservative of tooth structure	Facial margin of metal-ceramic crowns, ceramic restorations
Sloped shoulder	Bulk of material, advantages of bevel	Less conservative of tooth structure	Facial margins of metal-ceramic crowns
Beveled shoulder	Bulk of material, advantages of bevel	Less conservative, extends preparation apically	Facial margin of posterior metal-ceramic crowns with supragingival margins

preparation technique, is a geometric shape that prepares the tooth in a convergent form without a finish line (modified feather margin).[93] Randomized clinical trial found posterior 3-unit zirconia FPDs on biologically oriented tooth preparations have high survival rates and low gingival index after 5 years.[94] A variation of the feather edge, the chisel edge margin (see Fig. 7.23B), is formed when the angle between the axial surfaces and the unprepared tooth structure is larger. Unfortunately, this margin is frequently associated with preparations with excessive angles of convergence (taper) and preparations in which the orientation of the axial reduction is not correctly aligned with the long axis of the tooth.

Feather edge preparations may be the best option for porcelain laminate veneer preparations (see Chapter 8), inasmuch as maintaining enamel for the bonded restoration is important for the longevity of the bond. Bulk of the ceramic at the margin can be reduced after bonding (see Chapter 25), and because laminate veneer margins are accessible to the patient, plaque control around veneers is rarely a problem, in contrast to complete crowns.

A chamfer margin (see Fig. 7.23C) is particularly suitable for high-strength ceramic, cast metal crowns, and the metal-only portion of metal-ceramic crowns (Fig. 7.24). It is distinct and easily identified, and it provides room for adequate bulk

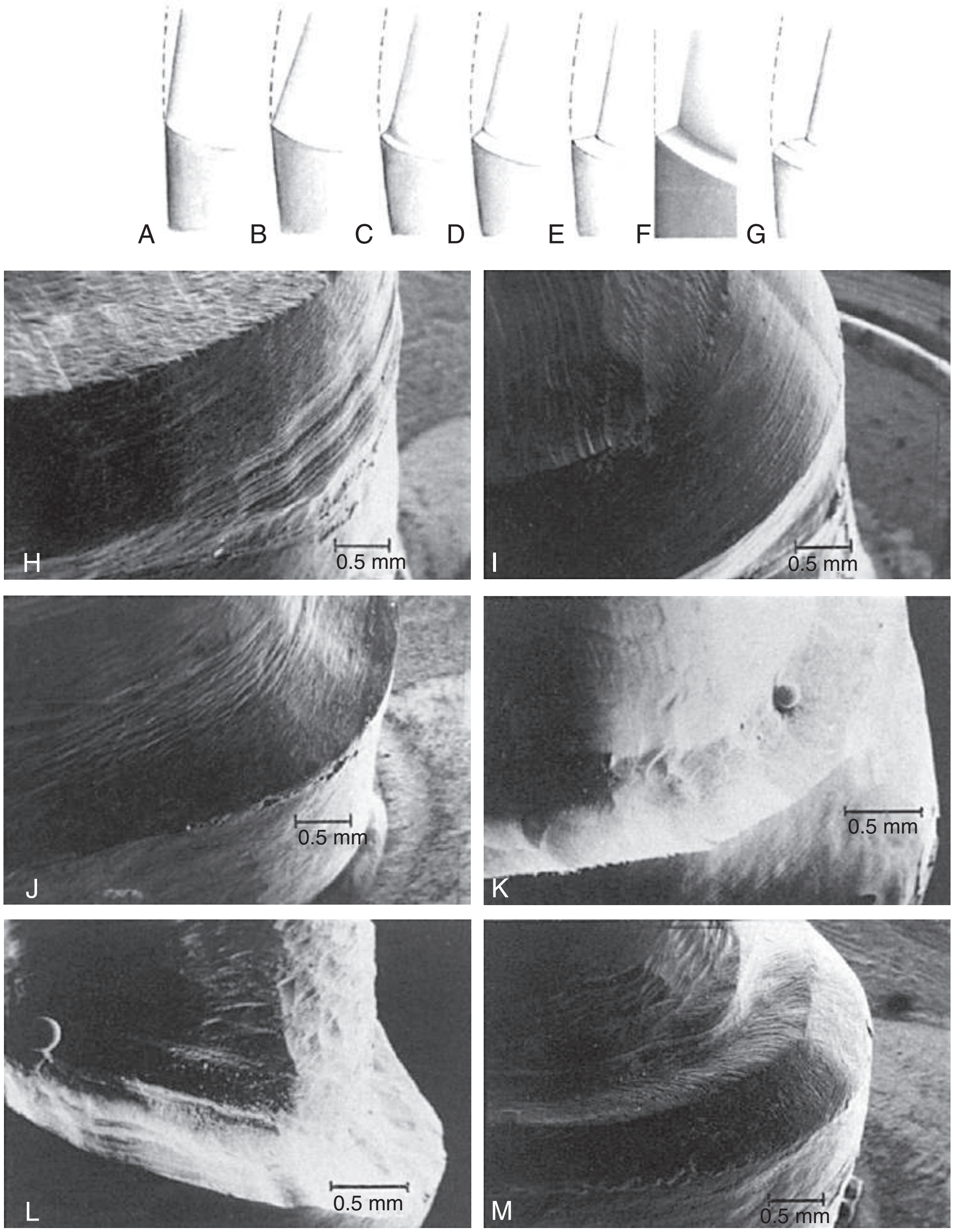


Fig. 7.23 Margin designs: illustrations (A–G) and scanning electron micrographs (H–M). (A) Feather edge. (B) Chisel. (C) Chamfer. (D) Beveled. (E) Shoulder. (F) Sloped shoulder. (G) Beveled shoulder. (H) Feather or chisel edge. (I) Beveled. (J) Chamfer. (K) Shoulder. (L) Sloped shoulder. (M) Beveled shoulder. (Courtesy Dr. H. Lin.)

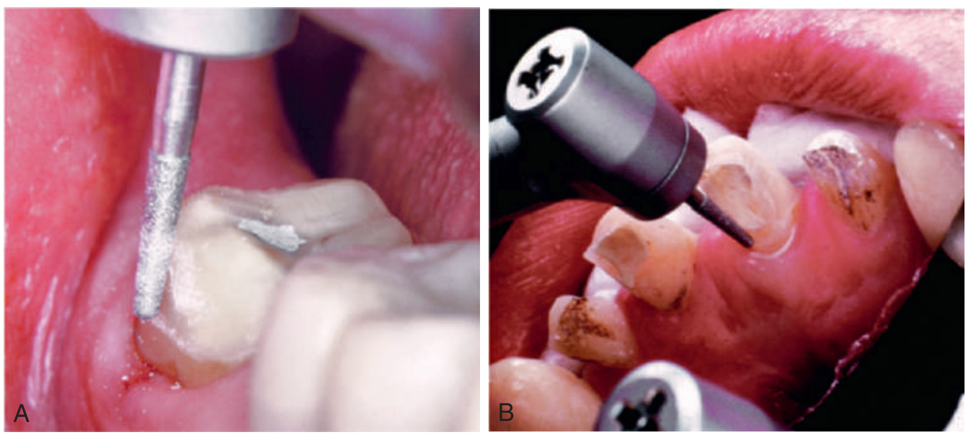


Fig. 7.24 Chamfer margins are recommended for cast metal crowns (A) and the lingual margin of a metal-ceramic crown (B).

of material and the development of anatomically correct axial contours. Chamfer margins can be placed expediently and with precision, although care is needed to avoid leaving a lip of unsupported enamel (Fig. 7.25).

The most suitable instrument for making a chamfer margin is probably a torpedo shaped diamond with a rounded tip; the resulting margin is the exact profile of the instrument (Fig. 7.26). Marginal accuracy depends on having a high-quality diamond and a true-running handpiece. The gingival margin is prepared with the diamond held precisely in the intended path of placement of the restoration (Fig. 7.27).

Tilting it away from the tooth produces an undercut, whereas angling it toward the tooth leads to excessive convergence and reduction and loss of retention. The chamfer margin should never be prepared wider than half the tip of the diamond; otherwise, an unsupported lip of enamel may result (see Fig. 7.25). Some authorities have recommended the use of a diamond with a noncutting guide tip to aid accurate chamfer margin placement.[95] However, such guides have been shown to damage tooth structure beyond the intended preparation margin.[96]

In some circumstances, a beveled margin (see Fig. 7.23D) is more suitable for cast restorations, particularly if a ledge or shoulder margin already exists, possibly as a result of dental caries, cervical erosion, or a previous restoration. The objective in beveling is threefold: (1) to allow the cast metal margin to be bent or burnished against the prepared tooth structure; (2) to minimize the marginal discrepancy[78] caused by a complete crown that fails to seat completely (however, Pascoe[83] showed that when an oversized crown is considered, the discrepancy is

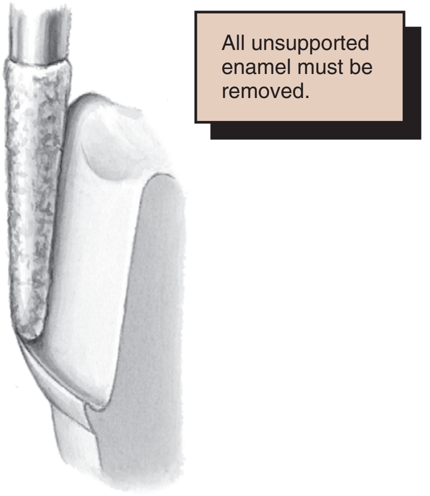


Fig. 7.25 A chamfer margin should not be wider than half the rotary instrument used to form it. Otherwise, a "lip" of unsupported enamel will be left.

Fig. 7.26 A chamfer margin is formed as the negative profile of a round-ended tapered diamond.

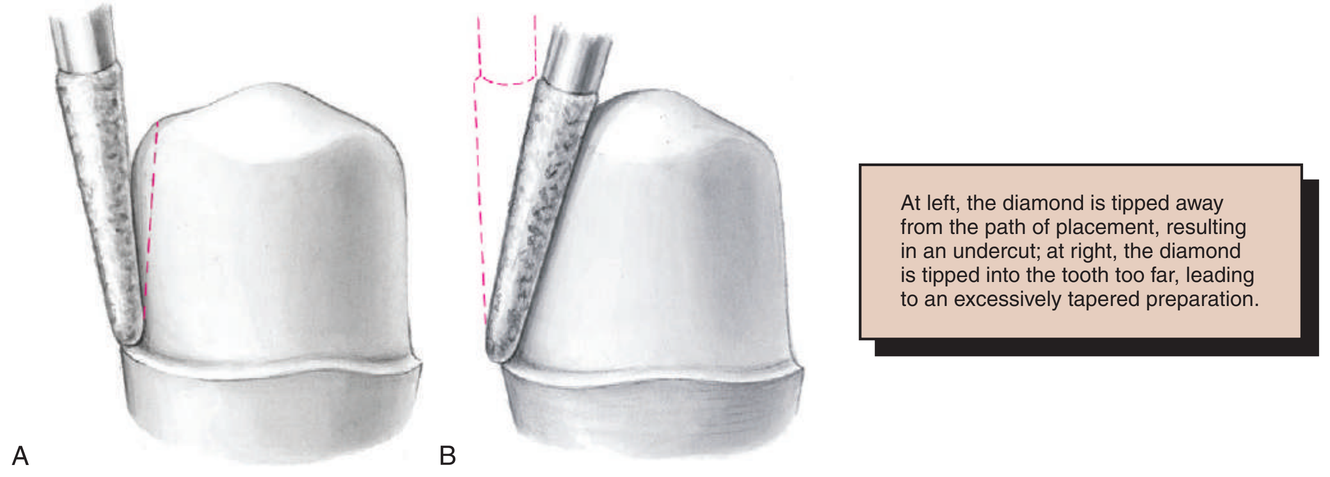


Fig. 7.27 Precise control of the orientation of the diamond is very important. (A) Tilting away from the tooth creates an undercut: Opposing axial preparation walls diverge in an occlusal direction. (B) Tilting toward the tooth results in an excessive convergence angle of the preparation.

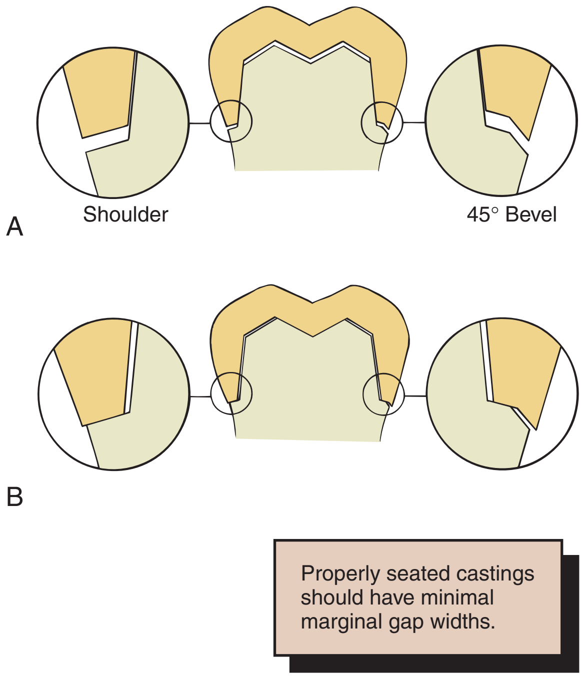


Fig. 7.28 Effect on marginal fit of beveling the gingival margin. (A) If the internal cross section of a crown is the same as or less than that of the prepared tooth, a 45-degree bevel decreases the marginal discrepancy by 70%. (B) If the internal diameter is slightly larger than the prepared tooth, beveling increases the marginal discrepancy. In practice, crowns are made slightly larger than the prepared tooth to allow for the luting agent.

increased rather than decreased; Fig. 7.28); and (3) to protect the unprepared tooth structure from chipping (e.g., by removing unsupported enamel). Of note is that when access for burnishing is limited, there is little advantage in beveling. This applies particularly to a gingival margin, in which beveling would lead to subgingival extension of the preparation or placement of the margin on dentin rather than on enamel.

Because a shoulder margin (see Fig. 7.23C) allows room for porcelain and an alloy, it is recommended for the facial part of metal-ceramic crowns, especially when the porcelain margin technique is used. It should form a 90-degree angle with the unprepared tooth surface. An acute angle is likely to chip (Fig. 7.29A). In practice, dentists tend to underprepare the facial shoulder margin,[97,98] leading to restorations with inferior esthetics or poor (excessive) axial contour.

Some authorities[87] have recommended a heavy chamfer margin rather than a shoulder margin, and some find a chamfer margin easier to prepare with precision. Earlier workers[81,82] found less distortion of the metal framework during porcelain application with a shoulder margin, although with modern alloys, these results could not be replicated.[99–102]

A 120-degree sloped shoulder margin (see Fig. 7.23F) is sometimes used as an alternative to the 90-degree shoulder margin for the facial margin of metal-ceramic crowns. The sloped shoulder margin reduces the possibility of leaving unsupported enamel but leaves sufficient bulk to allow thinning of the metal framework to a knife edge for acceptable esthetics.

A beveled shoulder margin (see Fig. 7.23G) has been recommended by some authorities for the facial surface of a metal-ceramic restoration if a metal collar is planned (as opposed to a porcelain labial margin). The beveling removes unsupported enamel and may allow some finishing of the metal. It is particularly useful for restoring structurally compromised anterior teeth that have preexisting large shoulder finish lines and minimal ferrule effect. The existing shoulder is incorporated into the preparation, but a bevel is placed subgingivally onto the root surface to increase the ferrule effect. The shoulder bevel margin design is a more conservative option for retreating previously restored teeth with existing shoulder margins and slender roots instead of extending the shoulder subgingivally to lengthen axial walls and gain retention. However, when the tooth structure is available, a shoulder or sloped shoulder margin is preferred for esthetic reasons. This allows improved esthetics because the metal coping of the crown can be thinned to a knife edge margin and hidden in the sulcus without the need for positioning the margin closer to the epithelial attachment (see Fig. 7.29B). Table 7.2 illustrates chamfer and shoulder margin preparations obtained with selected instruments.

A comprehensive literature review of current scientific knowledge on complete-coverage tooth preparations suggests that margin design should be selected on the basis of the type of crown, applicable esthetic requirements, ease of formation, and operator experience. Research has not validated the expectation of enhanced fit being associated with the selection of certain types of finish line geometry.[103]

Occlusal Considerations

A satisfactory tooth preparation allows sufficient space to develop a functional occlusal scheme in the finished restoration. To deliver successful functional occlusion, the clinician has to evaluate the occlusion before occlusal reduction is performed and determine if the patient's occlusion will be maintained or altered. Typically, the goal of a single crown is to maintain the current occlusal relationship in maximal intercuspation. When the patient's occlusion is changed, it is customary to involve multiple restorations and to have a diagnostic set up before tooth preparation. The diagnostic setup is discussed later in the chapter. At the assessment of the occlusion, it is important to distinguish between occlusal reduction and interocclusal clearance. The glossary of prosthodontic terms defines occlusal reduction as the quantity of tooth structure that is removed to establish adequate space for a restorative material between the occlusal aspect of the tooth preparation and the opposing dentition.[104] In contrast, interocclusal clearance is defined as the amount of reduction achieved during tooth preparation to provide for an adequate thickness of restorative material.[104]

To summarize, the amount of tooth occlusal tooth structure removed is to achieve the appropriate amount of prosthetic space for a specific type of crown so that it can maintain or deliver a successful occlusal scheme for that specific patient. Sometimes, the patient's occlusion is disrupted by supra-erupted or tilted teeth (Fig. 7.30; see Fig. 3.8B and C). When such teeth are prepared for crowns, the eventual occlusal plane must be carefully analyzed and the teeth reduced accordingly. Considerable reduction is

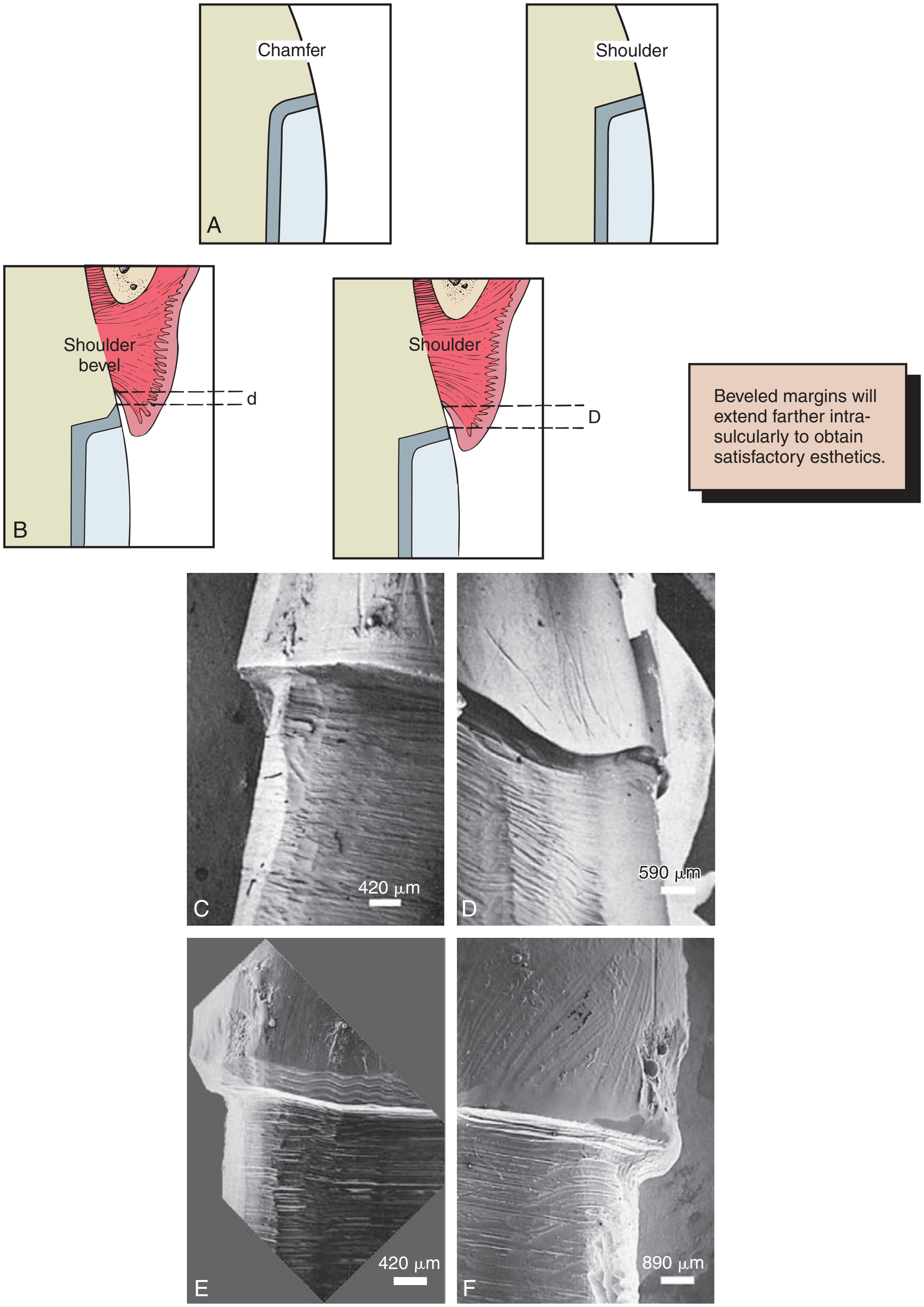


Fig. 7.29 (A) A shoulder margin provides more bulk of metal than a heavy chamfer margin, which may facilitate the laboratory steps. (B) A disadvantage of the beveled shoulder margin is that it must be placed deeper in the gingival sulcus so that the wider band of metal will be hidden (compare depth *d* with depth *D*). (C) Scanning electron micrograph of a shoulder margin prepared with a high-speed diamond. (D) Scanning electron micrograph of a margin refined with a sharp chisel. (E) Scanning electron micrograph of a margin beveled with a tungsten carbide bur. (F) Scanning electron micrograph of a bevel placed with a sharp hand instrument. (Microscopy by Dr. J. Sandrik; teeth prepared by Dr. G. Byrne.)

Fig. 7.30 (A) Nonreplacement of missing teeth has led to supra-occlusion and a protrusive interference *(arrow)*. (B) Teeth reduced with the help of trial tooth preparations and diagnostic waxing. (C) Restorations with anterior guidance.

often needed to compensate for the supra-eruption of abutments. In turn, this may shorten tooth preparation axial wall height to the extent that mechanical properties such as retention and resistance are compromised (see the later section on Restoration/Tooth Interface Considerations), which may necessitate the preparation to rely on an adhesive preparation and cementation protocol or perform clinical crown lengthening. In mechanically compromised situations where the residual tooth structure is not adequate for bonding and periodontal crown lengthening is not indicated, it is advised to supplement preparations with secondary retentive features. Secondary retention consists of grooves, boxes, and cast pin retention. It must be noted that internal features like boxes and groves are classically considered for cast alloy restorations and not for ceramics. However, one fatigue study showed that zirconia-based crowns with a mesial and distal groove of 1 mm wide and 1 mm deep, .5 mm coronal of the finish line, halted crack progression at the crowns cameo surface and preparations without grooves did not.[105] In addition, a finite element analysis study identified retentive grooves reduced stress concentrations in both the tooth and lithium disilicate glass-ceramic endocrowns.[106] Caution must be used with extrapolating clinical results from laboratory studies; however, the data offered looks promising for teeth with questionable mechanical retentive forms.

Sometimes even endodontic treatment is necessary to make enough inter-arch space. However, in these circumstances, compromising the principle of conservation of tooth structure is preferable to the potential harm that might result from a restoration that incorporates a traumatic occlusal scheme. Careful judgment is obviously needed. Diagnostic tooth preparations and diagnostic waxing procedures are essential to help determine the exact amount of reduction necessary to develop an optimum occlusion (see Chapter 4).

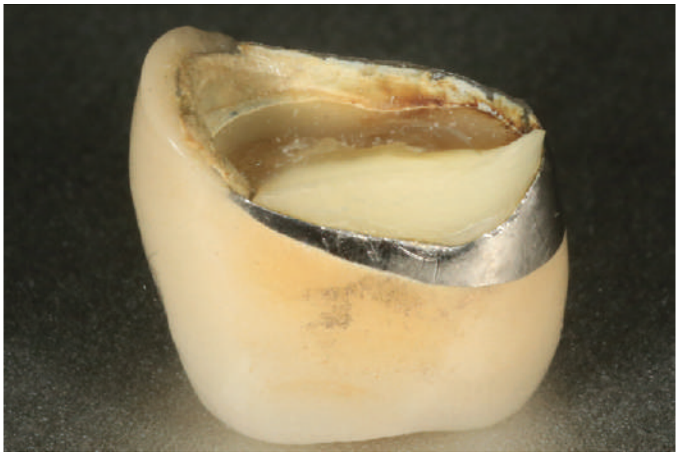


Fig. 7.31 A tooth that was restored with a metal-ceramic crown. The crown was in service for 20 years. Although the crown did not break, the tooth underwent a catastrophic horizontal fracture. Note the discolored appearance of the zinc phosphate cement starting at the interface of the crack.

Preventing Tooth Fracture

No tooth is unbreakable (Fig. 7.31). If teeth are suddenly smashed together (as in an automobile accident, sports injury, or biting unexpectedly on a hard object), a cusp may break. Cuspal fracture can also result from parafunctional habits such as bruxism.

The likelihood that a restored tooth will fracture can be lessened if the tooth preparation is designed to minimize potentially destructive stresses (Fig. 7.32). For example, an intracoronal cast restoration (inlay) has a greater potential for

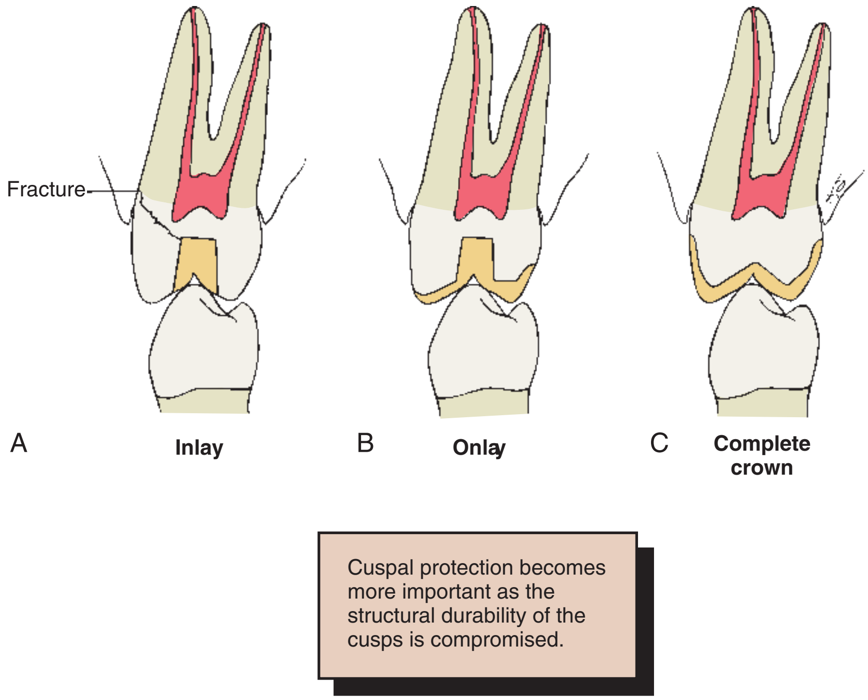


Fig. 7.32 (A) An intracoronal cast restoration (inlay) can act as a wedge during cementation or function. If the cusps are weakened, fracture will occur. (B) A cuspal-coverage onlay provides better protection but often lacks retention. (C) A complete crown provides the best protection against fracture. It also has the best retention, but it can be associated with periodontal disease and poor esthetics. (Redrawn from Rosenstiel SF. Fixed bridgework—the basic principles. In: Rayne J, ed. *General Dental Treatment*. London: Kluwer Publishing; 1983.)

fracture because when occlusal forces are applied to the restoration, it tends to serve as a wedge between opposing walls of the preparation. This wedging must be resisted by the remaining tooth structure; if the remaining tooth structure is thin (as with a wide preparation isthmus), the tooth may fracture during function. As a result, wide inlay preparations with cohesively cemented gold restorations result in less cuspal stress when the preparation is extended to wrap over the cusps (onlay).[107] Teeth with missing vital anatomical parts like marginal ridges and dentin above the pulp chamber are structurally weak in comparison to fully intact teeth.[108] In contrast, an in vitro study showed that when indirect composite restorations were adhesively bonded to tooth structure, the restored teeth had similar fracture strength and fracture modes independent of isthmus width and cuspal coverage.[109] Another in vitro study concluded that bonded ceramic inlays with isthmus widths and depths of 2 and 3 mm respectively restored the fracture load of teeth to a comparable level to intact teeth.[110] However, a different in vitro study investigated large mesio-occluso-distal (MOD) inlay preps with the isthmus depth of 4 and 3 mm wide at the pulpal floor. The faciolingual dimensions of the proximal boxes were prepared to 6 mm wide. The data showed that bonding ceramic to large inlay preparations with week cusps did not strengthen the tooth. It was determined that the MOD preparations weakened the tooth by approximately 59%.[111] In situations where the residual cusps are thin and marginal ridges are missing, it may be advisable to perform occlusal reduction to cover the weak cusps with a restoration.

RESTORATION/TOOTH INTERFACE CONSIDERATIONS

Traditional Mechanical Geometric Shapes for Tooth Preparation

Traditional tooth preparation design for fixed prosthodontics was developed before adhesive dentistry and still has relevance today. With badly broken-down teeth and questionable substrates for bonding, an in-depth understanding of certain mechanical principles are valuable; otherwise, the restoration may dislodge, distort, or fracture during service. These principles have evolved from theoretical and clinical observations and are supported by experimental studies. The monolithic zirconia complete crown and FPDs are examples of contemporary restorations that is steeped in traditional tooth preparation design.

Mechanical considerations can be divided into three categories:

1. Providing retention form
2. Providing resistance form
3. Preventing deformation of the restoration

Retention and resistance form coexist and work together to develop a geometric form of preparation to prevent a restoration from dislodging.[104] For theoretical purposes only, retention and resistance will be discussed separately; however, clinically, it is not possible to have one without the other.

Retention Form and Vertical Forces

Vertical forces (e.g., when the jaws are moved apart after biting on very sticky food) act on a cemented restoration in the same direction as the path of placement. The quality of a preparation that prevents the restoration from becoming dislodged by such forces parallel to the path of placement is known as its *retention form*. Retention form has to consist of two opposing walls. An axial wall without an opposing axial wall has no mechanical benefit to the geometric space of a tooth preparation. With a complete crown preparation, the tooth is prepared 360 degrees around the tooth to deliver circumferential opposing axial walls at every point. As a result of a complete crown preparation, when the crown is seated on the preparation along its path of placement the axial walls deliver circumferential retention to a crown that will counteract vertical forces of removal. The opposing axial walls of a crown preparation create the *primary retention* of a crown. Only dental caries and porcelain failure cause more failure of crowns and fixed dental prostheses than does lack of retention.[112,113]

The dentist must consider the following factors when deciding whether retention is adequate for a given fixed restoration:

1. Magnitude of the dislodging (vertical) forces
2. Geometry of the tooth preparation
3. Roughness of the fitting surface of the restoration
4. Materials being cemented
5. Film thickness and properties of the luting agent

Magnitude of the Dislodging (Vertical) Forces

Forces that tend to remove a cemented restoration along its path of placement are small in comparison with those that tend to seat or tilt it. An FPD or splint can be subjected to such forces by pulling with floss under the connectors; however, the greatest removal forces generally arise when exceptionally sticky food (e.g., caramel) is eaten. The magnitude of the dislodging forces exerted by the elevator muscles depends on the stickiness of the food and on the amount of surface area of the preparation. The surface area is affected by the height of axial walls and the diameter of a tooth. Each tooth type has a different inherent risk dependent on its perimeter and height to resist vertical forces generated in the mouth.

Geometry of the Tooth Preparation

Many fixed dental prostheses depend on the geometric form of the preparation and then are supplemented with adhesion. To understand the theory of mechanical retentive forms, it is helpful for one to first understand traditional luting agents. Zinc phosphate, a traditional luting agent, is nonadhesive (i.e., they act by increasing the frictional resistance between tooth and restoration). Interestingly, zinc phosphate is also water soluble. The grains of the luting agent prevent two surfaces from sliding, although they do not prevent one surface from being lifted from another. This is analogous to the effect of particles of sand or dust within machinery: They do not adhere specifically to metal, but they increase the friction between sliding metal parts. If sand or dust gets into a mechanical camera or watch, the increase in friction can effectively jam the mechanism. To demonstrate the success of mechanical retention, zinc phosphate, and the highest level of clinical precision of cast gold restorations, a retrospective clinical evaluation of 1314 cast gold restorations by Dr. R. V. Tucker was performed. Over a period of service that ranged from 1 to 52 years, data showed an overall failure rate of 4.6% with a survival rate of 95.4% (Fig. 7.33).[114]

Traditional luting agents are effective only if the restoration has a limited number of paths of placement (i.e., the tooth is shaped to restrain the free movement of the restoration). The relationship between a nut and a bolt is an example of restrained movement (Fig. 7.34): The nut is not free to move in just any direction; it can move only along the precisely determined helical path of the threads on the bolt.

The relationship between two bodies, one (in this case, a tooth preparation) restraining movement of the other (a luted restoration), has been studied mathematically and is known in analytical mechanics as a *closed lower pair of kinematic elements*.[115] In fixed prosthodontics, a sliding pair is the only pair that has relevance. It is formed by two cylindrical[a] surfaces constrained to slide along one another. The elements are constrained if the curve that defines the cylinder is closed or shaped to prevent movement at right angles to the axis of the cylinder (Fig. 7.35).

A tooth preparation is cylindrical if the axial surfaces are prepared by a cylindrical rotary instrument held at a constant angle. The fixed curve of the mathematical definition is the gingival margin of the preparation, and the occlusoaxial line angle of the tooth preparation should be a replica of the gingival margin geometry. The curve of a complete crown preparation is closed, whereas the grooves of a partial crown preparation prevent movement at right angles to the long axis of the cylinder. However, if one wall of the complete crown preparation is overtapered, it is no longer cylindrical, and the cemented restoration is not constrained by the preparation because the restoration will have an increased number of pathways for withdrawal. Under these circumstances, the cement particles tend to lift away from rather than slide along the preparation, and the only retention is a result of the cement's limited adhesion (Fig. 7.36).

Taper. *Taper* is defined as the convergence of two opposite-facing external walls of a crown preparation as viewed in a given plane (e.g., taper between a mesial wall and a distal wall, or between a buccal wall and a lingual wall of a crown preparation). The extension of those planes forms an angle described as the *angle of convergence*. Theoretically, maximum retention is obtained if a tooth preparation has parallel walls. However, it is neither desirable nor practical to prepare a tooth this way with current techniques and instrumentation because (1) some convergence is desirable to allow escape of excess luting agent during seating of the crown and (2) slight undercuts are often present in preparations that are too cylindrical and prevent the restoration from seating.

An *undercut* on a complete crown preparation is defined as any irregularity in the wall of a prepared tooth that prevents the

[a]*Cylinder* is defined in its mathematical sense as the solid generated by a straight line parallel to another straight line and moving so that its ends describe a fixed curve.

Fig. 7.33 Clinical treatments. (A) Gold inlay preparation. (B) Cemented gold inlay with zinc phosphate cement. (C) 7/8th gold crown preparation. (D) Occlusal view of 7/8th cast gold crown. (E) Buccal view of 7/8th crown after cementation with zinc phosphate. Note esthetics achieved by preservation of mesial buccal cusp. (F) Modified inlay/onlay cast gold preparation. (G) Cemented partial-coverage cast gold restoration. (Courtesy of Dr Richard D. Tucker.)

withdrawal or seating of a wax pattern or crown. Such is the case when divergence is inadvertently created between opposite-facing external axial walls, or wall segments, in a cervico-occlusal direction (Fig. 7.37A). In other words, if the cervical diameter of a tooth preparation at the margin is narrower than at the occlusoaxial junction (reverse taper), it is impossible to seat a complete crown of similar geometry (see Fig. 7.37A and B). Undercuts can be present whenever two axial walls face opposite directions (see Fig. 7.37C). Thus, the mesial wall of a complete crown preparation can be undercut in relation to the distal

> Minimizing taper effectively limits the number of directions in which a cast crown can be dislodged.

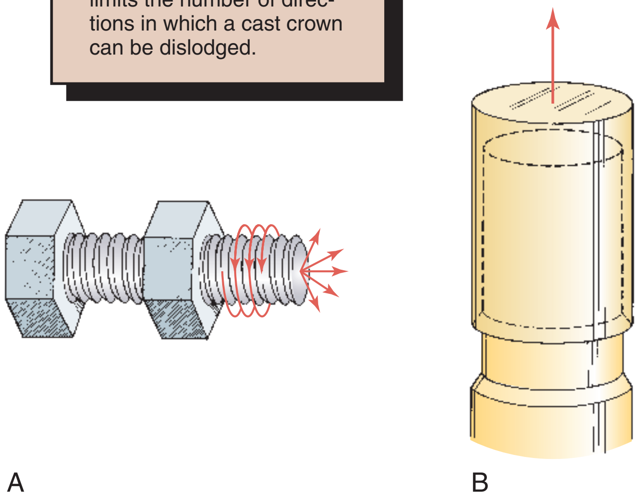


Fig. 7.34 (A) The relationship between a nut and a bolt is an example of restrained movement: The nut can move only along a precisely defined helical path *(arrows)*. (B) For effective retention, a tooth preparation must constrain the movement of a restoration; therefore, it must be cylindrical (see Fig. 7.35.)

wall, or the buccal wall can be undercut in relation to the lingual wall, and the mesiobuccal wall can be undercut in relation to the distolingual wall. In a partial veneer preparation, in accordance with the same principle, the lingual wall of a proximal groove can be undercut in relation to the lingual wall of the preparation, but the buccal wall of the same groove cannot be undercut in relation to the lingual axial preparation wall; either of these walls may, however, restrict the number of directions in which a restoration can be placed on the preparation in relation to the other.

A slight convergence, or taper, is clinically desirable in complete crown preparations. As long as this taper is small, the movement of the luted restoration will be effectively restrained by the preparation and will have what is known as a *limited path of placement*. As taper increases, so does the number of paths of placement. An increase in the number of paths of placement decreases the tooth preparations retention form.

The relationship between the degree of axial wall taper and the magnitude of retention was first demonstrated experimentally by Jørgensen[116] in 1955. He cemented brass caps on Galalith cones of different tapers and measured retention with a tensile-testing machine. The relationship was found to be hyperbolic, with retention rapidly becoming less as taper

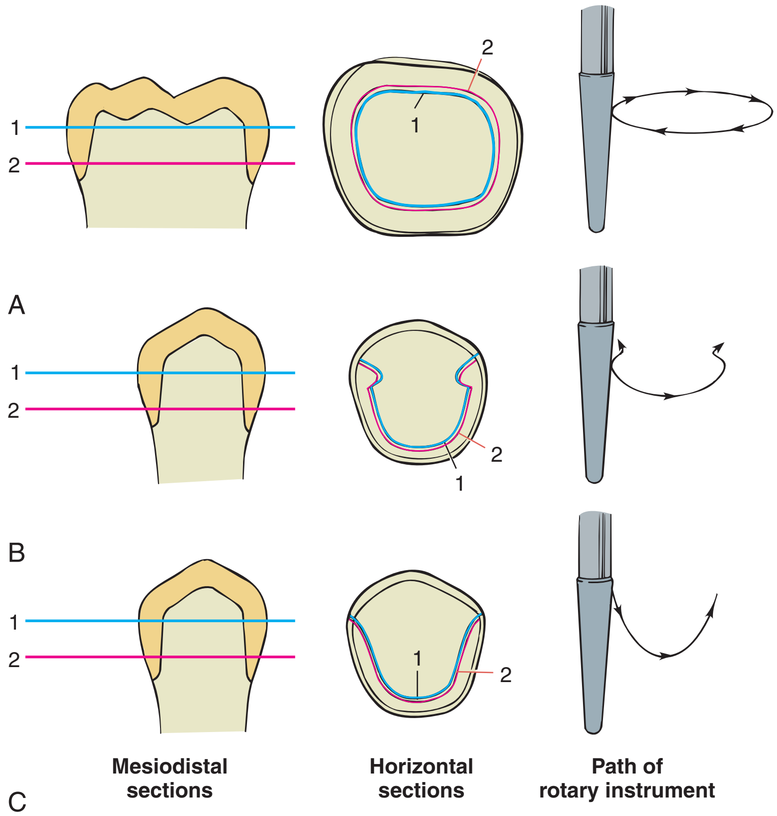


Fig. 7.35 A preparation is cylindrical if the two horizontal cross sections of the prepared axial tooth surface (*1* and *2*) are coincident. (A) This complete crown is cylindrical and therefore retentive. (B) A partial crown is retentive if its sections are coincident and perpendicular movement is prevented by grooves. (C) This preparation is cylindrical (*1* and *2* coincide), but because it can move perpendicularly to the axis of the cylinder, it is not retentive. (Reproduced by permission of the Editor-in-Chief, BDJ, Rosenstiel E. The retention of inlays and crowns as a function of geometrical form. *Br Dent J*. 1957;103:388.)

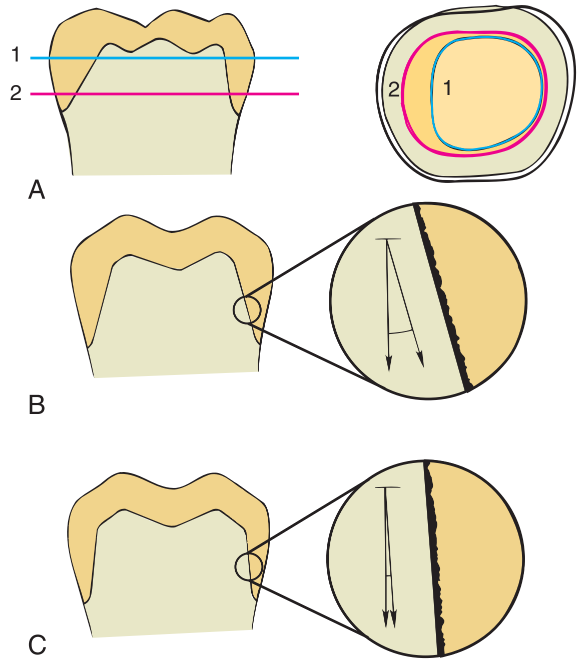


Fig. 7.36 (A) Cross sections *1* and *2* do not coincide, and the preparation thus has little retention. (B) Under these circumstances, very little friction develops between the cement and the axial walls, and the cement is subjected to tensile stress. (C) A retentive near-parallel preparation with frictional resistance. The cement is placed under shear stress. (A, Reproduced by permission of the Editor-in-Chief, BDJ, Rosenstiel E. The retention of inlays and crowns as a function of geometrical form. *Br Dent J*. 1957;103:388.)

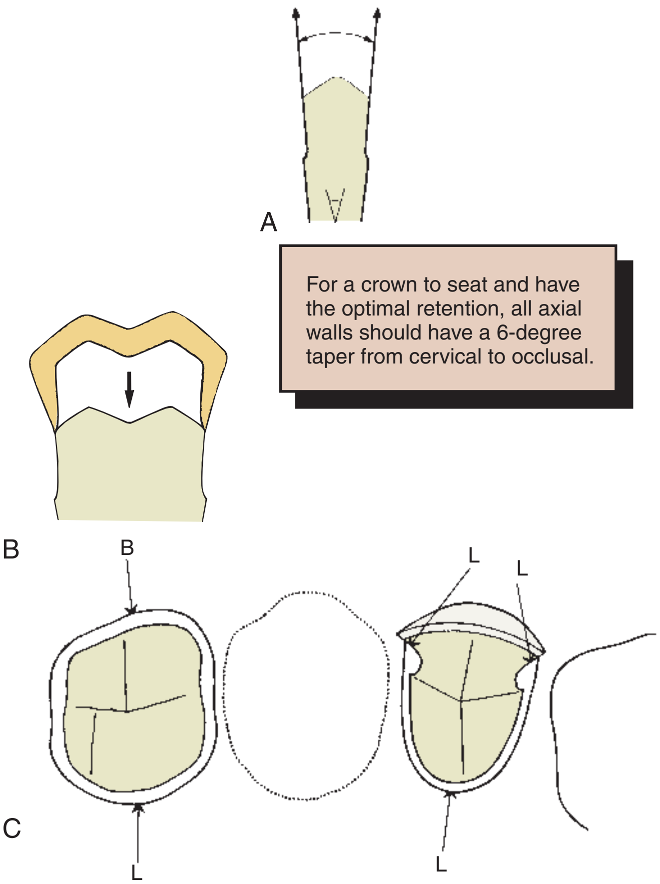


Fig. 7.37 (A) An undercut is formed if opposing walls diverge. (B) A tooth prepared with an undercut does not allow the crown to seat, inasmuch as it cannot pass over the divergent walls. (C) Undercuts are possible in other locations when fixed dental prostheses or restorations with preparation features such as grooves or boxes are prepared. In this example, one buccally facing wall *(B)* can be undercut in relation to (four) lingual facing walls *(L)*.

increased (Fig. 7.38), although the relationship was no longer hyperbolic when the internal surfaces of the caps were roughened. The retention of a cap with 10 degrees of taper[b] was approximately half that of a cap with 5 degrees. Similar results have been reported by other workers.[117–119]

Selection of the appropriate degree of taper for tooth preparation involves compromise. Too small a taper may lead to unwanted undercuts; too large leads to a lack of retention. The traditionally recommended convergence between opposing walls has been 6 degrees. The 6 degrees of convergence was developed between two opposing axial walls of 3 degrees of convergence to a path of removal chosen by a clinician. However, to give perspective, the traditional 6-degree convergence form was recommended to optimize retention for zinc phosphate cement.[120] Being able to recognize this angle is important (Fig. 7.39). It is necessary to be able to quickly quantify the approximate angle of convergence between preparation walls. To evaluate the angle from an occlusal perspective, it is recommended to close one eye to judge the relative convergence of all involved axial walls.[121] When both eyes are used to evaluate taper, axial walls that are divergent (undercut) up to 10 degrees cannot be detected from a typical viewing distance of 25 to 45 cm (10 to 20 inches).[121] Since most individuals are quite skilled at discerning subtle differences in height and width, but less effective in terms of our depth perception, evaluating preparation convergence from the buccal or lingual is often straightforward. Since adjacent teeth can partially obstruct the view of the preparation silhouette from mesial or distal, most will evaluate convergence from as many different directions as conveniently feasible.

It is not necessary to deliberately tilt a rotary cutting instrument to create a taper because this invariably leads to overpreparation. Rather, teeth are easily prepared with a rotary instrument of the desired taper held at a constant orientation. The tapered rotary instrument is moved through a cylindrical path as the tooth is prepared, and the taper of the instrument should produce the desired axial wall taper on the completed preparation. In practice, many dentists experience difficulty consistently avoiding excessively tapered preparations, particularly when preparing posterior teeth with limited access.[122–124] Comprehensive review of the dental literature suggests that clinically acceptable taper for a complete crown preparation

[b]In this discussion, as is generally the case in the dental literature, taper and convergence are used interchangeably and refer to the angle between diametrically opposed axial walls.

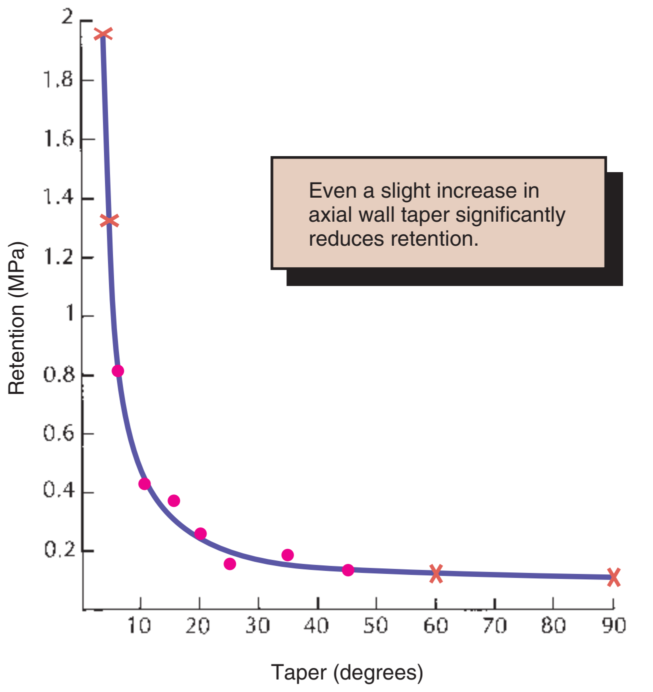


Fig. 7.38 Relationship between retention and convergence angle. •, Experimental values; *x*, calculated values outside the experimental range. (Redrawn from Jørgensen KD. The relationship between retention and convergence angle in cemented veneer crowns. *Acta Odontol Scand*. 1955;13:35.)

Fig. 7.39 The recommended convergence angle is 6 degrees; this is a very slight taper. For illustrative purposes, the hands of this clock show 12:01, which is an angle of 5½ degrees.

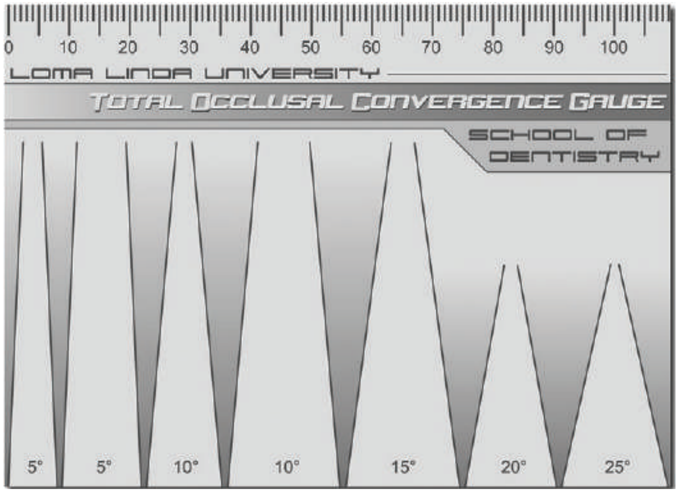


Fig. 7.40 Axial wall convergence gauge to evaluate taper of a preparation. (Courtesy of Dr. Charles J. Goodacre.)

may range from 10 up to 20 degrees.[111] It should be noted, however, that angles of convergence in excess of 10 degrees will result in reduced dentin thickness between the pulpal tissues and the axial walls of the prepared tooth.

Clinicians have a tendency to overtaper preparations. Abutments for fixed dental prostheses tend to be prepared with greater taper than do single crown preparations.[121] The visual quantification skill is low enough that some may need additional training.[125] One technique that is useful intraorally is the use of a dental bur of known taper to survey the tooth preparation. Another technique is a total occlusal convergence template of known angles to overlay on to tooth preparations to evaluate the amount of taper (Fig. 7.40).

Some authorities recommend the routine use of *secondary retention* features like grooves, boxes, or even pin holes to supplement the primary retention of crown preparations. Theoretically, they can reduce the incidence of restoration displacement. But it is unclear, however, whether accurate alignment of secondary retentive features is achieved more easily than restricted axial wall convergence. Skillfully prepared axial walls at a minimal convergence are mechanically desirable for primary retention while having a very conservative tooth structure. Furthermore, one research article evaluated the dentin thickness with different amounts of axial taper. In regard to maxillary first premolar, when the axial reduction was preformed with a margin width of 1.2 mm and the axial walls converged at 20 degrees, the proximity to the pulp ranged from 0.3 to 1.8 mm of dentin thickness.[126] Dentin is a porous material that delivers protection to the dental pulp. An axial wall of 0.3 mm in thickness raises a clinical concern of creating irreversible pulpitis. Twenty degrees of axial wall convergence may be acceptable for a large molar but is a questionable practice on teeth with smaller diameters. Secondary retentive features may be useful to supplement the primary retention form when retreating teeth that have previously been prepared and over tapered. In the case of a maxillary first premolar with 20 degrees, there may not be enough dentin thickness for a groove without getting a pulp exposure. Since 1955, adhesive resin cements have been developed that have increased the retention of crowns. For some restorations, research suggests that the selection of a resin cement over a water-based luting agent may have more clinical relevance to enhance crown retention than does preparation taper.[127,128]

Surface area. If the restoration has a restricted taper, and thus a limited path of placement, its retention depends on the length of this path or, more precisely, on the surface area that is in sliding contact. Therefore, crowns with tall axial walls are more retentive than those with short axial walls,[129] and molar crowns are more retentive than premolar crowns of similar taper because of the greater diameter of molar teeth. Surfaces from which the crown is essentially being pulled away (rather than sliding along the tooth), such as the occlusal surface, do not add significantly to total mechanical retention.

Stress concentration. When a retentive failure occurs, the luting agent often adheres to both the tooth preparation and the fitting surface of the restoration. In these cases, cohesive failure occurs through the cement layer because the strength of the luting agent is less than that of the induced stresses. A computerized analysis of these stresses[130,131] reveals that they are not uniform throughout the luting agent but are concentrated around the junction of the axial and occlusal surfaces. Sharp occlusoaxial line angles should be rounded to minimize these stresses, which can precipitate retentive failure.[130,131] Changes in preparation geometry may thus indirectly increase the retention of the restoration.

Type of preparation. Different types of preparation have different retentive values that correspond fairly closely to the total surface area of the axial walls with restricted taper, as long as other factors (e.g., preparation height) are kept constant. Thus, the retention of a complete crown is more than double that of partial-coverage restorations (Fig. 7.41).[132]

Adding grooves or boxes (Fig. 7.42) to a preparation with a limited path of placement does not markedly affect its retention because the surface area is not increased significantly. However, where the addition of a groove limits the paths of placement, retention is increased.[133,134]

Roughness of the Surfaces Being Cemented

When the internal surface of a restoration is very smooth, retentive failure occurs not through the cement but at the interface between the luting agent and the restoration. Under these circumstances, retention is increased if the restoration is roughened or grooved.[135–137] Metal castings are most effectively prepared by airborne-particle abrading the fitting surface with 50 μm of alumina. This should be done carefully to avoid abrading the polished surfaces or margins. Airborne-particle abrasion has been shown[138] to increase in vitro retention by 64%. Similarly, acid etching of the fitting surface of restorations can improve retention with certain luting agents.

Failure rarely occurs at the interface between the luting agent and the tooth. Therefore, deliberately roughening the tooth preparation hardly influences retention and is not recommended because roughness adds to the difficulty of subsequent technical steps in crown fabrication such as imaging, impression making, milling, and waxing (see Chapters 14 and 18).

Materials Being Cemented

Retention is affected by both the type of casting alloy and any core or buildup material that is present on the axial walls of the crown preparation. The clinical significance of laboratory testing results has yet to be confirmed by longer-term clinical studies, but it appears that the more reactive the alloy is, the better adhesion there is with selected luting agents. Therefore, base metal alloys are better retained than are less reactive metals with high gold content.[139] The effect of adhesion to different core materials also has been tested, with conflicting results. In one laboratory study,[140] researchers examining adhesion between luting agents and core materials found that the luting agent adhered better to amalgam than to composite resin or cast gold. However, when other researchers[141] tested crowns for retention, they found higher values with the composite resin cores than with amalgam cores. The differences may have resulted from dimensional changes of the core materials, although the clinical implications of this finding are not clear.

Luting Agent

Type. The type of luting agent chosen affects the retention of a cemented restoration.[142–144] However, the decision regarding which agent to use is also based on other factors. In general, the data suggest that adhesive resin cements are the most retentive

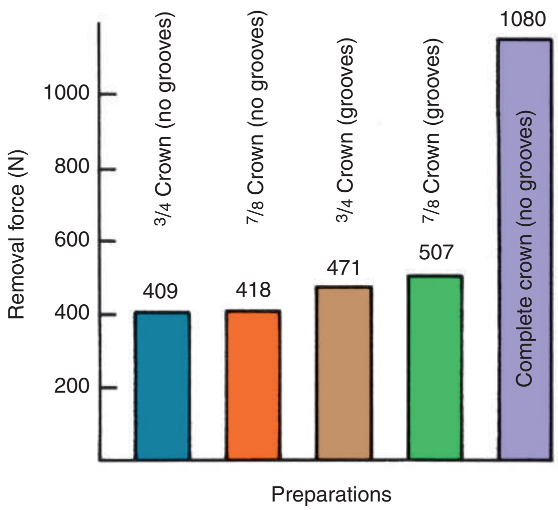


Fig. 7.41 Retention of different preparation designs. (Redrawn from Potts RG, Shillingburg HT Jr, Duncanson MG Jr. Retention and resistance of preparations for cast restorations. *J Prosthet Dent.* 1980;43:303.)

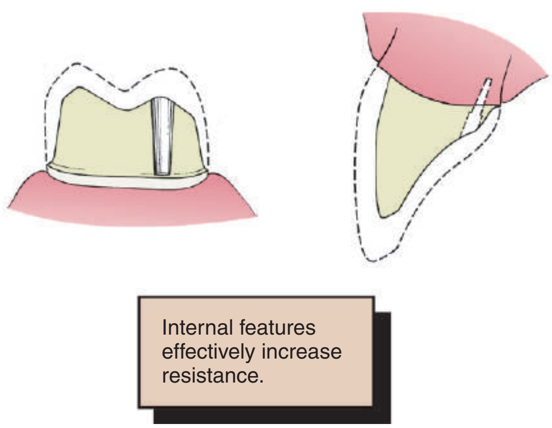


Fig. 7.42 Retention form of an excessively tapered preparation can be increased by adding grooves or pinholes because these limit the paths of withdrawal.

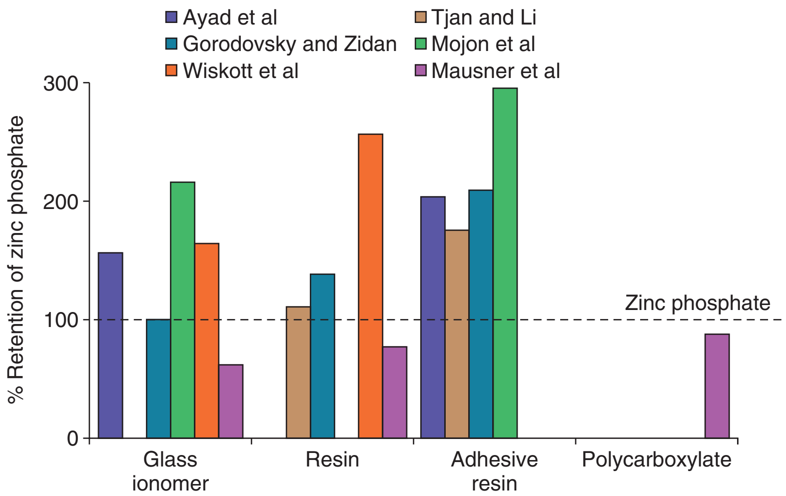


Fig. 7.43 Crown retention studies. Effect of luting agent. In six in vitro studies,[144,146,154,184] researchers evaluated the effect of luting agent on crown retention. The data were normalized as a percentage of the retention value with zinc phosphate cement. Adhesive resins had consistently greater retention than did zinc phosphate. Conventional resins and glass ionomers yielded less consistent results. (Redrawn from Rosenstiel SF, Land MF, Crispin BJ. Dental luting agents: a review of the current literature. *J Prosthet Dent*. 1998;80:280.)

(Fig. 7.43).[127,145,146] Of concern is that long-term in vitro studies have shown deterioration of the resin-dentin bond in association with so-called nanoleakage (ability of small ions or molecules to permeate the hybrid layer).[147,148]

Film thickness. There is conflicting evidence[149–152] about the effect of increased thickness of the cement film on retention of a restoration. This may be important if a slightly oversized restoration is made (as when the die-spacer technique is used; see Chapter 18), or when milled crowns are fabricated (see Chapter 25). The factors that influence the retention of a cemented restoration are summarized in Table 7.4.

Resistance Form and Horizontal Forces

Certain features must be present in the preparation to prevent dislodgment of a cemented restoration in a horizontal plane. Mastication and parafunctional activity may subject a prosthesis to substantial horizontal or oblique forces. These forces are normally much greater than the ones overcome by retention, especially if the restoration is loaded during eccentric contact between posterior teeth. Lateral forces tend to displace the restoration by causing rotation around the gingival margin, effectively tipping the crown off its preparation. Rotation is prevented by any areas of the tooth preparation that are placed in compression, called *resistance areas* (Fig. 7.44). Multiple resistance areas cumulatively make up the *resistance form* of a tooth preparation, which is defined as the features of a tooth preparation that enhances the stability of a restoration and resist dislodgment along any axis other than the path of placement.

Adequate resistance depends on the following:

1. Magnitude and direction of the dislodging forces
2. Geometry of the tooth preparation (primary and secondary retentive features)
3. Physical properties of the luting agent

Magnitude and Direction of the Dislodging Forces

Some patients can develop enormous biting forces. Gibbs and colleagues[153] described one individual (Fig. 7.45) who had a biting force of 4340 N (443 kg).[c] Although this is considered extraordinary, historically, restoration designs attempted to withstand forces approaching such magnitude. In one laboratory study,[130] a complete crown cemented on a nickel-chromium test die was found to be capable of withstanding more than 13,500 N (1400 kg)—a far greater force than would occur in the mouth—before becoming displaced (Fig. 7.46).

In a normal occlusion, biting force is distributed over all the teeth; most of it is axially directed. If an FPD is carefully made with a properly designed occlusion, the load should be well distributed and favorably directed (see Chapter 4). However, if a patient has a biting habit such as vaping or parafunctional movements, it may be difficult to prevent fairly large oblique forces from being applied to a restoration. Consequently, the successful tooth preparation and restoration must be able to withstand considerable oblique forces, as well as the normal axial ones, and it has been argued that from a clinical durability perspective, adequate resistance form may be more crucial than overall preparation retentiveness.[154,155]

Geometry of the Tooth Preparation

As with retention, preparation geometry plays a key role in attaining desirable resistance form. The tooth preparation must be shaped so that specific areas of the axial wall prevent rotation of the crown. A good way to determine whether tooth preparation geometry provides adequate resistance form is to answer a specific question: "How much tooth structure needs to break off in order for this crown to be displaced by tipping off the tooth?"

[c]In comparison, the world record super heavyweight (>105 kg) snatch is 220 kg.

TABLE 7.4 Factors Influencing the Retention of a Cemented Restoration

Factor	Greater Retention →			Lesser Retention
Taper	Parallel →	6 degrees →		Excessive
Surface area	Large →			Small
Type of preparation	Molar complete crown →	Premolar complete crown →	Partial crown →	Intracoronal restoration
Surface texture	Rough →			Smooth
Film thickness		Effect uncertain		
Luting agent	Adhesive resin →	Glass ionomer →	Polycarboxylate/ Zinc oxide–eugenol →	Zinc phosphate

When quantifying resistance, ask yourself the following question: How much tooth structure needs to break, or how much does the crown have to deform in order to dislodge this restoration?

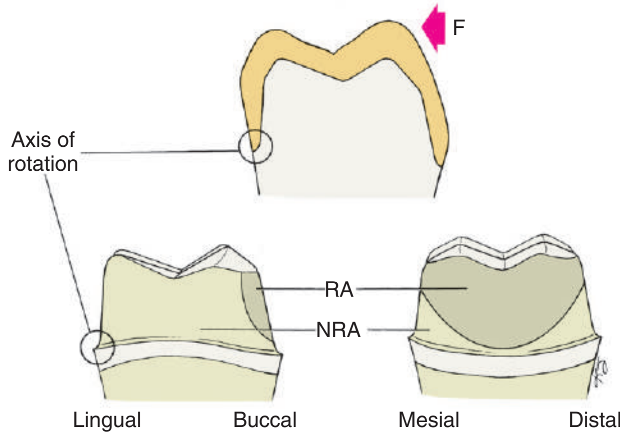


Fig. 7.44 The resistance area *(RA)* of a complete crown is placed under compression when a lateral force *(F)* is applied. *NRA*, Nonresisting area. (Redrawn from Hegdahl T, Silness J. Preparation areas resisting displacement of artificial crowns. *J Oral Rehabil*. 1977;4:201.)

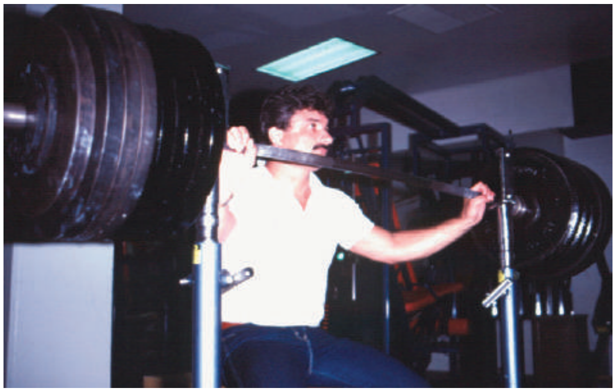


Fig. 7.45 Mr. H. sitting beside 443 kg of gymnasium weights to illustrate the magnitude of his biting strength. (From Gibbs CH, Mahan PE, Mauderli A. Limits of human bite strength. *J Prosthet Dent*. 1986;56:226.)

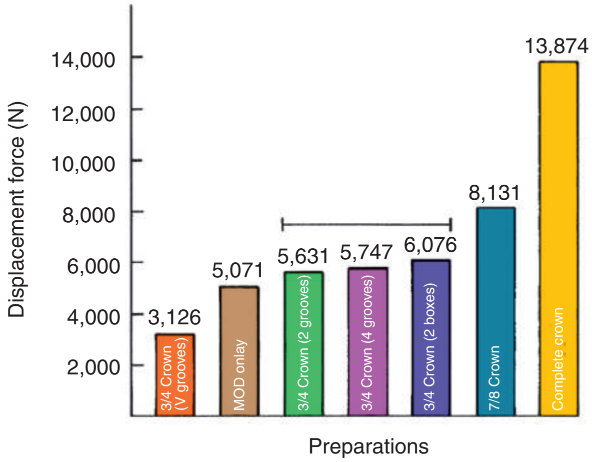


Fig. 7.46 Resistance of different preparation designs. The line connects preparations with statistically similar displacement forces ($P > .05$). *MOD,* Mesio-occluso-distal. (Modified from Kishimoto M, Shillingburg HT Jr, Duncanson MG Jr. Influence of preparation features on retention and resistance. Part II: three-quarter crowns. *J Prosthet Dent*. 1983;49:188.)

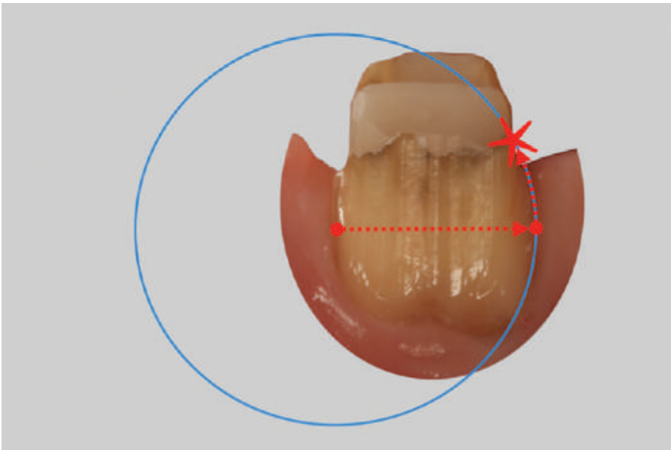


Fig. 7.47 Theoretical circular path a crown would take when pivoting off of its margin. The length of the radius interferes with the axial wall of the preparation to deliver resistance form in a horizontal direction.

Resistance is a function of the relationship between axial wall taper, preparation diameter, and preparation height. Consider the diameter of a tooth as a radius of an imaginary circle. The radius represents a pathway a crown would theoretically pivot off of a tooth. If the arch of the radius interfered with the axial wall of its tooth preparation, the crown would have resistance (Fig. 7.47). If the arch of the radius did not interfere with the axial wall of its tooth preparation, the crown would not have resistance and rotate off the preparation (Fig. 7.48). Resistance decreases as taper or diameter increases or as preparation height is reduced.[156] The relationship between preparation height, or diameter, and resistance to displacement is approximately linear.[157]

Preparation taper of 5 to 22 degrees has been suggested as being within a clinically acceptable range.[158,159] However, at the higher end of this range, the tipping resistance of both cemented and uncemented cast restorations is inadequate but increases significantly as taper is reduced.[158,160]

Short tooth preparations with large diameters were found to have very little resistance form.[161] In general, molar teeth require more parallel preparation than do premolar or anterior teeth to achieve adequate resistance form.[161] A 3-mm preparation height provides adequate resistance if taper is restricted to 10 degrees or less,[160] but additional height is necessary as tooth diameter

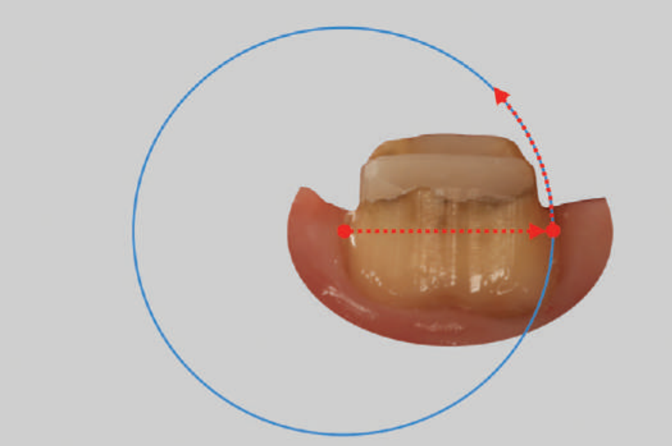


Fig. 7.48 Theoretical circular path a crown would take when pivoting off of its margin. The length of the radius does not interfere with the axial wall of the preparation. The preparation does not have adequate resistance form to restrict a horizontal force.

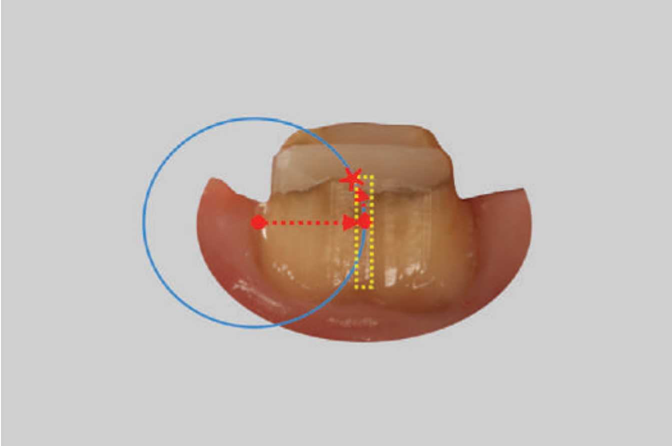


Fig. 7.49 The radius of rotation from Fig. 7.48 has been shortened with the incorporation of a buccal secondary retentive groove. The new arch of rotation delivers resistance to a theoretical horizontal force.

increases. On molar crown preparations in which many more preparations are observed that lack resistance,[162] minimal preparation wall height should thus be in the range of 3.5 to 4 mm. A fairly simple way to quantify this at chairside is to evaluate whether the height-to-width ratio of a preparation is 4:10 or greater. If so, resistance is probably adequate.

Hegdahl and Silness[162] analyzed how the areas that provide resistance form change as the geometry of the tooth preparation is modified. They demonstrated that increasing preparation taper and rounding of axial angles tend to reduce resistance; pyramidal preparations thus have greater resistance than do conical ones. Secondary retentive grooves or boxes placed in healthy tooth structure are particularly effective in enhancing the resistance form of crown preparations because these shorten the theoretical radius of rotation which results in a greater chance of interfering with rotational movement (tipping) of the crown and thereby subject additional areas of the luting agent to compression (Fig. 7.49). Therefore, the resistance form of an excessively tapered preparation can be improved by adding such grooves or boxes. As an alternative, pinholes can be prepared to achieve the same effect by making use of dentin that surrounds the pin.

Preparation modifications appear not to be used as often[157] as clinical failure data suggest they should be.[155]

A partial-coverage restoration may have less resistance (Fig. 7.50) than a complete crown because it has no buccal resistance areas. In this case, resistance is provided by proximal boxes or grooves (Fig. 7.51) and is greatest if the groove, box walls, or both are perpendicular to the direction of the applied force. Thus, U-shaped grooves or flared boxes provide more resistance than do V-shaped ones.[132] On short preparations, the reverse scenario can apply: Short complete crown preparations may lack resistance, where proximal grooves, in comparison, will then result in better resistance on a partial veneer crown. In general, ideal grooves and boxes should be prepared so that their walls are located in a healthy tooth structure. Placing proximal grooves as close as possible to the location of the original proximal contact offers the opportunity to maintain as much dentin as possible because this is where the tooth has its greatest mesiodistal dimension. However, the proximal axial walls are typically shorter in the occlusogingival dimension than the buccal and lingual axial walls because of the scalloped shape of the periodontium. As a result, buccal and or lingual retentive grooves are generally longer than mesiodistal grooves. An in vitro study reported that mesial-distal grooves delivered better resistance to dislodgment than buccal-lingual grooves.[160] However, the study only looked at forces applied in a buccal direction. Whereas it is reasonable to assume that most loads resulting in crown dislodgment are applied from either a buccal and lingual direction since some bracing of the restoration occurs as a function of stabilizing proximal contacts, it is not possible to declare an absolute optimal location for retentive grooves. Each tooth has to be individually assessed for its resistance form in all horizontal directions. The weakest area of the tooth preparation will have the longest radius of rotation for a crown to pivot off. Once the longest radius has been identified, a retentive groove can be placed in the axial wall that will shorten the radius of the specific rotation (see Figs. 7.48 and 7.49).

Similarly, in order to more effectively enhance resistance, grooves that are placed in excessively inclined preparation walls should be prepared to greater depth in their cervical aspect than in their occlusal aspect. Taper restriction in the cervical aspect of an excessively tapered crown preparation has been shown to enhance resistance more effectively than do grooves that are prepared flush into excessively inclined preparation walls because the number of paths of removal is reduced.[163]

Physical Properties of the Luting Agent (Cohesive Versus Adhesive Cements)

Resistance to deformation is affected by physical properties of the luting agent, such as compressive strength and modulus of elasticity.[164] To satisfy American Dental Association/American National Standards Institute specification no. 96 (International

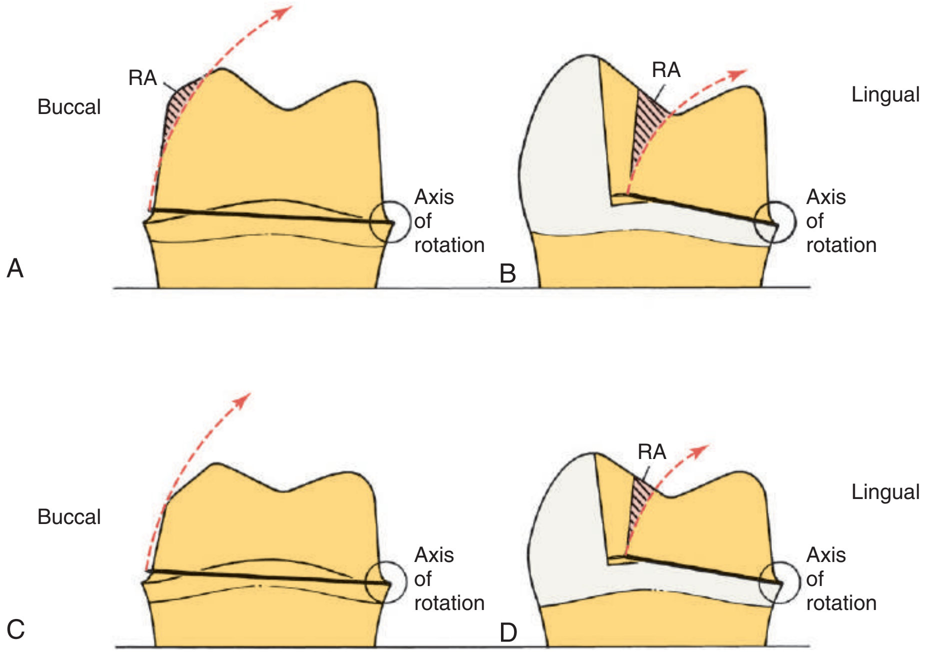


Fig. 7.50 Resistance form of partial and complete crowns. (A) The buccoaxial wall of a complete crown should be a good resistance area *(RA)* for preventing rotation around a lingual axis. (B) In a partial crown, resistance must be furnished by mesial and distal grooves. (C) In a short or excessively tapered complete crown, resistance form is minimal because most of the buccal wall is missing. A mesiodistal groove should be placed to increase resistance form. (D) Poor resistance form is less a problem in a short partial crown if the grooves have sufficient definition. However, lack of retention form may indicate the need for complete coverage.

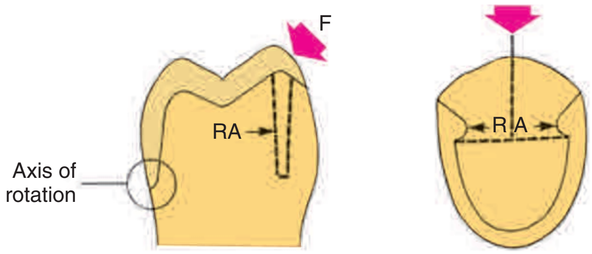


Fig. 7.51 (A) The grooves of a partial crown should provide the maximum resistance to rotation around an axis situated at the linguogingival margin. (B) The lingual walls of the groove—the resistance areas *(RA)*—should be prepared perpendicular to the direction of force *(F)*.

Standards Organization specification no. 9917), the compressive strength of zinc phosphate cement must exceed 70 MPa[d] at 24 hours (Fig. 7.52).[165–168] Glass ionomer cements and most resins have higher compressive strength, whereas polycarboxylates have values similar to those of zinc phosphate.[164]

Increasing temperature has a dramatic effect on the compressive strength of luting agents, particularly weakening reinforced zinc oxide–eugenol cement (Fig. 7.53). An increase from room temperature (23°C) to body temperature (37°C) halves the compressive strength of reinforced zinc oxide–eugenol cements, and a rise in temperature to 50°C (equivalent to hot food) reduces the compressive strength by more than 80%.[169] Equivalence testing of more modern luting agents has not been reported.

Zinc phosphate cements have a higher modulus of elasticity than do polycarboxylate cements, which exhibit relatively large plastic deformation.[170] This may account for the observation that the retentive ability of polycarboxylate cement is more dependent on the taper of the preparation than is the retention with zinc phosphate cement.[171]

In the selection process of choosing a durable luting agent, clinicians have a choice in how the dental cement is delivered and mixed. Cements come in a liquid-powder or dual paste form and can be hand mixed, auto-mixed through convenient dispensing tips, or triturated in prepackaged capsules (see Chapter 30). Although the decision process of luting agent selection may be driven by factors such as mixing ease and cleanup time, the method of luting agent mixing and delivery can affect resulting physical properties as well. One thermocycle study investigated the long-term aging effect of monolithic zirconia crowns cemented on natural teeth with powder-liquid and paste-paste forms of the same resin-modified glass ionomer. Interestingly, the retention of the zirconia crowns luted with the dual paste method required less than half of the removal force than the crowns cemented with the same commercial resin-modified glass ionomer cement that was a powder-liquid mix.[172]

[d]One megapascal equals 1 million N/m^2, or about 145 pounds per square inch (psi).

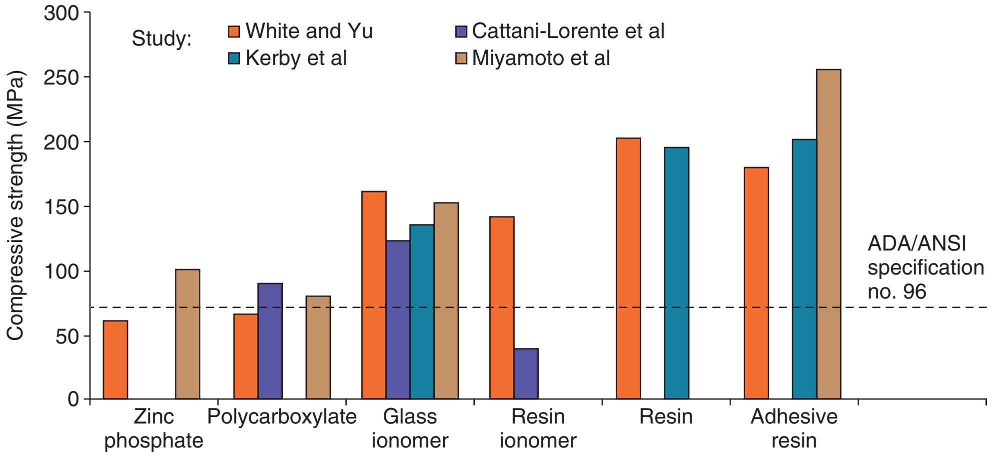


Fig. 7.52 Compressive strength of luting agents. Higher-strength values were reported in these studies[165–168] with the resin cements and glass ionomers than with zinc phosphate or polycarboxylate. Resin-modified glass ionomer exhibited greater variation than other cements. *ADA*, American Dental Association; *ANSI*, American National Standards Institute. (Redrawn from Rosenstiel SF, Land MF, Crispin BJ. Dental luting agents: a review of the current literature. *J Prosthet Dent*. 1998;80:280.)

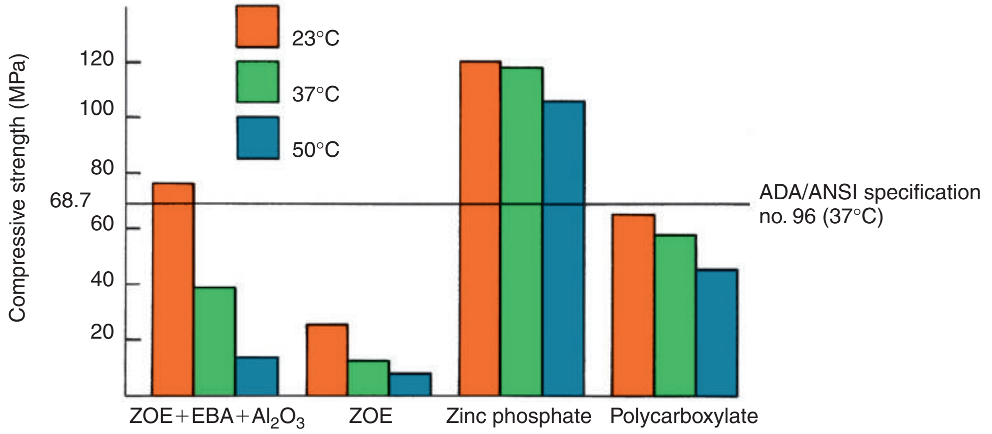


Fig. 7.53 Compressive strength of luting agents at different temperatures. *ADA*, American Dental Association; *ANSI*, American National Standards Institute; *EBA*, ethoxybenzoic acid; *ZOE*, zinc oxide–eugenol. (Redrawn from Mesu FP. The effect of temperature on compressive and tensile strengths of cements. *J Prosthet Dent*. 1983;49:59.)

The factors that affect the resistance to displacement of a cemented restoration are summarized in Table 7.5.

Preventing Deformation

A restoration must have sufficient strength to prevent permanent deformation during function (Fig. 7.54); otherwise, it will fail (typically at the restoration-cement interface or at the metal-porcelain interface). This may be a result of unsuccessful bonding, poor tooth preparation, inappropriate alloy selection, or poor metal-ceramic framework design (see Chapter 19).

Bonding

Composite luting agents shrink upon polymerization and deliver a pre-compressive force to bonded ceramics.[173] On thermal loading, the luting composite also expands and generates tensile forces within ceramic restorations.[174] When bonded

Fig. 7.54 Ceramic failure resulting from deformation of the metal substructure.

TABLE 7.5 Factors Influencing the Resistance of Cemented Restorations

Factor	Higher Resistance → Lower Resistance
Dislodging forces	Habits → Eccentric interferences → Anterior guidance
Taper	Minimum → 6 degrees → Excessive
Diameter	Small (premolar) → Large (molar)
Height	Long → Average → Short
Type of preparation	Complete coverage → Partial coverage → Onlay
Luting agent	Adhesive resin → Glass ionomer → Zinc phosphate → Polycarboxylate → Zinc oxide–eugenol

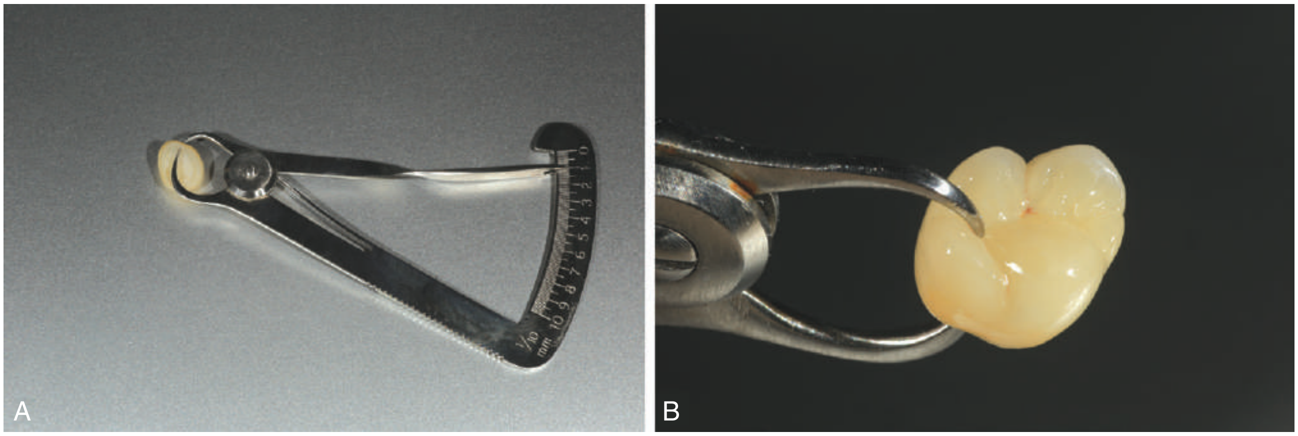


Fig. 7.55 (A and B) Calipers confirming ceramic thickness of 1 mm.

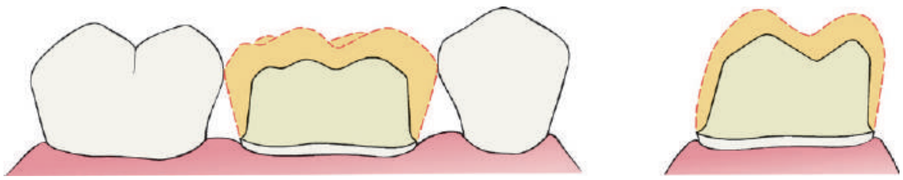


Fig. 7.56 Anatomic occlusal reduction is conservative of tooth structure and provides rigidity to the restoration.

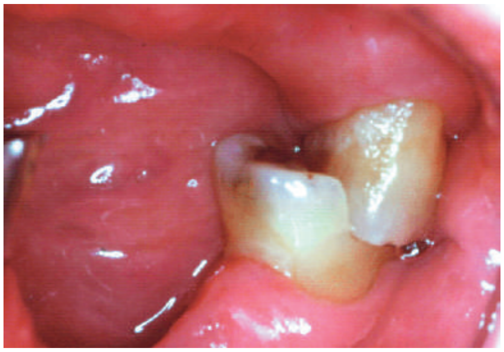


Fig. 7.57 This molar relationship is a result of extreme occlusal wear. When a tooth preparation is designed, the eventual occlusal plane must be considered. This is done with the aid of a diagnostic tooth preparation and waxing procedures.

feldspathic ceramic restorations fit well (i.e., a gap width of approximately 100 μm) the luting composite tends to protect the ceramic against thermal expansion.[174] Lithium disilicate and zirconia restorations have also been shown to mechanically benefit from adhesive luting.[175,176] Laboratory research reports that for posterior ceramic occlusal veneers, there is no significant difference in fracture resistance between 1 mm and 2 mm of lithium disilicate ceramic when bonded to tooth structure (Fig. 7.55).[177]

Adequate Tooth Reduction

Largely according to empirical data, metal restorations require a minimum alloy thickness of about 1.5 mm over functional cusps (buccal in the mandible, lingual in the maxilla). The less stressed nonfunctional cusps can be protected with less metal (1 mm is adequate in most circumstances) for a strong and long-lasting restoration. Occlusal reduction should be as uniform as possible, following the cuspal planes of the teeth; this ensures that sufficient occlusal clearance is combined with the preservation of as much tooth structure as possible. In addition, an anatomically prepared occlusal surface (Fig. 7.56) gives rigidity to the crown because of the "corrugated effect"[178] of the planes.

When teeth are misaligned or overerupted, the occlusal surface needs to be prepared with the thickness requirements of the eventual restoration in mind. For example, a supra-erupted tooth may need considerably more than 1.5 mm of reduction to establish adequate clearance so that optimal occlusal form and the appropriate plane can be reestablished and adequate restoration thickness ensured (Fig. 7.57). Diagnostic tooth preparation and waxing are helpful in determining the correct tooth reduction. A practical approach is to reshape the supra-erupted tooth on the diagnostic cast to the desired occlusal plane that is anticipated. Diagnostically, the opposing teeth and, if necessary, the target tooth itself can be waxed to final form. An external matrix is then fabricated over the diagnostic endpoint from a suitable elastomeric putty. After sectioning, this can be used intraorally as a reduction guide to ensure that optimal, yet conservative tooth reduction is achieved (Fig. 7.58).

Margin Design

To prevent distortion of the restoration margin occlusally, the dentist should design the preparation outline form so that occlusal contact is avoided in this area. Keeping preparation margins approximately 1 to 1.5 mm away from occlusal contact locations satisfies this requirement.

Ideally, cervical enamel should be conserved to maintain structural integrity of the tooth and for bonding. When finish lines need to be extended apically, tooth reduction must provide sufficient room for the bulk of restorative material at the margin to prevent distortion. For example, as discussed before, one disadvantage of the feather edge margin preparation is that the resulting thin layer of gold is not as strong as the comparatively thicker restoration of a chamfer margin preparation. When teeth have been prepared with increased taper, however, it is advisable to reduce margin width in order to maintain adequate dentin thickness between the axial preparation wall and the pulpal tissues.[179]

Quantitatively, the amount of reduction in the cervical part of a preparation is a function of the restorative material selected. For gold castings or high-strength anatomic contour zirconia and bonded lithium disilicate, 0.3 to 0.5 mm is adequate; for bilayered ceramic and metal-ceramic crowns, 1 to 1.2 mm of facial shoulder or chamfer margin width is desirable but not easily achieved on small teeth or teeth with large pulps. Lower strength ceramic crowns can be fabricated successfully on shoulder margin preparations with a margin width of 0.8 to 1.0 mm, although minimum dimensions may increase for certain materials and fabrication techniques.[180] With the advent of CAD-CAM restorations, the limitations of the milling systems used may influence specific reduction requirements. Not all milling machines are equal. The selection of CAD-CAM laboratory equipment or a laboratory that uses CAD-CAM technology should be weighed carefully against the biological criteria discussed at the beginning of this chapter.

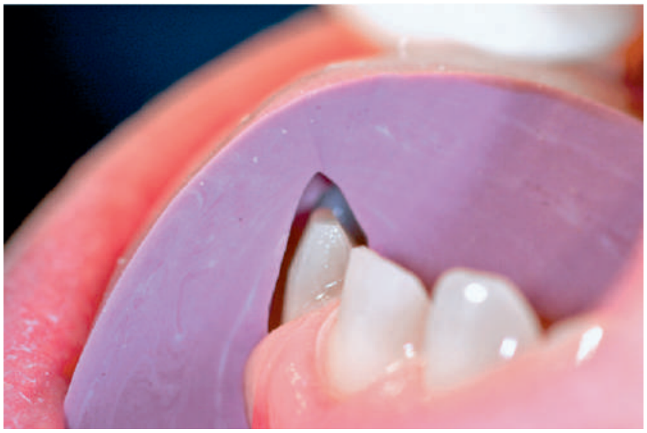


Fig. 7.58 Putty index made before tooth preparation facilitates evaluation of tooth reduction uniformity.

The grooves and ledges incorporated in a partial-coverage preparation provide essential strengthening for such castings that yet remain inherently weaker than their complete-coverage counterparts; in particular, the classic anterior pinledge retainer benefited from the beamlike reinforcement that resulted from the incorporation of ledges in the tooth preparation design (Fig. 7.59).

Alloy Selection

Although type I and type II gold alloys (see Chapter 22) are satisfactory for intracoronal cast restorations, they are too soft for crowns and fixed dental prostheses, for which type III or type IV gold alloys (or an appropriate low-gold alternative) are chosen. These are harder, and their strength and hardness can be further increased by heat treatment.

Metal-ceramic alloys with high noble metal content have a hardness equivalent to that of type IV gold alloys, whereas nickel-chromium or cobalt-chromium alloys are considerably harder yet. These may be indicated when large forces are anticipated, as with a long-span FPD, although their use presents certain challenges (see Chapter 19). Even the stronger alloys need sufficient bulk if they are to withstand occlusal forces.

ESTHETIC CONSIDERATIONS

The restorative dentist should develop skill in understanding the esthetic expectations of the patient. Most patients prefer their dental restorations to look as natural as possible. However,

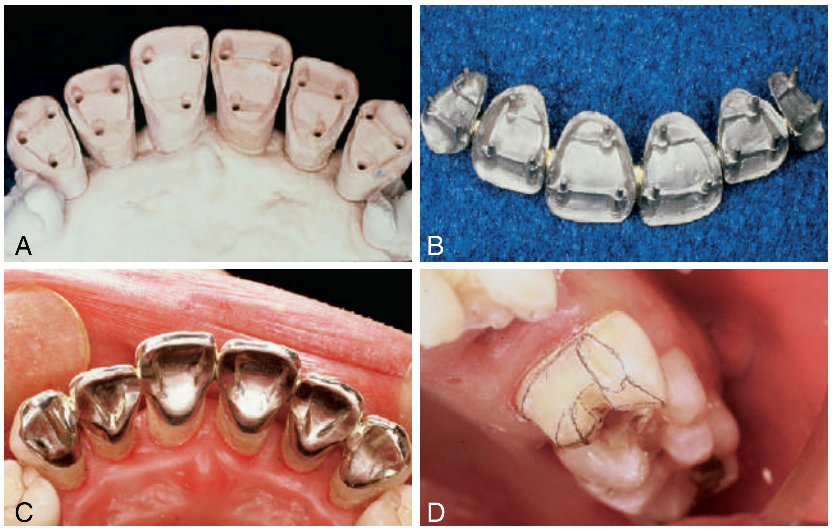


Fig. 7.59 (A–C) Grooves and ledges provide added rigidity to pinledge restorations. (D) This partial veneer crown preparation benefits from added material thickness in the central groove area and in the location of the mesial and distal proximal grooves.

esthetic considerations should not be pursued at the expense of the prognosis of the patient's long-term oral health or function.

At the initial examination, the dentist fully assesses the appearance of each patient, noting which areas of which teeth show during speech, smiling, and laughing (Fig. 7.60). The patient's esthetic expectations must be discussed in relation to oral hygiene needs and to the potential for development of future disease. Simply asking the question "Are you happy with the way your teeth look?" and observing the patient while carefully listening to the response is important and helpful. The final decision regarding an appropriate restoration can then be made with the full cooperation and informed consent of the patient.

Fig. 7.60 Smile analysis.

Options for esthetic restorations include partial veneer crowns which maintain an intact labial or buccal surface in original tooth structure; metal-ceramic restorations, which consist of a metal cast substructure that in visible areas has an esthetic porcelain veneer; and ceramic restorations (Fig. 7.61).

Ceramic Restorations

Some of the most conservative and pleasing esthetic restorations are ceramic inlays, onlays, veneers, and crowns (see Chapters 25 and 26). They can mimic original tooth color better than the other restorative options. Although ceramic restorations are at somewhat greater risk of brittle fracture than are other restorations, the newest materials have improved physical properties and can be strengthened through the use of resin-bonded luting agents.

Metal-Ceramic Restorations

The appearance of some metal-ceramic restorations (see Chapters 19, and 24) is often compromised by insufficient porcelain thickness. However, adequate porcelain thickness is sometimes obtained at the expense of proper axial contour (such overcontoured restorations almost invariably lead to periodontal disease). In addition, the labial margin of a metal-ceramic crown is not always accurately placed. To correct all these deficiencies, certain principles are recommended during

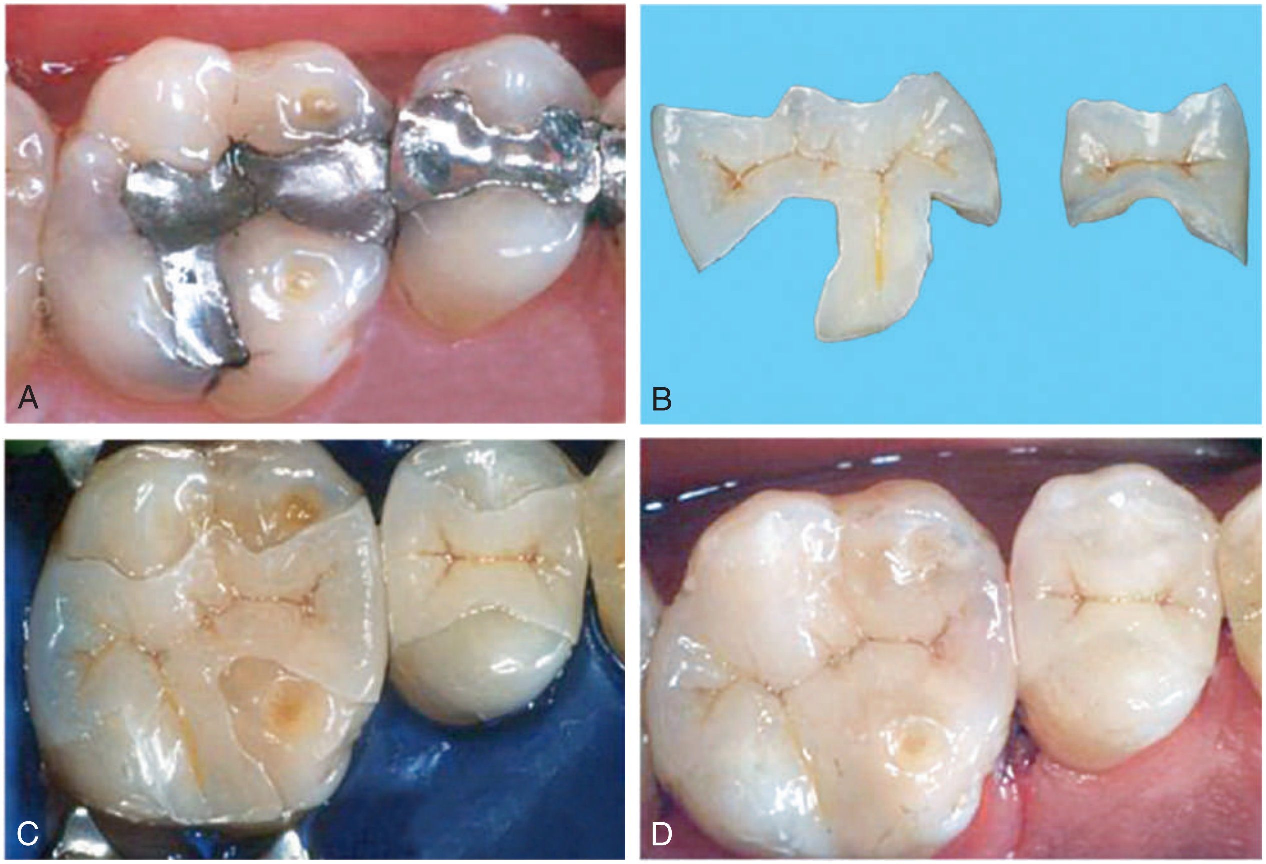


Fig. 7.61 Ceramic inlays are an esthetic replacement for more readily visible amalgam restorations. (A) Defective amalgam restorations. (B) Two ceramic inlays. (C) Inlays are seated for clinical evaluation and adjustment. (D) Inlays have been luted in place and finished. (From Freedman G. *Contemporary Esthetic Dentistry*. St. Louis: Mosby; 2012.)

tooth preparation that ensures sufficient room for porcelain and accurate placement of the margins. Otherwise, good appearance would be achievable only at the expense of periodontal health.

Facial Tooth Reduction

If there is to be sufficient bulk of porcelain for appearance and metal thickness for strength, adequate reduction of the facial surface is essential. The exact amount of reduction depends to some extent on the physical properties of the alloy used for the substructure, as well as on the manufacturer and the shade of the porcelain. A good color match for some restorations in older individuals typically requires a slightly greater porcelain thickness than is needed in younger patients. A minimum reduction of 1.5 mm is typically required for optimal appearance. Adequate thickness of porcelain (Fig. 7.62) is needed to create a sense of color depth and translucency. Shade problems are frequently encountered in maxillary incisor crowns at the incisal and cervical thirds of the restoration, where direct light reflection from the opaque layer can make the restoration very noticeable. Because opaque porcelains generally have a shade different from that of body porcelains, they often need to be modified with special stains in these areas (see Chapter 24).[181]

With very thin teeth (e.g., mandibular incisors), it may be impossible to achieve adequate tooth reduction without exposing the pulp or leaving the tooth preparation severely weakened. Under these circumstances, a less-than-ideal appearance may have to be accepted.

The labial surfaces of anterior teeth should be prepared for metal-ceramic restorations in two distinct planes (Fig. 7.63). If they are prepared in a single plane, the reduction in either the cervical or the incisal area of the preparation is insufficient.

Incisal Reduction

The incisal edge of a metal-ceramic restoration has no metal backing and can be made with a translucency similar to that of natural tooth structure. An incisal reduction of 2 mm is recommended to enable the ceramist to achieve good esthetics. Excessive incisal reduction must be avoided because it reduces the resistance and retention form of the preparation.

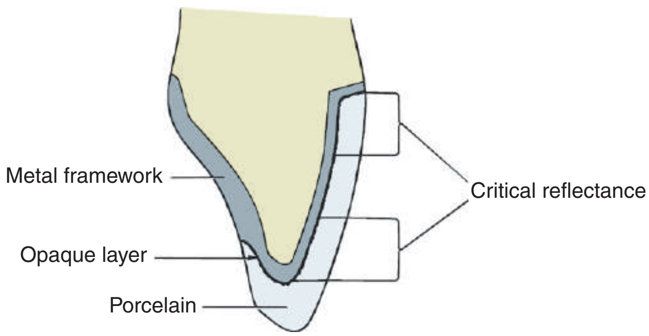


Fig. 7.62 Adequate porcelain thickness is essential for preventing direct light reflection from the highly pigmented opaque porcelain. The most critical areas are the gingival and incisal thirds; in practice, opaque modifying stains are often used in these areas. (Redrawn from McLean JW. *The Science and Art of Dental Ceramics*. Vol 1. Chicago: Quintessence Publishing; 1979.)

Proximal Reduction

The extent of proximal reduction is contingent on the exact predetermination of the location of the metal-ceramic junction in the completed restoration. The proximal surfaces of anterior teeth look most natural if they are restored at the incisal edges, without metal backing. This allows some light to pass through the restoration in a manner similar to what occurs on a natural tooth (Fig. 7.64). Obviously, if the restoration is part of an FPD, the need for connectors makes this impossible.

Labial Margin Placement

Supragingival margin placement has many biological and adhesive interface advantages. The restorations are easier to prepare properly and easier to keep clean. Nevertheless, margin placement at the free gingival crest or subgingival margins may be indicated for esthetic reasons, particularly when ceramic restorations need to mask cervical tooth colors.

The patient's smile is observed as part of the initial examination (see Chapter 1). It is important to record which teeth and which parts of each tooth are exposed. Patients with a high lip line, which exposes considerable gingival tissue, present the greatest problem if complete crowns are needed. Where the root surface is not discolored, appearance can be restored with a metal-ceramic restoration with a supragingival porcelain labial margin (see Chapter 24). If the patient has a low lip line,

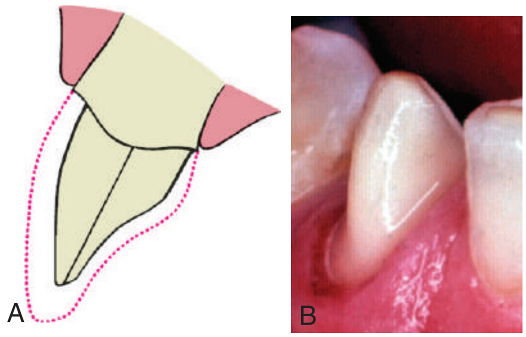


Fig. 7.63 Recommended tooth preparation for maxillary (A) and mandibular (B) metal-ceramic restoration. In each case, the facial reduction has two distinct planes.

Fig. 7.64 Optimal esthetics require proximal light transmission through the esthetic veneer. Occluding lingual surfaces are in metal, which extends into the proximal aspect.

a supragingival margin may be placed because the restorative interface is not seen during normal function

However, it cannot be assumed that the patient will be happy with a supragingival margin just because it is not visible during normal function. Some patients have reservations about exposed restorative interfaces, and the advantages of such supragingival margins must be carefully explained before treatment.

Metal collars can be hidden below the gingival crest, although there is some discoloration if the gingival tissue is thin. Successful margin placement within the gingival sulcus requires care to ensure that inflammation and recession, with resulting metal exposure, are avoided or minimized. The periodontium must be healthy before the tooth is prepared. If periodontal surgery is needed, the sulcular space should not be eliminated completely; rather, a postsurgical depth of about 2 mm should be the objective. Sufficient time should be allowed after surgery for the periodontal tissues to stabilize. Wise[182] found that the gingival crest does not stabilize until 20 weeks after surgery (see Chapter 5).

Margins should not be placed so far apically that they encroach on the attachment; extension to within 1.5 mm of the alveolar crest leads to bone resorption.[183] Subgingivally placed margins should follow the scalloped contour of the free gingival margin, being further apical in the middle of the tooth and further incisal interproximally. A common error (Fig. 7.65) is to prepare the tooth so that the margin lies almost in one plane, with exposure of the collar labially and irreversible loss of bone and papilla proximally.

Partial-Coverage Restorations

Whenever possible, an esthetically acceptable result without the use of complete crowns is preferred because tooth structure is conserved: no restorative material can approach the appearance of intact tooth enamel. Esthetic partial-coverage restorations (see Chapter 11) depend on accurate placement of the potentially visible facial and proximal margins. A visible display of metal is not esthetic and is thus unacceptable to many patients. If a partial-coverage restoration is poorly prepared, the patient may demand that it be replaced by a metal-ceramic crown, and the result is unnecessary loss of tooth structure and a greater potential for tissue damage.

Proximal Margin

Precise placement of the proximal margins (particularly the mesial, generally more visible, margin) is crucial for the esthetic result of a partial-coverage restoration. The rule is to place the margin just buccal to the proximal contact area, where metal is hidden by the distal line angle of the neighboring tooth and yet provides adequate access to the tooth-restoration interface for plaque control. Tooth preparation angulation is critical and should normally follow the long axes of posterior teeth and the incisal two-thirds of the facial surface of anterior teeth. If a buccal or lingual tilt is given to the tooth preparation, the likelihood that metal will be visible increases significantly (Fig. 7.66).

The distal margin of posterior partial-coverage restorations is less visible than the mesial margin. In this area, it is often advantageous to extend the preparation farther beyond the contact point for easier preparation and finishing of the restoration and to facilitate access for oral hygiene.

Facial Margin

The facial margin of a maxillary partial-coverage restoration should be extended just beyond the occlusofacial line angle. A short bevel is needed to prevent enamel chipping. A chamfer

Fig. 7.65 Poor preparation design. (A) The treatment plan for these badly damaged incisors was to use metal-ceramic crowns. (B and C) The apical margin of the preparation does not follow the free gingival contours. (D) The restoration displays a metal collar labially, and the deep proximal margins have led to periodontal disease.

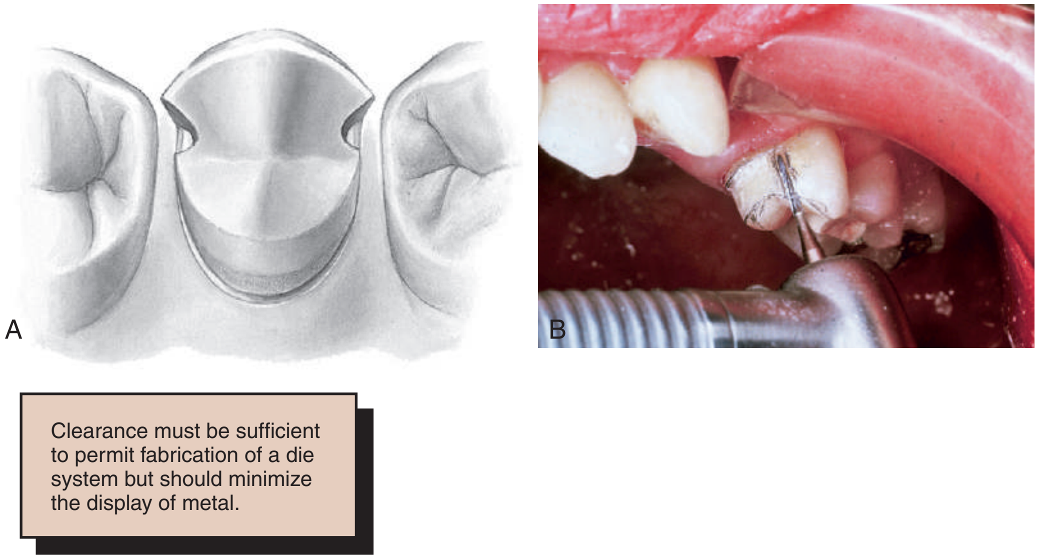


Fig. 7.66 (A) Correct placement of the mesial margin of a partial-coverage restoration is essential for good esthetics. To allow proper access for finishing, the restoration must extend just beyond the contact area, but the metal must remain hidden from the casual observer. (B) The tooth should be prepared in its long axis; otherwise, metal is displayed.

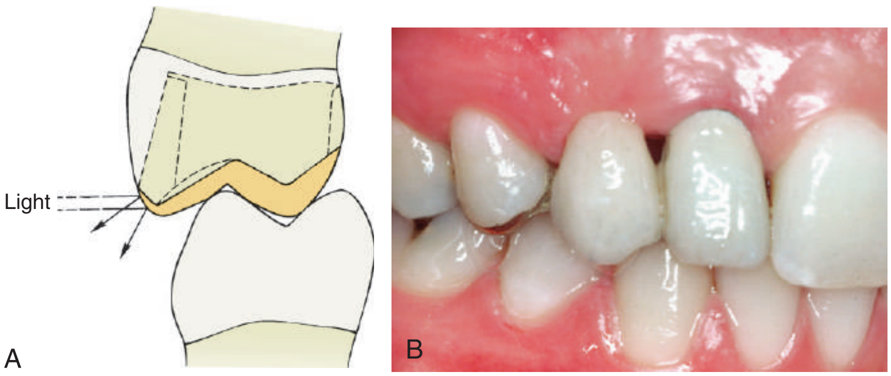


Fig. 7.67 (A) The facial margin of a partial cast crown should be shaped so that light is not reflected directly to the observer. (B) A three-unit fixed partial denture. The mesial abutment is a canine, shaped to look like a lateral incisor. The distal abutment is a partial cast crown, which proved to be esthetically acceptable because the metal had been correctly contoured.

margin can be placed in areas where appearance is less important (e.g., on molars) because this provides greater bulk of metal for strength.

If the facial margin of metal is correctly shaped (Fig. 7.67), it does not reflect light to an observer. As a result, the tooth appears to be merely a little shorter than normal and not as though its buccal cusp is outlined in metal. If the buccal margin is skillfully placed so as to follow the original cuspal contour, the appearance of the final restoration is acceptable.

When mandibular partial cast crowns are made, metal display is unavoidable because the occlusal surface of mandibular teeth can be seen during speech. A chamfer margin, rather than a beveled margin, is recommended for the buccal margin because it provides a greater bulk of metal around the highly stressed functional cusp (Fig. 7.68). If the appearance of metal is unacceptable to the patient, a metal-ceramic restoration with porcelain coverage on the occlusal surface can be made.

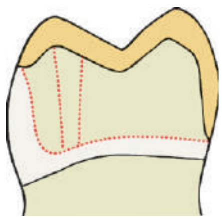


Fig. 7.68 A substantial chamfer margin is recommended for the functional buccal cusp of a mandibular partial cast crown. It provides greater bulk of metal in a stressed area.

Anterior partial-coverage restorations can be fabricated to show no metal (Fig. 7.69), but their preparation requires considerable care. The facial margin is extended just beyond the highest contour of the incisal edge but not quite to the incisolabial line angle. In this case, the metal protects the tooth from chipping but is not visible.

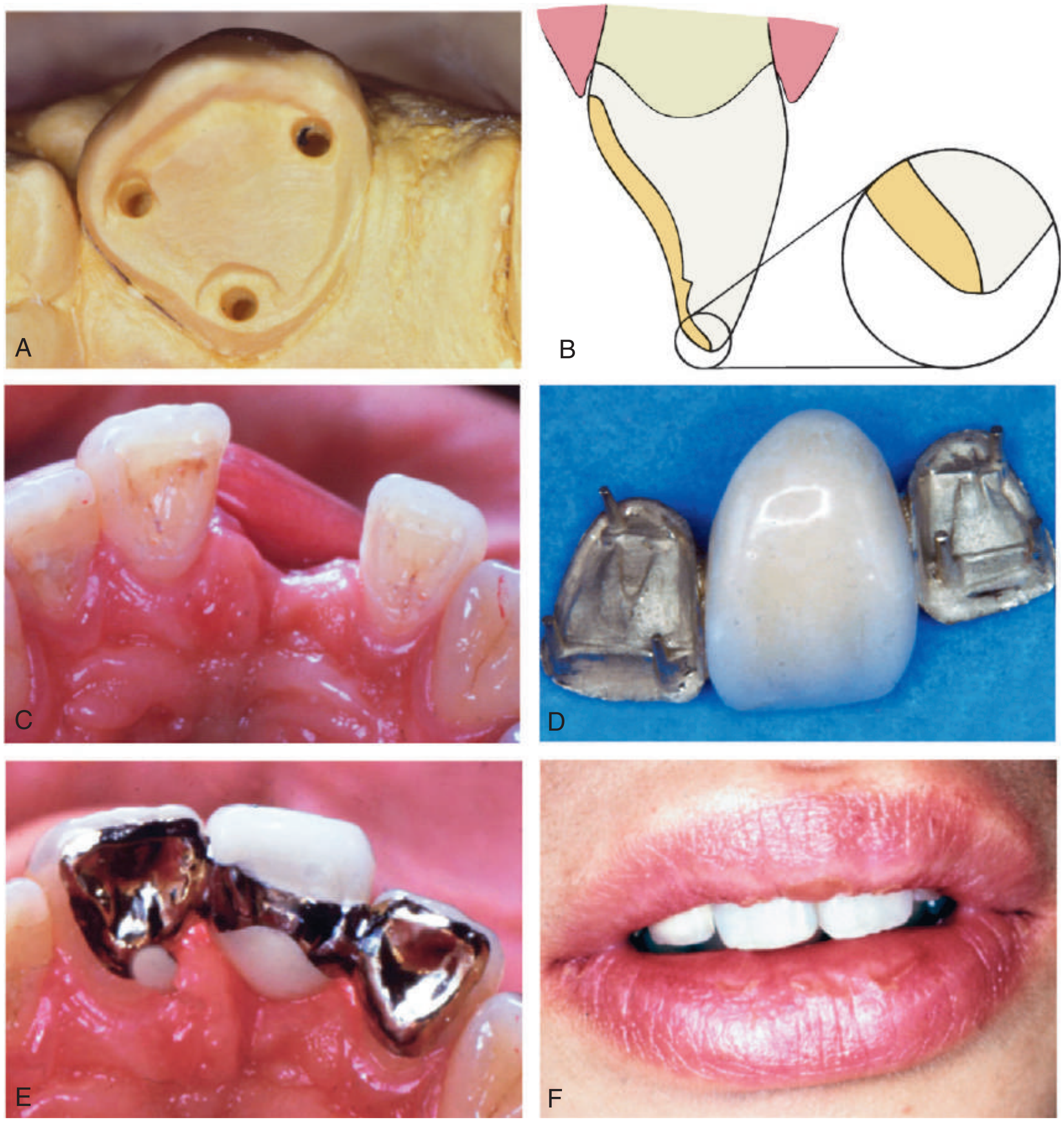


Fig. 7.69 (A) Teeth can be prepared for partial-coverage restorations that do not show any metal. Success depends on very careful margin placement. (B) The incisal edge is not completely covered. The restoration margin is located between the highest point of the incisal contour and the incisofacial angle. (C) Intact anterior teeth on either side of an edentulous space. (D) Three-unit fixed partial denture with pinledge retainers and a metal-ceramic pontic. (E) Occlusal view of fixed partial denture. (F) Acceptable esthetic result is obtained.

PLANNING AND EVALUATING TOOTH PREPARATIONS

Tooth preparation is a precise, technically complicated, and irreversible procedure. Thus, it is the practitioner's responsibility to carry it out properly, every time. Mistakes are often difficult, if not impossible, to correct. Rehearsing the planned preparations on diagnostic casts invariably proves helpful in achieving a better quality preparation.

Diagnostic Tooth Preparations

Diagnostic tooth preparations are performed on articulated casts before the actual clinical preparation. They yield information about the following:

- Selecting the appropriate path of placement for an FPD, particularly for abutment teeth that are tilted, are rotated, or have an atypical coronal contour (Figs. 7.70 and 7.71).
- Deciding on the amount of tooth reduction necessary to accomplish a planned change in the occlusion.
- Determining the best location for the facial and proximal margins of a partial-coverage restoration so that the metal is not visible.

An important advantage of diagnostic tooth preparations is that the operator can practice each step of the intended restoration. Mistakes are not permanently destructive. Also, diagnostic preparations can be used in the prefabrication of interim restorations, significantly reducing the appointment time duration

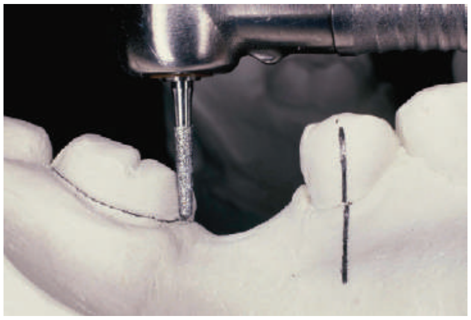


Fig. 7.70 Selecting the best path of placement for a fixed partial denture with the aid of diagnostic tooth preparations.

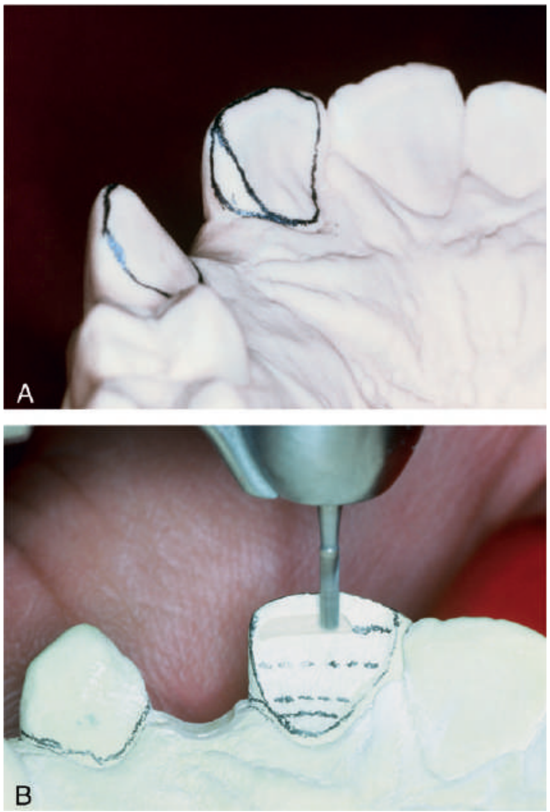


Fig. 7.71 (A and B) Diagnostic tooth preparations are extremely helpful in determining the ideal reduction for esthetic partial-coverage restorations.

after the clinical tooth preparation has been completed (the indirect/direct interim restoration fabrication technique is described in Chapter 15).

Diagnostic Waxing Procedures

For all but the most straightforward prosthodontic treatment plans, a diagnostic waxing procedure (Fig. 7.72) should be performed. This is done on diagnostic casts and helps determine optimal contour and occlusion of the eventual prosthesis. The procedure is of particular benefit if the patient's occlusal scheme or anterior (incisal) guidance requires alteration (Fig. 7.73). Once the teeth are prepared consistent with the needs identified during the diagnostic waxing, interim

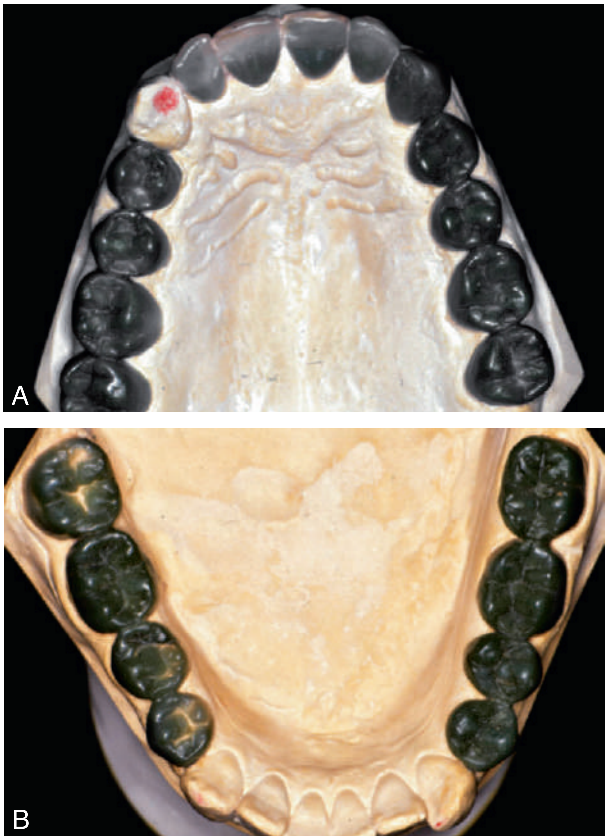


Fig. 7.72 (A and B) Diagnostic waxing for extensive treatment. (Courtesy Dr. M. Padilla.)

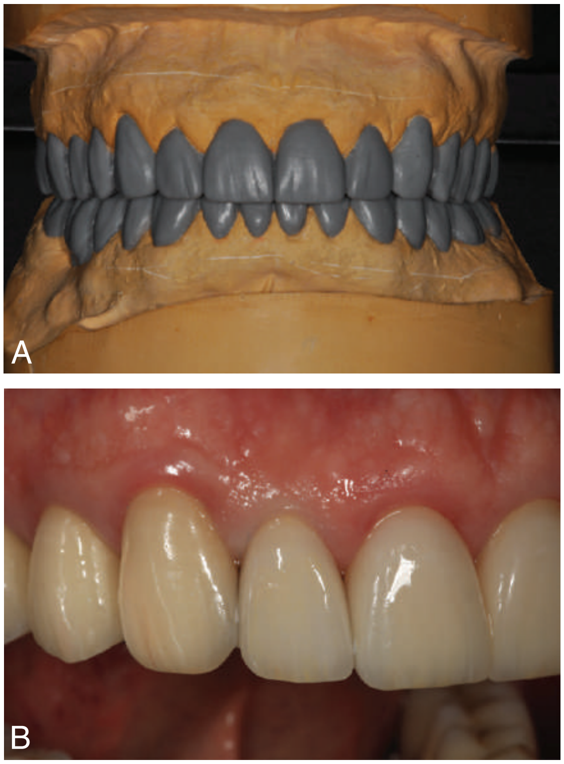


Fig. 7.73 (A) Diagnostic waxing for a comprehensive reconstruction. (B) Cemented comprehensive reconstruction. The crown contours and proportions were based on the initial diagnostic waxing (shown in A).

Fig. 7.74 Calipers measuring the thickness of the interim restorations and the cement. Measurements confirmed 1.2 mm of prosthetic space for the framework and veneering ceramic in the definitive restorations.

Fig. 7.75 A dental surveyor can be used to evaluate the axial alignment of tooth preparations.

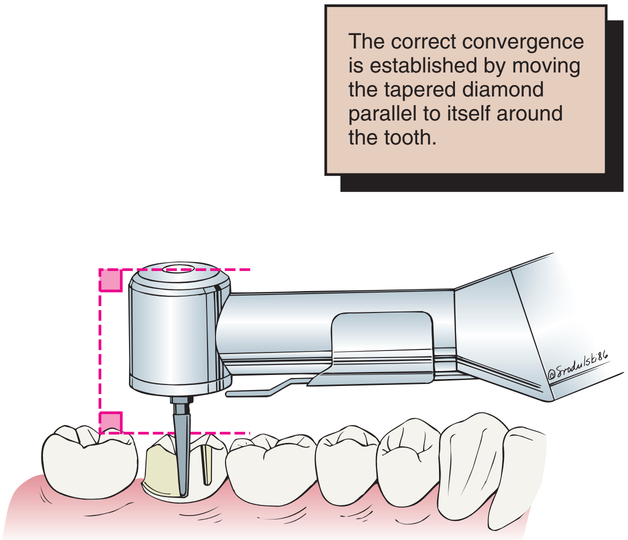


Fig. 7.76 Top surface of the handpiece held parallel to the occlusal surface. In this illustration, the rotary instrument is in correct axial alignment.

restorations can be created from the waxing. At a subsequent appointment before making a definitive impression, the interim restorations are removed and the thickness of the restorations and interim cements are evaluated to verify that there is appropriate prosthetic space for the specific definitive restoration(s) (Fig. 7.74).

Evaluative Procedures During Tooth Preparation

Each step of a tooth preparation should be carefully evaluated with direct vision or indirectly with a dental mirror. Alignment of multiple abutment teeth can be problematic, and use of the mirror helps superimpose the image of adjacent abutment teeth. To evaluate complex preparations, the dentist should make an alginate impression and pour it in fast-setting stone. A dental surveyor (Fig. 7.75) can then be used to precisely measure the axial inclinations of the tooth preparation. Making such an impression may appear to take unnecessary time; however, the information obtained often saves time in subsequent procedures by identifying problems that can then be addressed immediately. For tooth preparation, the contra-angle handpiece can be used for both measuring and cutting. This is done by concentrating on the top surface of the turbine head, which is perpendicular to the shank of the rotary instrument. If the top surface is kept parallel to the occlusal surface of the tooth being prepared, the rotary instrument is automatically in the correct orientation (Fig. 7.76). To prevent undercuts or excessive convergence during axial reduction, the handpiece must be maintained at the same angulation. The correct taper is imparted by the diamond instrument. Keeping the turbine head at its correct angulation initially is often most effectively done by supporting it with a finger of the opposite hand.

Patient and Operator Positioning

Learning the proper patient and operator positions is as beneficial as learning the proper preparation steps. Of particular importance are the advantages of obtaining a direct view of the preparation, which is always preferred to an indirect or mirror view. However, certain areas (e.g., the distal surfaces of maxillary molars) cannot be seen directly.

Inexperience, coupled with a hesitation to move the patient's head into a more favorable position, can unnecessarily complicate tooth preparation. For instance, having the patient rotate the head to the left or right side can considerably improve

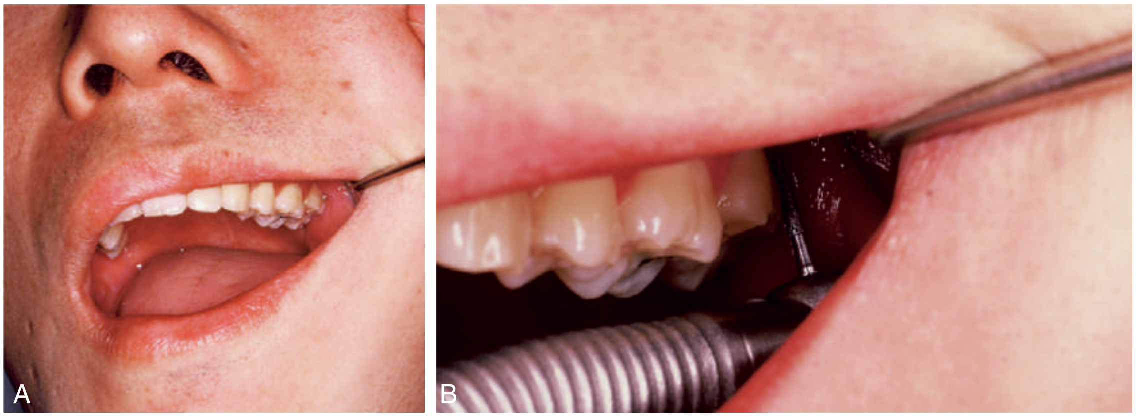


Fig. 7.77 Careful patient positioning can help obtain a direct view during tooth preparation. (A) Often access is better if the mouth is not open maximally because partial opening allows the cheek to be more easily retracted. (B) Access to the buccal surface.

the visibility of molar teeth that are being prepared. In most instances, a direct view can be obtained by subtly changing the operator's or the patient's position. Having the patient open maximally does not necessarily provide the best view. If the jaws are only partially open, the cheek may be retracted more easily (Fig. 7.77), and if the patient is encouraged to make a lateral excursion, the distobuccal line angle, together with the buccal third of the distal wall, may be seen directly. In practice, the mirror is essential only for visualizing a small portion of the distal surface. When a complete crown is prepared, the parts of the tooth most easily seen should be prepared first; the other areas can be prepared with the help of the mirror in a final stage.

Fig. 7.78 shows positioning of the patient and a right-handed dentist for tooth preparation of the less accessible maxillary posterior teeth.

It can be fatiguing for the patient to have the mouth opened for longer periods of time, which is not only uncomfortable during the appointment but can also cause some discomfort after the appointment. It is helpful to use a bite block on the opposite side of the arch. This allows the patient to relax by closing down onto the block and maintaining slight positive pressure, which eliminates or minimizes the concern.

SUMMARY

The principles of tooth preparation can be categorized into biological, esthetic, and restoration/tooth interface considerations. Often, these principles conflict, and the dentist must decide how the restoration should be designed to best fit the clinical situation. One area may be given too much emphasis, and the long-term prognosis may be limited by a lack of consideration of other factors.

Experience helps in determining whether preparations are "complete." Each tooth preparation must be measured by clearly defined criteria, which can be used to identify and correct problems. Diagnostic tooth preparations and the evaluation of impressions are often very helpful. The types of preparation described in the following chapters are explained in a step-by-step format. Although detailed techniques are provided, the rationale and goals to be attained in fixed prosthodontic procedures are of greater importance than the technique itself. Understanding the pertinent theories underlying each step is crucial. Successful preparation can be obtained most easily by systematically following the steps. It is crucial to refrain from "jumping ahead" before the previous step has been evaluated and, if necessary, corrected. If the clinician proceeds too rapidly, precious chair time will be lost, and the quality of the preparation will probably suffer.

STUDY QUESTIONS

1. Discuss how the manipulation and condition of the armamentarium being used can contribute to injury.
2. Discuss optimal occlusocervical margin placement. What are some reasons for deviating from the ideal? Why?
3. Discuss the difference between retention and resistance. What can be done to enhance retention, and what can be done to improve the resistance form of a tooth preparation?
4. Discuss six different margin configurations. Discuss their advantages, disadvantages, indications, and contraindications as applicable.
5. What is an undercut? How is an undercut eliminated? Can a buccal and lingual wall be undercut in relation to each other? Why or why not?
6. What are the differences in retention and resistance form between a partial veneer crown preparation and a complete cast crown preparation on the same tooth? How do clinical crown length and tooth size influence either? Why?
7. List six different means of conserving tooth structure during tooth preparation design, and explain why they achieve the objective.
8. What is the purpose of diagnostic waxing? Give four indications for a diagnostic waxing procedure.

Fig. 7.78 Positioning of patient and right-handed dentist for tooth preparation of the maxillary posterior teeth. (A) Maxillary right posterior sextant. Buccal or buccal half of occlusal surface reduction. The dentist is at the 9 to 11 o'clock position in relation to the chair. The patient turns the head to the left to improve the dentist's direct vision. (B) Maxillary right posterior sextant. Palatal or palatal half of occlusal surface reduction, including functional cusp bevel. The dentist is at the 11 o'clock position. The patient turns the head to the right to improve the dentist's direct vision. (C) Maxillary left posterior sextant. Buccal or buccal half of occlusal surface reduction. The dentist is at the 9 o'clock position. The patient turns the head to the right to improve the dentist's direct vision. (D) Maxillary left posterior sextant. Palatal or palatal half of occlusal surface reduction, including functional cusp bevel. The dentist is at the 9 o'clock position. The patient turns the head to the left to improve the dentist's direct vision. (E) Maxillary left posterior sextant. Distal surface reduction. The dentist is at the 9 o'clock position. The dentist's access is improved by having the patient tilt the head, partially close the jaws, and move the mandible in a left lateral excursion.

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8

Tooth Preparation for Ceramic Restorations

ANTERIOR AND POSTERIOR TOOTH PREPARATION FOR ETCHABLE CERAMIC RESTORATIONS

Historically, ceramic inlays, onlays, veneers, and crowns were challenging to fabricate, but with the development of newer ceramics and fabrication techniques, they have evolved into a predictable, durable, and conservative treatment option. When a tooth requires esthetic restorative treatment, the clinician must determine if the ceramic restoration will be adhesively retained through composite resin bonding or if development of the appropriate geometric form will be necessary to achieve retention and resistance form. Typically, the decision is driven by the type and quality of tooth structure available to bond to, the anticipated location of the finish lines, and the size of any pre-existing restorations. Bonding to enamel is more predictable than bonding to dentin. In addition, a reliable adhesive bond is more readily achieved on clean and healthy tooth structure than on sclerotic, decalcified, or discolored tooth structure.

Moisture control is also imperative for a predictable adhesive protocol to optimize a long-lasting bond between the tooth, composite resin, and ceramic. Accordingly, deep subgingival preparation margins do not promote dependable adhesion between the tooth and ceramic. When adhesives and primers interact with saliva or blood a reliable bond is not possible. Once the cementation protocol has been selected, the design of the tooth preparation and the selection of the most suitable ceramic can be made. The geometric principles for retentive and resistance forms of tooth preparations are discussed in Chapter 7. High-strength ceramics, such as zirconia, function well with classic geometric preparation forms that impart retention and resistance.

In addition to the geometric shape of the preparation, its surface texture should also be considered. Tooth preparations with slightly rough axial walls enhance micromechanical retention when classic water-based luting agents are used.[1,2] Tooth preparation roughness does not provide improved retention with contemporary adhesive luting agents. Currently, it is desirable to have a smooth finish on the tooth preparation. A smooth preparation surface improves the accuracy of fit, delivers a thinner cement space, and promotes less microleakage.[3]

Tooth preparations that depend on adhesive resin for bonding have to be coupled with a ceramic that can be etched (see also Chapter 25). The most popular current etchable ceramic routinely used for anterior and posterior ceramic restorations is lithium disilicate or a similar material.

Popular fabrication processes for lithium disilicate restorations include milling and heat pressing. A thorough understanding of the characteristics of a given ceramic material and how the restoration is fabricated closely relate to optimal tooth preparation design. The brittleness of most ceramics makes sharp line angles and abrupt transitions undesirable. The preparation must have smooth surfaces, rounded line angles, and precise, flowing finish lines. Preparation design must also anticipate the specific laboratory fabrication technique to be used. For instance, many dental milling units have preparation guidelines for limits that can and cannot be milled. A uniform, minimal film thickness can reduce lithium disilicate restoration fracture;[4] however, intaglio surfaces are commonly overmilled, resulting in an uneven cement film between tooth and restoration.

Analysis of Type, Quality, and Quantity of Tooth Structure

A person's genotype determines the phenotype for enamel thickness (Fig. 8.1).[5–7] This can impact clinical decisions about restorative choices. In laboratory studies, the microtensile bond test is considered ideal for evaluation of long-term durability of resin-hard-tissue bonds.[8] Enamel has a higher microtensile bond strength to composite resin than dentin.[9] Logically, an adhesively retained restoration would benefit from a tooth preparation that conserved enamel. However, other variables must be considered. Non-carious discolored tooth structure cannot be

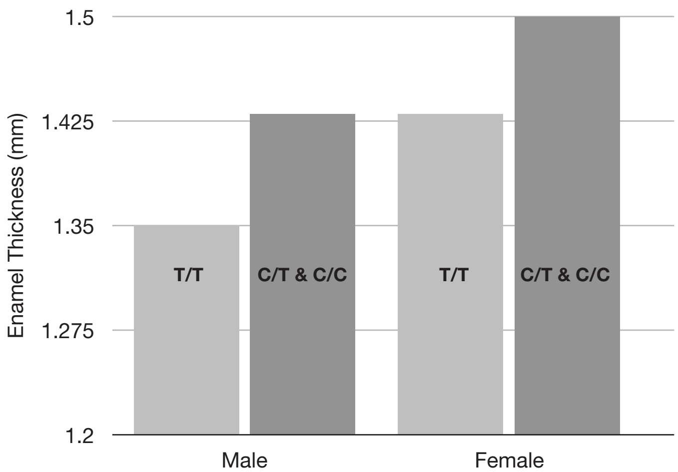

Fig. 8.1 Distribution of enamel thickness by sex and genotype. *C/C*, Two copies of the ancestral allele; *C/T*, ancestral allele and derived allele; *T/T*, two copies of the derived allele. (Adapted from Daubert DM, Kelley J, Udo Y, et al. Human enamel thickness and ENAM polymorphism. *Int J Oral Sci*. 2016;8:93–97.)

masked with a thin veneer of translucent ceramic. More tooth structure needs to be removed when a significant color change is the problem. Thin translucent ceramic of 0.5 mm or less may not have the optical properties to significantly change the color of a tooth.[10,11] In facial areas of a tooth that do not require significant shift in color, conservative preparations of 0.3 to 0.5 mm deep are feasible. To aid in the decision of whether to adhesively or cohesively retain restorations, preoperative radiographs can be used to evaluate interproximal enamel thickness (Fig. 8.2).[5,12,13] Not all tooth preparations have to be 100% subtractive in volume of tooth structure. It is possible to add esthetic ceramics to existing tooth contours without enamel removal. If the lips and tooth positions allow such additions, care must be taken to maintain contours that permit promotion and maintenance of periodontal health as well as enhance esthetics.

Considerations for Anterior Tooth Preparation

For a tooth that has not received a crown, it is recommended that the ceramic preparation starts as if the tooth will be receiving an adhesively retained restoration (Fig. 8.3). In other words, first prepare the tooth for a veneer and then modify the preparation to fit the needs of the tooth. In the anterior region, prepare a tooth for a veneer and remove all diseased tooth structure and failing restorations. Through these steps, maxillary anterior teeth will maintain enamel in the occlusal contacting areas. Furthermore, less cervical reduction on anterior teeth results in a stronger abutment while minimizing the increased risk of horizontal tooth fracture after preparation for a complete crown. Fig. 8.4 shows an example of use of an esthetic anatomic contour trial restoration to allow an additive process to the definitive contours of anterior teeth. Such a trial restoration can be fabricated from interim restorative material. It overlays the teeth to be prepared, and depth cuts can be made through the template to aid in the assessment of how much tooth structure should be removed to achieve the desired function and appearance in the definitive restorations. Once the tooth has been preliminarily prepared, two things have to be evaluated. First, ideally, the occlusal contacts are all maintained in enamel. Yet the opposing teeth should not occlude on the inciso-lingual margins of the ceramic restoration. Second, the tooth preparation has to permit the rigid definitive restoration to seat. If undercuts are present, additional tooth structure may have to be removed, or undercuts may be blocked out by adding a composite resin base. When anterior tooth preparations are initially started as veneer preparations, often more conservative preparations result. If on evaluation of the preliminary preparation it proves necessary to modify the design, it is often possible to achieve a form that combines features of a traditional porcelain laminate veneer preparation and a traditional crown with mechanical retentive features with opposing walls. However, such opposing walls are much shorter in the non-esthetic areas as long as the margins are not in occlusion. Consequently, cervical reduction is minimized and complete cingulum preservation may be possible. Preservation of cervical tooth structure and the cingulum promote a more durable abutment and during dental reevaluation appointments the margins are easily assessed for direct visual inspection.

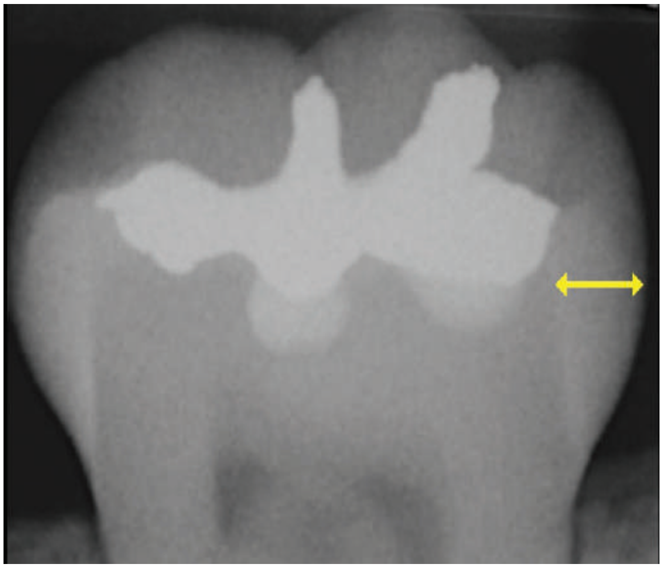

Fig. 8.2 Radiographic evaluation of interproximal enamel thickness.

Considerations for Posterior Tooth Preparation

Posterior tooth preparation may be approached in a somewhat analogous fashion: initially, occlusal clearance is established. However, instead of thinking of occlusal clearance as the first

Fig. 8.3 (A) Maxillary central incisor in cross section. *White line* proposes facial reduction for labial veneer. (B) *Solid white line* illustrates outline form of labial veneer with incisal reduction. (C) *Solid white line* outlines a bonded ceramic crown preparation with preservation of the cingulum. *Dashed white line* illustrates the interproximal finish line. *Red line* and *blue arrow* is the width off the incisal area that must be measured to be compatible with a milling unit. This area is not a concern if the restoration is to be heat-pressed.

Fig. 8.4 (A) Preoperative view of maxillary incisors with lips. Patient chief concern: to close gingival embrasures. (B) Frontal view in maximal intercuspation. (C) Maxillary lateral incisors have proximal caries, central incisors built have large composite resin restorations. (D) Lingual view of incisors showing failing composite resin restorations. (E) Esthetic template placed over incisors to obtain patient's esthetic approval and to be used as a preparation guide to maintain preparations in enamel as much as possible. (F) Depth cuts placed through esthetic template and colored with an indelible marker. (G) Initial facial and incisal reduction completed. (H) Completed etchable ceramic preparations of maxillary incisors. Interproximal contacts were extended to close gingival embrasures. Finish lines placed supragingivally. (I) Preparation shade recorded. (J) Shade of opposing dentition determined. (K) Definitive lithium disilicate restorations. (L) Lithium disilicate restorations bonded to maxillary incisors. (M) Completed supragingival ceramic restorations with closed gingival embrasures.

step of a complete crown preparation, it may be considered as the initial step in preparing the tooth for a posterior veneer. After the occlusal clearance is achieved, again the quantity and quality of enamel and dentin are evaluated. The width of the residual circumferential enamel ring with preparations without axial walls has been shown in vitro fatigue testing to impact the longevity of an adhesively retained ceramic onlay.[14] A statistically significant difference was found between teeth with a complete circumference of an enamel ring equal to or greater than 1.5 mm in width compared with teeth with an enamel width of 1 mm or less.[14] Fig. 8.5 shows examples of two posterior teeth with different thicknesses of circumferential enamel. Even flat preparations without axial walls have been shown to be durable when at least 1.5 mm or greater widths of circumferential enamel were present for bonding. Tooth preparations without adequate enamel for bonding require supplemental mechanical retention. Research suggests that the traditional 3- to 4-mm axial wall height for a crown preparation may not be needed with adhesive dentistry. Circumferential axial walls 2 mm in height have been reported to be sufficient for bonding posterior ceramic onlays.[15–18] Fig. 8.6 is a clinical example of a failed gold onlay that was removed, and the residual tooth structure was evaluated. The buccal enamel was thick; however, enamel on the other surfaces was not. When re-preparing the tooth, the mesial, lingual, and distal axial walls were intentionally finished supragingivally to supplement mechanical retention and to facilitate maintenance of a dry field during the adhesive bonding procedure for the subsequently fabricated ceramic restoration.

Highly visible posterior teeth and endodontically treated teeth that have darkened may benefit from the addition of a buccal veneer. Placing such an esthetic buccal veneer can offer a relatively conservative solution to such esthetic challenges (Fig. 8.7).

Indications for Etchable Ceramic Restorations

Bonded ceramics should always be considered as a conservative alternative to cemented crowns, where a more conservative restoration—such as a composite resin restoration—would be inadequate (Fig. 8.8). Usually, such a tooth has proximal and facial damage and can no longer be effectively restored with composite resin. Existing class 3 restorations are not a contraindication to porcelain laminate veneers as long the cingulum is intact. In many practices, such veneers have largely replaced metal-ceramic or ceramic crowns in the treatment of teeth that have not yet been prepared for complete crowns. The complete ceramic crown is indicated only when the tooth has already been restored with a complete crown or when all five surfaces of the tooth are compromised.

Fig. 8.5 Molar occlusal veneers illustrating two different scenarios with different thicknesses of enamel.

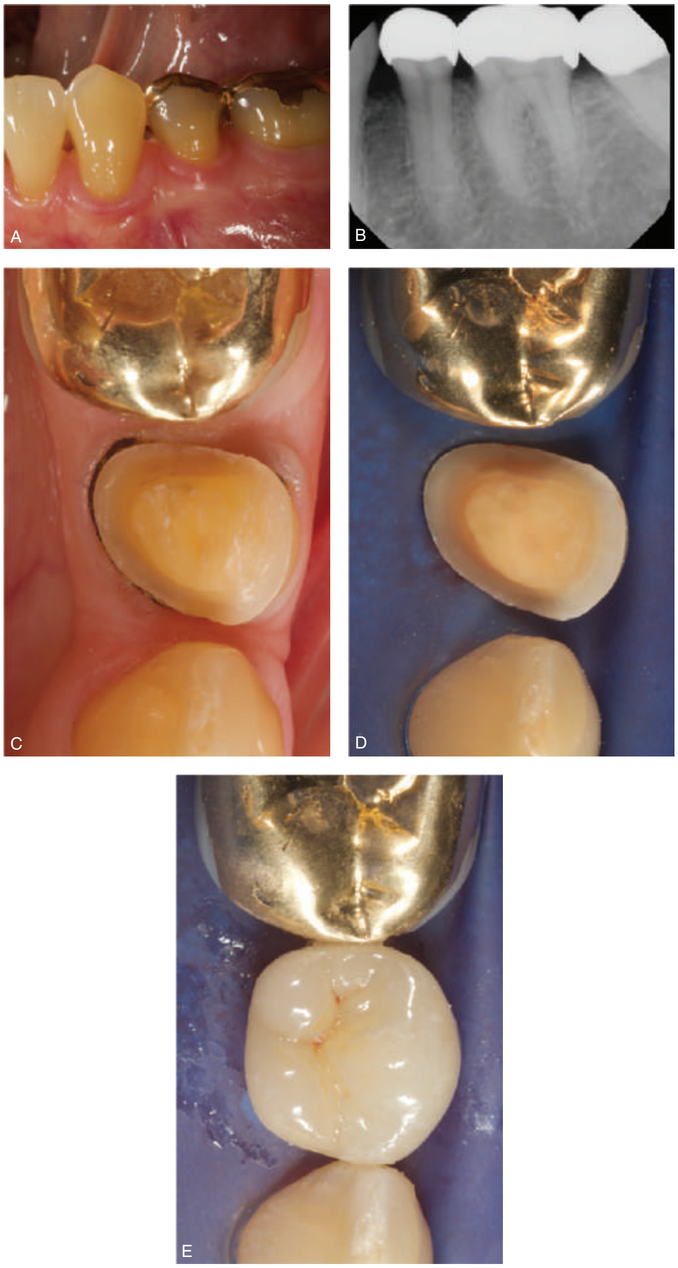

Fig. 8.6 (A) Preoperative view of mandibular premolar with failing MOD cast gold onlay. (B) Preoperative radiograph of mandibular premolar with secondary caries. (C) Distal caries removed and preparation finalized with supragingival finish lines. (D) Preparation done so that a dental dam can be placed at the cementation appointment. (E) Monolithic lithium disilicate restoration bonded.

Fig. 8.7 (A) Preoperative radiograph of maxillary first premolar after endodontic therapy. (B) Evaluation of shade before tooth preparation. (C) Existing MOD restoration was removed and occlusal reduction completed. An esthetic buccal veneer was completed with a 0.3 mm subgingival finish line. No preparation of lingual tooth structure. (D) Dental dam with #212 clamp placed to isolate the preparation to optimize moisture control. (E) Bonded pressed lithium disilicate posterior restoration.

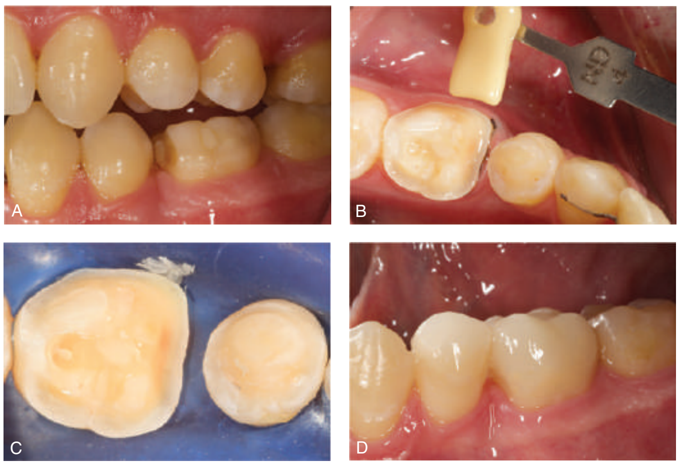

Fig. 8.8 (A) Initial presentation of mandibular premolar and molar out of occlusion. (B) Recording shade of preparations to communicate to dental laboratory technician. (C) Minimal finish line placed on premolar for an occlusal ceramic onlay. The occlusal, mesial, and buccal surfaces had preexisting composite restorations that were removed and converted to one minimally invasive adhesively retained ceramic restoration. (D) Occlusion restored with two pressed lithium disilicate restorations.

A prerequisite is for the tooth to be relatively intact with sufficient coronal structure to support the restoration. A general guideline is to not exceed a thickness of 2 to 3 mm of ceramic thickness on the occlusal surface. If thicker ceramic is necessary, a monolithic or layered zirconia restoration may provide an alternative solution. Although such restorations are not etchable, adhesion can be promoted with airborne-particle abrasion and a phosphate-based adhesive luting agent.[19]

Because of the relative weakness of etchable ceramics, the occlusal load should be favorably distributed. In general, this means that centric contacts are acceptable, but there should be no lateral interfering contacts. Anterior guidance that results in posterior disclusion minimizes the risk of posterior porcelain restorations chipping in lateral functional or parafunctional mandibular movements. Comparatively, posterior ceramic restorations in group function may be at a higher risk of fracture.

Contraindications

The adhesively retained ceramic preparation is contraindicated when a more conservative preparation can be used. Although certain ceramic materials may offer additional strength in comparison with some of the original ceramic materials, the strongest solution for a molar remains a metal casting, which may be partially veneered with ceramic material if visible when the patient smiles. In situations with high occlusal load and a reduced esthetic demand, metal-ceramic restorations with a metal occlusal surface are then the treatment of choice and have been shown to have excellent long-term success rates.[20]

Advantages of Etchable Ceramic Restorations

Clinical research over time periods ranging from 3 to 20 years support favorable long-term performance of bonded lithium disilicate restorations, when carefully planned.[21–29] The 20 year survival rate may or may not, however, come close to replicating the clinical survival of metal-ceramic crowns.[30]

The advantages of a ceramic restoration include its superior esthetics in comparison with metal-ceramic crowns, its excellent translucency (similar to that of natural tooth structure), and a generally good soft tissue response. Depending on the inherent translucency of the chosen material, the appearance of the completed restoration can truly mimic the appearance of natural teeth. When compared with composite resin restorations, ceramic restorations are superior in color stability. Cements of different colors can also be used to affect the final color of translucent restorations. Changing cement color under restorations that rely on an opaque core for strength, such as a zirconia core system or monolithic zirconia (see Chapter 25), is ineffective.

Compared with metal-ceramic crown preparations, the lack of reinforcement by a metal substructure enables slightly more conservative reduction of the facial surface. Usually, approximately 0.3 to 1.0 mm of labial reduction is needed at the gingival finish lines for ceramic restorations. As a result of preserving cervical tooth structure with a veneer style of tooth preparation, the mode of failure may differ from that of the metal-ceramic crown. An anterior tooth with a metal-ceramic crown is at risk of horizontal fracture of the tooth at the margin, whereas with a veneer, the mode of failure is typically limited to the ceramic and the interface. Conservative tooth preparations promote structural integrity of the abutment and shift catastrophic failures to more reparable ones. Obviously, caries affects teeth the same, independent of the selected restoration. However, if margins are placed equal to or above the gingival crest, early caries detection becomes easier.

Anterior ceramic restorations that preserve lingual tooth structure in the occlusal contact areas are preferred to minimize wear on the opposing teeth. Wear has been observed on the functional surfaces of natural teeth that oppose ceramic restorations.[31] This also applies to teeth opposed by metal-ceramic restorations, especially the mandibular incisors, which can exhibit significant wear over time (see Fig. 19.1). Preparing teeth for adhesively retained ceramic restorations where tooth enamel in the area of functional contact is preserved reduces that risk.

Disadvantages of Etchable Ceramic Restorations

Making complex veneer-crown preparations draw can be challenging. Traditionally, a ceramic veneer will have a path of placement in a more facial direction compared with a complete crown which typically has a path of placement that is parallel to the long axis of the tooth.

Although highly esthetic ceramic restorations can be created in the dental laboratory, the definitive result is strongly influenced by what is done clinically. The color of the underlying tooth structure can affect the final color of the restoration. Healthy tooth structure can contribute to achieving a natural appearance in the definitive restoration. Unfortunately, when restoring severely discolored teeth, translucent ceramic restorations have limited efficacy. The dental laboratory technician needs to know when, where, and how much to mask the discolored tooth preparation and when not to. Excellent communication between clinician and technician is essential. Intraoral scans can minimize the time needed to communicate the preparation color because many scanners have color spectrometers built in. The color of the definitive ceramic restoration is also affected by the composite resin luting agent. Evaluation pastes of the same color as the resin cements are available to preview the eventual outcome. However, variations in color have been shown between evaluation pastes and the corresponding composite resin luting agent.[32]

At the insertion appointment, care must be taken to not chip delicate margins while confirming the fit and proximal contacts before the restoration is bonded. Bonding ceramics impart additional strength. Before they are adhesively connected to the abutment, they are fragile and vulnerable to fracture.

With conservative preparations, a potential disadvantage of the procedure is that the obtained restorations may be excessively contoured. If the clinical situation precludes such an additional amount of ceramic material, more reduction is indicated, which can lead to dentin being exposed. However, with the high flexure strength of lithium disilicate, compared with feldspathic ceramics and improvements in dentin bonding technologies, bonding porcelain laminate veneers to dentin is not contraindicated.

The placement of a dental dam along with the steps to adhesively cement a ceramic restoration is more time consuming than cementing a crown with a cohesive cementation process. Likewise, the cleanup and removal of all residual cement can be tedious.

A disadvantage of a complete ceramic crown is the reduced strength of the tooth because of the more aggressive preparation of the lingual wall. However, if a ceramic crown is to be adhesively retained, the lingual finish line does not have to be placed subgingivally as with traditional mechanical retention and resistance forms. With a bonded ceramic crown, many times the lingual finish line can even be kept incisal of the occlusal contacts. Table 8.1 lists the properties of the various material options.

It can be challenging to obtain well-fitting margins when certain techniques are used. Milling machines do not mill irregular margins well. If the preparation has rough or jagged finish lines, a milled ceramic restoration will be fabricated with poorly adapted margins. Heat-pressed lithium disilicate ceramics may compensate for small irregularity in a preparation margin. However, a restoration is only as good as its preparation. The unforgiving nature of porcelain, if an inadequate tooth preparation goes uncorrected, can result in an ill-fitting restoration and/or premature fracture.

Proper preparation design is critical for mechanical success. A 90-degree and greater cavosurface angle is needed to prevent

TABLE 8.1 Properties of Three Types of Ceramics

Property	Leucite	Lithium Disilicate	Zirconia (Y-TZP)
Crystallinity (volume %)	35	70	≥97.5 (may also include crystalline HfO_2, Al_2O_3, Na_2O, SiO_2, Fe_2O_3, and so forth)
Flexural strength (MPa)	85–112	215–400	900
Fracture toughness (Mpa • $m^{1/2}$)	1.3–1.7	2.2–3.3	8–10.3
Vickers hardness (GPa)	5.9	6.3	8.8–11.8
Expansion coefficient (10^{-6}/K)	15.0–15.4	9.7–10.6	10.0–11.0
Elastic modulus (GPa)	65–86	95–103	210
Chemical durability (μg/cm^2)	100–200	30–50	30

Adapted from Shen C, et al. *Phillips' Science of Dental Materials.* 13th ed. St. Louis: Saunders; 2022.

unfavorable stress distribution and to minimize the risk of fracture. The preparation should provide support for the porcelain along its entire incisal edge, unless the ceramic system chosen includes a high-strength core (see Chapter 25).

ANTERIOR LITHIUM DISILICATE PREPARATION—PORCELAIN LAMINATE VENEERS AND BONDED CERAMIC CROWNS

Laminate veneering (see Fig. 8.3A) is a conservative method of restoring the appearance of discolored, carious, worn, and fractured anterior teeth. Because of the conservative nature of the porcelain laminate veneer, it should always be considered before contemplating complete crowns. It consists of bonding ceramic laminates onto the labial surfaces of affected teeth. Bonded ceramic crown preparations can extend around to the incisolingual but do not cover the cingulum. The bonding procedure is the same as that for posterior ceramic restorations except that a photopolymerizing resin is usually used instead of a dual polymerizating luting agent (see Chapter 30).

Preparation

Armamentarium

The instruments needed for preparing a porcelain laminate veneer and a bonded ceramic crown include the following:

- 1-mm round rotary instrument or 0.5-mm depth cutter
- Narrow, round-ended, tapered diamonds, regular and fine grit (0.8 mm)
- Finishing strip
- Finishing stones
- Mirror
- Periodontal probe
- Explorer

Step-by-Step Procedure

The gingival third and proximal line angles are often over contoured with these restorations Therefore, maximum reduction should be achieved with minimum penetration into the dentin (Figs. 8.9 and 8.10).

Facial reduction

1. The use of a self-limiting rotary instrument is a practical way to make initial depth grooves while avoiding undesired penetration of abnormally thin enamel. The amount of reduction required depends, to some degree, on the extent of discoloration and existing structural damage. A minimum of 0.3 to 0.5 mm in the cervical area is usually adequate to keep the preparation in enamel, although the fabrication of such thin restorations requires them to be pressed since they cannot be milled. However, a greater ceramic thickness is helpful when the restoration has to mask the underlying tooth color or the intent is to mill. When a thicker ceramic is indicated, the facial reduction can be 1 to 1.2 mm. The reduction should follow the anatomic contours of the tooth. Where the labial contour of the tooth requires alteration, a carefully made putty reduction guide from a diagnostic waxing is essential to help determine optimum reduction (Fig. 8.11).

Fig. 8.9 Porcelain facial veneer preparation. (A) The proximal contact areas and incisal edge are preserved, and the preparation is limited to enamel. Normally, a reduction depth of about 0.5 mm is recommended, but making a series of depth holes with a round bur guards against penetrating thin enamel. (B) Tetracycline-stained teeth. Composite resin veneers were placed earlier but failed to mask the discoloration satisfactorily. Six maxillary porcelain labial veneers would be provided. (C and D) Completed tooth preparations. (E) Interim restorations made directly with composite resin, which are retained by etching small areas of enamel (see Chapter 15).

Fig 8.10 (A) Patient's smile before treatment with porcelain laminate veneers. (B) Incisal view of the maxillary teeth to be veneered. (C) Application of 0.5-mm depth cuts. (D) Reduction of depth cuts with chamfer-ended diamond. (E) Facial reduction complete. (F) A 1.5-mm incisal reduction. (G) "Elbow" preparation to the proximal contact. (H) Interproximal stripping with diamond strip. (I) Horizontal seating groove. (J) Finished preparations, facial view. (K) Lateral view of finished preparations. (L) Incisal view of finished preparations. (Courtesy Dr. Ross Nash. Freedman G. *Contemporary Esthetic Dentistry*. St. Louis: Mosby: 2012.)

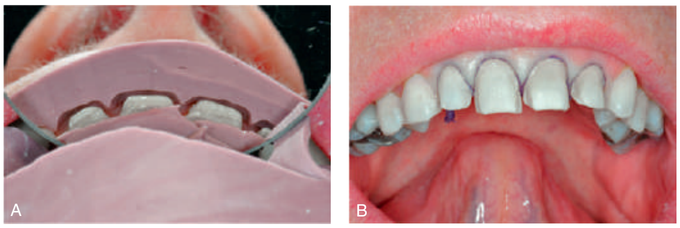

Fig. 8.11 (A) A putty reduction guide is essential for ensuring adequate and uniform porcelain thickness for veneers if the labial contours require modification. (B) Maxillary incisors prepared for porcelain laminate veneers. (Courtesy Dr. R.D. Douglas.)

2. Place the long chamfer finish line while removing the islands of remaining tooth structure between the depth grooves (Fig. 8.12). This design has an obtuse cavosurface angle, which exposes the enamel prism ends at the margin for improved etching. The finish line should closely follow the gingival crest so all discolored enamel prisms are veneered without undue encroachment on the gingival sulcus.
3. Wherever possible, place the preparation finish line labial to the proximal contact area to preserve the area in enamel. However, slight proximal clearance is essential for separating the definitive cast and for accessing the proximal margins for finishing and polishing. A diamond finishing strip helps create such. Sometimes, it is necessary to extend the proximal margins lingually to include existing restorations. This can necessitate considerable tooth reduction to avoid creating an undercut. Some authorities advocate placing the ceramic margin on composite resin material rather than extending the preparation to enamel. If diastemas are to be closed, the veneer finish line must wrap from the gingival sulcus toward the lingual to allow the development of new axial contours to close the proximal contact without creating a periodontal compromise.
4. It is preferable not to reduce the incisal edge (see Fig. 8.3B), although this cannot always be avoided; keeping it intact helps support the porcelain and makes chipping less likely. If the incisal edge length is to be altered or increased, the preparation must be extended onto the lingual surface. Care is needed to avoid undercuts when this modification is made. Visualizing the path of placement of the restoration is important because an undercut will prevent placement of the veneer.

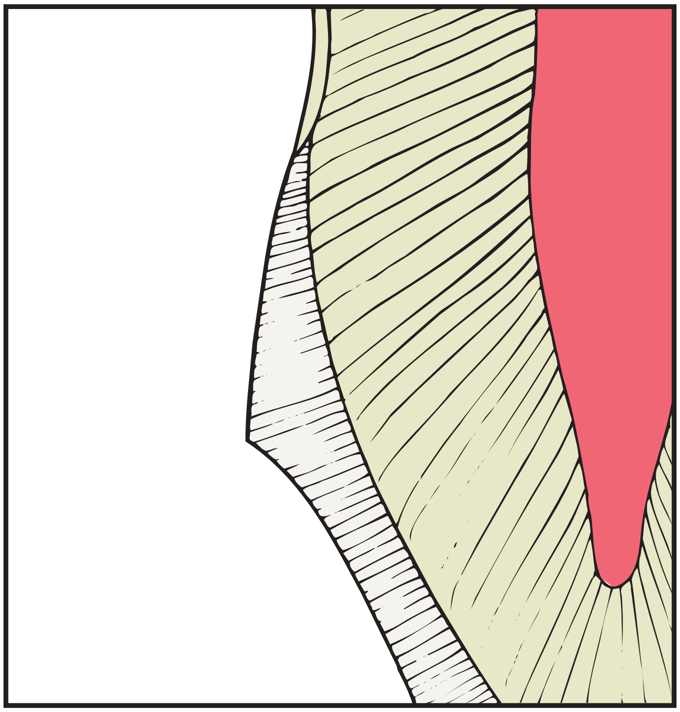

Fig. 8.12 The recommended margin (long chamfer) for facial veneers has an obtuse cavosurface angle, and so the ends of the enamel prisms are exposed for differential etching.

5. To prevent areas of stress concentration in the porcelain, be sure that all prepared surfaces are rounded without any sharp transitions.

Incisal reduction. Incisal reduction provides prosthetic space to restore the tooth with ceramic at the incisal edge (see Fig. 8.3B), needed when the incisal area is to be restored or altered. If no modification is indicated, the veneer can be designed for the facial surface only. It is important to differentiate between *incisal reduction*, which is independent of *occlusal clearance* with the opposing tooth. Occlusal clearance is the prosthetic space between two occluding teeth. For a veneer preparation, the occluding (lingual) portion of the tooth is not prepared.

1. Place two to three depth cut grooves in the incisal edge, with a 1.0 mm diamond rotary instrument. The depth grooves are positioned perpendicular to the long axis of the tooth and run in a facial-lingual direction. A 1.0 mm deep grove allows for additional removal of tooth structure during finishing. The endpoint of incisal reduction is generally 1 to 2 mm.
2. Complete the incisal reduction, reducing half the incisal edge at a time until the incisal edge is a flat surface, perpendicular to the long axis of the tooth.

Transitioning the veneer to a bonded ceramic crown—lingual reduction. In patients where the opposing tooth occludes on a ceramic margin or when the lingual surface needs to be restored, additional lingual reduction is indicated (see Fig. 8.3C). The goal with lingual reduction is to restore affected tooth structure and gain prosthetic space for ceramic to completely restore the occlusal contacting area. The lingual margin is kept as far incisally as possible to conserve tissue. If possible, leave the mandibular incisor occluding on tooth structure. With bonded anterior ceramic restorations, lingual reduction is not done for mechanical retention (Fig. 8.13). In contrast, if the lingual wall is needed to mechanically retain a crown on a structurally compromised tooth, a zirconia ceramic crown should be considered.

1. Use the football-shaped diamond rotary instrument for lingual reduction after placing depth grooves approximately 0.8 mm deep. Perform the lingual reduction in the same way as for other single anterior tooth preparations (see Chapter 10) until clearance in all mandibular excursive movements is 1 mm, to ensure adequate room for the ceramic in all load-bearing areas.
2. Once the lingual reduction is completed, evaluate the buccolingual thickness at the prepared incisal edge. Milling units can mill the intaglio surface of a crown to 0.5 to 1.0 mm. It is important to know the dimensions of the milling bur that will be used to fabricate the restorations. If the buccolingual dimension is less than the parameter of the mill, the intaglio area of the restoration will be excessively milled, resulting in a large and undesirable cement space. Large, uneven cement film thicknesses can increase susceptibility of ceramic fracture. An alternative solution is to increase the reduction of the incisal edge to gain a wider faciolingual dimension. In contrast, with the heat-pressed method, with milling, the buccolingual dimension is not limiting as long as the incisal edge is rounded.

Transitioning to a complete ceramic crown. The complete crown preparation is indicated on anterior teeth with cervical damage or defects, or if an existing crown requires replacement (Fig. 8.14).

1. After the selected path of placement has been transferred from the cervical wall of the facial preparation, place a depth groove in the middle of the cingulum wall.
2. Repeat the chamfer margin preparation, this time from the center of the cingulum wall into the proximal aspect, until the lingual chamfer margin meets the facial chamfer margin. This margin should follow the free gingival crest and should not extend too far subgingivally. It is recommended that initial placement be slightly above the intended endpoint. Once it is possible to position the rotary instrument in the interproximal area, refine the margin and extend it to its final location, working in the direction of proximal to mid-lingual (downslope) because such reduces the risk of encroaching on the epithelial

Fig. 8.13 (A) Initial presentation of maxillary anterior teeth with attrition, midline diastema, malocclusion, and aberrant gingival margins. (B and C) Veneer preparations into dentin to gain more restorative space while preserving the lingual tooth structure. (D) Definitive veneers on maxillary incisors.

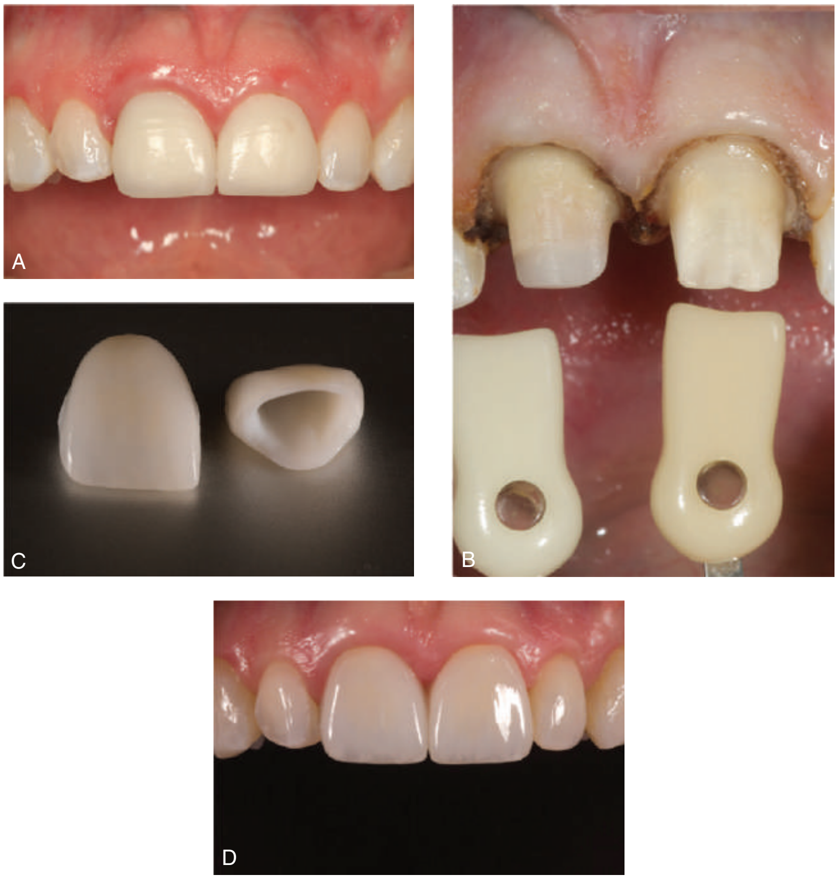

Fig. 8.14 (A) Chief concern: monochromatic ceramic crowns with red gingival margins. (B) Ill-fitting unesthetic ceramic crowns removed and evaluating the residual tooth color. (C) Layered lithium disilicate complete crowns. (D) Complete ceramic crowns bonded with acceptable soft tissue response.

attachment. As previously emphasized, if the centric contact is incisal of the cingulum and the cingulum is intact, a bonded ceramic crown does not need to cover the cingulum.

POSTERIOR LITHIUM DISILICATE PREPARATION

Complete ceramic crowns should have reasonably uniform thickness circumferentially. The two popular ceramics for posterior complete crowns are lithium disilicate and zirconia. Lithium disilicate becomes stronger when bonded to the tooth whereas zirconia does not. For the hot-pressed ceramic crown (i.e., max press [Ivoclar AG; Amherst, NY] or OPC [Pentron Ceramics, Inc.; Wallingford, CT]) (Fig. 8.15), usually about 1.0- to 1.2-mm thickness is needed to create an esthetically pleasing restoration.

Only minor differences in tooth preparation design exist among the restorations fabricated with the various techniques. Therefore, the preparation for a pressed crown preparation is described in detail, and the necessary variations are discussed when pertinent.

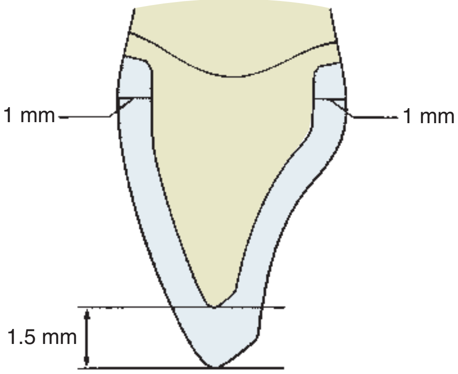

Fig. 8.15 Recommended reduction for ceramic crowns.

Preparation

Armamentarium

The instruments needed for preparing a ceramic crown (Fig. 8.16) include the following:

- Round-ended, tapered diamonds, regular and coarse grit (0.8 mm)
- Square-ended, tapered diamond, regular grit (1.0 mm), or end-cutting diamond
- Football-shaped diamond
- Fine grit finishing diamonds or carbides
- Mirror
- Periodontal probe
- Explorer
- Chisels and/or hatchets
- High- and low-speed handpieces

Fig. 8.16 Armamentarium for a ceramic crown preparation.

Step-by-Step Procedure

The preparation sequence for a posterior bonded ceramic restoration is similar to that for the anterior ceramic veneer; the principal difference is the need for a 1-mm-wide circumferential chamfer margin (see Fig. 8.12).

Occlusal reduction. On completion, the occlusal reduction should provide 1.5 to 2.0 mm of clearance for ceramic on all cusps and grooves. Clearance should also be evaluated in all excursive movements of the mandible. A minimal thickness of 1.0 mm is needed in the occlusal area of the definitive ceramic restoration. This renders the restoration to be durable, translucent, and esthetically pleasing.

1. Place depth grooves in all primary grooves and cusp summits, initially keeping them approximately 1.3 to 1.5 mm deep to allow for additional loss of tooth structure during finishing. The grooves are oriented along the three occlusal planes of a posterior tooth.
2. Occlusal reduction is completed with a larger diameter diamond rotary instrument, leveling the occlusal surface to the equal positions of the deepest parts of the depth grooves. Do not use the same rotary instrument that was used for the depth grooves. If this is used, it could inadvertently fall into the groove and make it deeper. Verify on completion that the desired clearance has been achieved.
3. Once the occlusal clearance is finalized, evaluate the thickness of the circumferential enamel. Enamel that is 1.5 mm or thicker provides adequate tooth structure for bonding a ceramic occlusal onlay. Anything less than 1.5 mm of enamel thickness must have supplemental mechanical retention with 2 mm axial walls. Ceramic occlusal onlays are ideal in non-esthetic areas because the buccal finish line is visible and may be unattractive in a smile. If 1.5 mm or greater thickness of enamel exists and it is determined to finalize the preparation at the occlusal reduction stage, the clearance between the adjacent teeth has to be evaluated. The ceramic occlusal onlay preparation may need proximal clearance between the adjacent teeth. To get clearance the enamel finish line can swoop apical to break through the proximal contact(s). However, once this is done, the residual enamel width must be evaluated again. Enamel width of 1.5 mm or greater is rare. It is typically seen when the occlusal vertical dimension is increased and interarch space is gained, allowing minimal tooth preparation to be performed in comprehensive reconstructions.[27,33]

Buccal reduction (esthetic veneer)

4. After placing depth grooves, reduce the labial or buccal surface, and verify that clearance is adequate for 1 mm of porcelain thickness. The finish line minimal depth can be 0.5 mm for a pressed ceramic restoration or 1.0 mm if milled. One depth groove is placed in the middle of the facial wall and one each in the mesiofacial and distofacial transitional line angles. The reduction is then performed with a cervical component parallel to the proposed path of placement (typically, the long axis of the tooth) and an occlusal component parallel to the original external buccal contour of the tooth. The depth of these grooves should be approximately 0.3 to 0.5 in the cervical area and 0.8 to 1.0 mm toward the occlusal, again slightly shallow to allow for finishing. Perform the reduction on half of the facial surface, evaluate its adequacy, and then complete the second half.
5. Accomplish the bulk reduction with the round-ended, tapered diamond (which results in a chamfer margin). Ensure copious irrigation throughout the procedure.

Modified chamfer margin preparation. For subgingival margins, control the tissue with displacement cord before proceeding with the chamfer finish line preparation. The ultimate objective is to direct stresses optimally in the completed porcelain restoration. A 90-degree or greater cavosurface angle is optimal; however, no residual unsupported enamel must be overlooked because it easily chips off.

The completed modified chamfer finish line should be 1 mm wide, have a rounded internal angle, be smooth, be continuous, and be free of any irregularities.

Finishing

6. Finish the prepared surfaces to a final smoothness as described for the other tooth preparations. Round any remaining sharp line angles to prevent a wedging action, which can cause fracture.
7. Perform any additional margin refinement as needed, using either the fine diamond or a carbide finishing rotary instrument of choice.

CERAMIC INLAYS AND ONLAYS

Christa D. Hopp

The application of ceramic as a restorative material is not limited to complete coverage crowns or esthetic veneers. Posterior teeth with moderate-sized defects can be restored with inlays or onlays as an alternative to amalgam, gold, or resin. For esthetic restorations, ceramic inlays and onlays provide a durable alternative to posterior composite resins. The esthetic quality of ceramic is rarely disputed, inasmuch as it is the material capable of matching the appearance of natural tooth structure most closely. The indirect fabrication of these restorations can eliminate potential issues associated with operator error, polymerization shrinkage, and layering composite resin in association with the direct technique. Bonding the ceramic restoration to tooth structure can help reinforce areas of weakened tooth structure and enable more conservative tooth preparation.

The procedure consists of bonding the ceramic restoration to the prepared tooth with an acid-etch technique. The bonding mechanism relies on acid etching of the enamel and the use of composite resin, as previously discussed, and like the resin-retained fixed dental prosthesis technique (see Chapter 26). Bonding to ceramic is achieved by etching with hydrofluoric acid and the use of a silane-coupling agent (materials are identical to those marketed as porcelain repair kits). A similar restoration entails the use of laboratory-processed composite resin instead of the ceramic.

Bonded ceramic inlays are showing promising longevity: 8- to 10-year performance. In a 10-year prospective study on IPS Empress inlays, survival probability was reported as 80% to 95%.[34–38]

Indications

A ceramic inlay can be used instead of amalgam or a gold inlay for patients with a low caries rate who require a class II restoration and wish to restore the tooth to its original appearance. It is a conservative restoration and enables most of the remaining enamel to be preserved. When an esthetic restoration is required in a posterior tooth, and the size of the defect is beyond what can predictably be restored with composite resin but small enough not to warrant a complete crown, a ceramic inlay or onlay is indicated. In general, when cuspal coverage is required for restoration of a tooth, composite resin is not a viable long-term restorative material.

Contraindications

Because these restorations are time consuming and expensive, they are contraindicated in patients with poor oral hygiene or active caries. Because of their brittle nature, ceramic restorations may be contraindicated in patients with excessive occlusal loading, such as those with bruxism. When more than two thirds of the occlusal table require restoration, a ceramic onlay or complete crown is generally preferred over a ceramic inlay.

Advantages

The obvious advantage of the ceramic inlay and onlay over alternative restorative materials is esthetics. The esthetic durability of ceramic restorations over time is superior to that of composite resin restorations, which stain over time. Ceramic inlays and onlays can be fabricated with the indirect technique in the dental laboratory, although chairside fabrication is possible with an in-office milling system (see Chapter 25). Restoration wear associated with posterior composite restorations is not a problem with ceramic restorations. Marginal leakage associated with polymerization shrinkage and with the high thermal coefficient of expansion of the resin is reduced because the luting layer is comparatively thin. In some situations, this restoration enables the clinician to conserve tooth structure. When a significant amount of tooth structure is already missing and retention form is limited, the ceramic restoration offers the advantage of bonding. For instance, if a premolar with a fractured cusp requires restoration, the defect is often treated with a complete crown, sometimes preceded by endodontic treatment and a suitable buildup (see Chapter 12). Such treatment necessitates removal of a significant amount of tooth structure and compromises the tooth's long-term prognosis. However, with a ceramic onlay, only the missing cusp need be replaced by bonding the ceramic material to a circumferential band of enamel; minimal if any additional retention form is required, and a significant amount of tooth structure is conserved, in comparison to the previously described approach (Fig. 8.17).

Disadvantages

Ceramics can be abrasive. If care is not taken to achieve a smooth, well-polished restoration, opposing enamel that is in sliding contact with the restoration can wear. Rough porcelain is extremely abrasive of the opposing enamel. Castable glass-ceramic restorations (see Chapter 25) are less abrasive than the traditional feldspathic porcelain. Wear of the composite resin luting agent can be a problem, leading to marginal gaps. These eventually allow chipping or recurrent caries.

Achieving accurate occlusion can be challenging with ceramic inlays and onlays. Because they are fragile, occlusal adjustment needs to occur intraorally—after cementation. Accurate adjustment of the occlusion can occur only after the restoration has

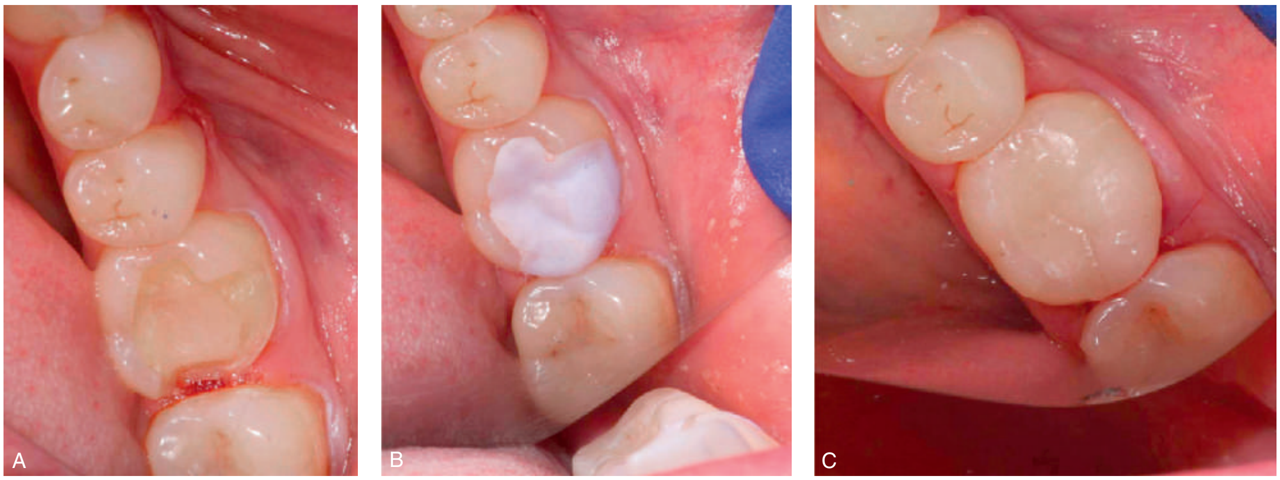

Fig. 8.17 Nontraditional preparation design for ceramic partial coverage. For this onlay preparation, the wide circumferential band of enamel provides for bonding. (A) Tooth preparation. (B) Clinical evaluation of lithium disilicate restoration before the crystallization step. (C) Completed restoration.

been bonded with an adhesive resin. Therefore, any roughening of the surface must receive the final polish intraorally, which can prove time consuming. Similarly, finishing of the margins can be difficult in the less accessible interproximal areas. Resin flash or overhangs can be difficult to detect and may initiate periodontal disease.

Ceramics are brittle. A thin area of ceramic can be subject to fracture because of its brittle nature.[39] Therefore, in some clinical scenarios as with many restorative materials, removal of sound tooth structure may be necessary in order to ensure adequate thickness for strength.

Bonding is highly technique-sensitive. Achieving an excellent bond between the tooth and the ceramic material is achievable, but not simple. The dentist must ensure excellent isolation, adhere precisely to the resin manufacturer's directions, and bond to meticulously clean tooth structure that is free of defects (i.e., sclerotic, decalcified, or otherwise compromised).

Accuracy is important with these restorations because accurately fitting restorations (marginal gaps less than 100 μm) have been shown to improve clinical outcomes. A study on adaptation differences between pressed and milled inlay and onlay restorations showed minimal differences after luting, ranging from 136 to 278 μm.[40] An appropriately adapted restoration to an abutment starts with the ideal preparation. All internal and external line angles must be well rounded. Cusp tips cannot be sharp. For milled ceramic inlays and onlays, the challenge associated with over and under milling due to the diameter of the milling bur is well recognized. If the ceramic restoration is going to be milled, the preparation has to be compatible to the milling bur. The clinical significance of the larger internal and marginal gap widths, in comparison to the classic cast gold inlay restorations, requires further study.

▪ ▪ ▪

Preparation

As with any indirect restoration, a path of placement must be established while undercuts and inconsistencies are avoided in the margin. Tapered diamond rotary instruments can produce the needed divergence to the internal walls and create the defined 90-degree cavosurface margins that help maintain the necessary bulk and strength. A slightly rounded end to a flat-ended tapered cylinder facilitates an internal form without sharp angles. A rounded internal form prevents stress concentrations or voids in the resin-bonding luting agent. It also enables the dentist to achieve excellent definition of the cavosurface margins (Fig. 8.18).

Armamentarium

As for metal inlays, tungsten carbide burs can be used for the preparation (Figs. 8.19–8.21), but diamonds may be substituted:

- Dental dam

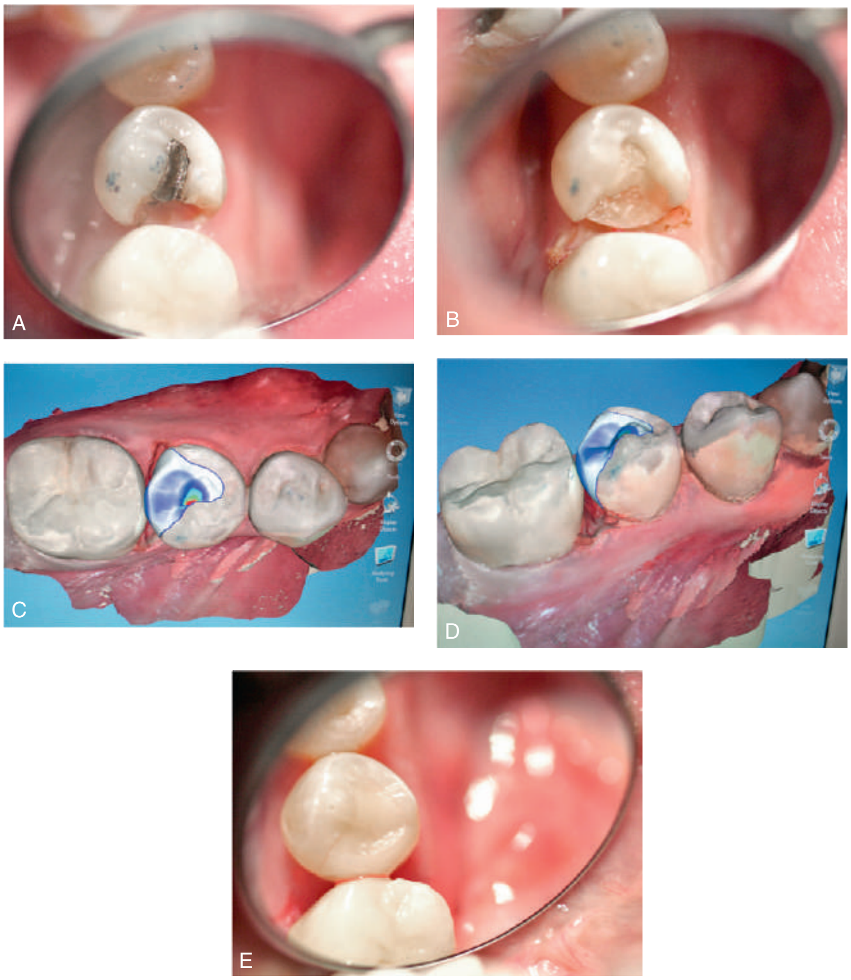

Fig. 8.18 Mandibular first premolar ceramic inlay. (A) Defective restoration and caries. (B) Preparation for disto-occlusal inlay. (C and D) Computer-aided designs of occlusal and buccal views of proposed ceramic restoration. (E) Bonded definitive restoration. (Courtesy Dr. James L. Schmidt.)

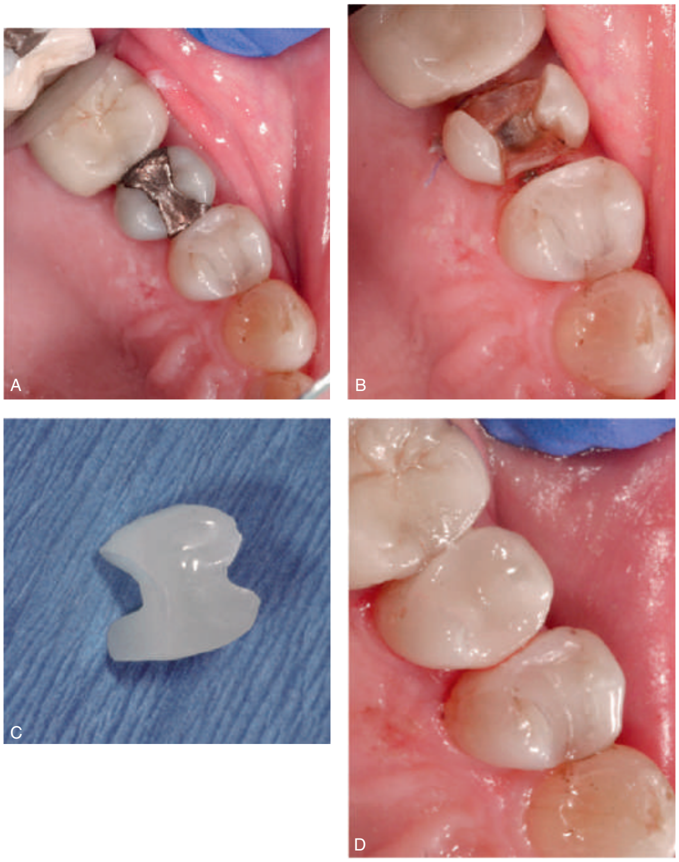

Fig. 8.19 (A) Large mesial-occlusal–distal (MOD) amalgam restoration on a maxillary premolar that had to be replaced. (B) Defective restoration and caries removed. (C) Leucite-reinforced ceramic restoration milled after CEREC Omnicam scan (see Chapter 14). (D) Bonded restoration. (Courtesy Dr. James L. Schmidt.)

Fig. 8.20 Armamentarium for the ceramic inlay preparation.

TABLE 8.2 Preparation Guidelines for All Ceramic Inlays and Onlays

Internal Dimensions	External Dimensions
Pulpal depth: 1.5–2.0 mm	Cavosurface margins: 90 degrees
Rounded internal line angles	Isthmus width: 2 mm
Axial wall convergence: 10–12 degrees	Occlusal reduction: 2 mm
Axial wall reduction (boxes): 1.0–1.5 mm	Smooth margins, no sharp transitions

Adapted from Hopp CD, Land MF. Considerations for ceramic inlays in posterior teeth: a review. *Clin Cosmet Investig Dent*. 2013;18(5):21.

- Tapered, round, and cylindrical diamond or tungsten carbide burs
- Finishing stones
- Mirror, explorer, and periodontal probe
- Chisels and gingival margin trimmers
- Excavators
- High- and low-speed handpieces
- Articulating film

Step-by-Step Procedure

The dental dam will improve operator visual acuity and optimize control of the surgical field. Inserting small inlays and onlays have a high risk of dropping in the patient's mouth and getting aspirated. Dental dam isolation is recommended during the preparation so the finish lines are ideally placed during the bonding appointment to create ideal isolation. Before applying the dam, the dentist should mark and assess the occlusal contact relationship with articulating film. To avoid chipping or wear of the luting resin, the margins of the restoration should not be at a centric contact. Minimal reduction values are necessary to allow enough ceramic thickness to prevent ceramic fracture. In general, weaker materials require additional bulk (Table 8.2).

Outline form

1. Prepare the outline form. The outline is generally governed by the existing restorations and caries (Fig. 8.21A). It is broadly similar to that for conventional metal inlays and onlays (see Chapter 11). Because of the resin bonding, axial wall undercuts can sometimes be blocked out with composite resin, which can allow preservation of additional enamel for adhesion. However, undermined or weakened enamel should always be removed. The central groove reduction (typically 2 mm) follows the anatomy of the unprepared tooth rather than a monoplane. This provides additional bulk for the ceramic. The outline should avoid occlusal contacts. Areas to receive onlays need 1.5 mm of clearance in all excursions to allow for adequate ceramic thickness and prevent fracture.
2. Extend the box to allow a minimum proximal clearance of 0.6 mm for a digital scan or impression. The margin should be kept supragingival, which makes isolation during the crucial bonding procedure easier and improves access for finishing. If necessary, electrosurgery or crown lengthening (see Chapter 6) can be performed. The axial depth of the gingival floor of the box should be approximately 1 mm. Round all

Fig. 8.21 (A) Initial presentation of posterior gold inlays with secondary caries. Mesial-distal vertical crack is identified on first molar. (B) Gold inlays and secondary caries removed creating undercuts in the preparations. (C) Composite resin is placed as a base to block out the undercuts in the preparations promoting conservative preparations by constricting the outline form while achieving path of placement of inlay preparations on premolar and second molar. (D) Completed inlay preparations on premolar and second molar. First molar has axial walls ranging from 2 to 3 mm tall to cover the vertical crack. (E) Lithium disilicate crown with short axial walls and inlays etched with hydrofluoric acid. (F) Lithium disilicate inlays bonded to restore the teeth.

internal line angles. Sharp angles lead to stress concentrations and increase the likelihood of resin voids during the bonding procedure.

Caries excavation

3. With an excavator or a round bur in the low-speed handpiece, remove any caries not included in the outline form preparation.
4. Place a composite resin base to restore deeply excavated tissue in the pulpal floor and axial walls (Fig. 8.21B and C). Excessively deep preparations require greater divergence of axial walls. Greater divergence of axial walls results in a larger preparation outline form, removal of healthy tooth structure and weakening of the tooth. Bonding composite resin to minimize the pulpal floor depth and block out und ercuts in the walls will conserve tooth structure by constricting the outline form.

Margin design

5. Use a 90-degree butt joint for ceramic inlay margins. Beveled margins are contraindicated because bulk is needed to prevent fracture. A distinct shoulder margin is recommended for ceramic onlays.

Finishing

6. Refine the margins with finishing burs and hand instruments, trimming back any composite resin base (Fig. 8.21D). Margins in enamel must be smooth and distinct for a ceramic restoration to fit accurately.

Occlusal clearance (for onlays)

7. Check the occlusal clearance after the dental dam is removed. Clearance must be a minimum of 1.5 mm in all excursions to prevent fracture. This can be easily evaluated through a digital scan of the prepared teeth or by measuring the thickness of the resin interim restoration with dial calipers.

Evaluation

8. On completion, verify that minimally desired clearance has been achieved to ensure adequate material thickness. Undercuts should be avoided, although minor undercuts may occasionally be blocked out. A cervico-occlusal wall divergence of approximately 10 to 12 degrees is consistent with guidelines for cast inlays and onlays and will allow excellent visual access to facilitate optical capture. Isthmus width should be at least 2 mm to reduce fracture risk (8.21E and F).[40]

STUDY QUESTIONS

1. For a posterior ceramic restoration, what are the guidelines for assessing tooth structure, and how do the clinical findings affect the preparations?
2. Explain the restorative philosophy for anterior and posterior teeth.
3. What are the indications for and contraindications to ceramic crowns and porcelain laminate veneers?
4. What are the advantages and disadvantages of ceramic crowns and porcelain laminate veneers?
5. What is the recommended armamentarium, and in what sequence should a maxillary central incisor be prepared, for a ceramic restoration?
6. What are the minimal criteria for steps 3 to 5? Why?
7. For ceramic inlays and onlays, discuss their advantages, disadvantages, indications, and contraindications.
8. What is the recommended armamentarium, and in what sequence should a mandibular molar be prepared, for a ceramic inlay and onlay?
9. What are the minimal criteria for steps 7 and 8? Why?

SUMMARY CHART

Etchable Ceramic Crown Preparation

Indications	Contraindications	Advantages	Disadvantages	Preparation Steps	Recommended Armamentarium	Criteria
• High esthetic requirement • Considerable proximal caries • Incisal edge reasonably intact • Endodontically treated teeth with post and cores • Favorable distribution of occlusal load	• When superior strength is warranted and metal or zirconia crown is more appropriate • Extensive caries • Insufficient coronal tooth structure for support • Thin teeth faciolingually • Unfavorable distribution of occlusal load • Bruxism	• Esthetically unsurpassed • Good tissue response even for subgingival margins • Among the most conservative preparations • Slightly more conservative of facial wall than metal-ceramic restorations	• Reduced strength in comparison with metal and zirconia crowns • Proper preparation extremely crucial • Brittle nature of material • Can be used only as single restoration	Depth grooves for incisal reduction	Tapered diamond	Approximately 1.3 mm deep to allow for additional reduction during finishing; perpendicular to long axis of opposing tooth
				Incisal reduction	Tapered diamond	Clearance of 1.5 mm; check excursions
				Depth grooves for facial reduction	Tapered diamond	Depth of 0.8 mm needed for additional reduction during finishing
				Labial reduction	Tapered diamond	Reduction of 1.2 mm needed; two planes, as for metal-ceramic crown preparation
				Depth grooves and lingual reduction Depth grooves for cingulum reduction	Tapered and football-shaped diamonds Tapered diamond	Initial depth, 0.8 mm; recreate concave configuration; do not maintain any convex configurations (stress) Parallel to cervical aspect of facial preparation; 1 mm of reduction; shoulder margin follows free gingival margin
				Depth grooves and lingual reduction Depth grooves for cingulum reduction Lingual shoulder margin preparation Finishing	Square-ended diamond Fine-grit diamond or carbide	Rounded shoulder margin 1 mm wide; minimize "peaks and valleys"; 90-degree cavosurface angle All surfaces smooth and continuous; no unsupported enamel; 90-degree cavosurface angle

SUMMARY CHART

Ceramic Inlay and Onlay Preparation

Indications	Contraindications	Advantages	Disadvantages	Preparation Steps	Recommended Armamentarium	Criteria
• Demand for esthetics • Low caries rate • Intact buccal and lingual enamel	• Extensive caries • Poor plaque control • Bruxism	• Superior esthetics • Conservation of tooth structure • Durable	• Abrasive of opposing tooth • Occlusion difficult to adjust • Wear of luting agent • Expensive • Long-term success rate unknown	Outline	Tapered carbide	Includes existing restorations and caries; about 1.8 mm deep; small undercuts tolerated
				Proximal box	Tapered carbide	Gingival floor 1 mm wide
				Caries removal	Excavator or round bur	Clearance for impression: 0.6 mm
				Margins	Finishing burs	Block out undercuts with glass ionomer
				Occlusal clearance	Hand instruments	90-degree butt joint
				Finishing	Round-ended diamond Finishing burs Fine-grit diamonds	Heavy chamfer margin for onlays Clearance in all excursions of 1.5 mm Rounded internal angles Smooth margins

SUMMARY CHART

Porcelain Laminate Veneers

Indications	Contraindications	Advantages	Disadvantages	Preparation Steps	Recommended Armamentarium	Criteria
• Discolored or damaged anterior teeth	• Extensive caries • Poor plaque control • Extensive existing restorations • Bruxism	• Superior esthetics • Wear and stain resistant	• Increased tooth contour • Expensive	Depth cuts	1-mm round bur or 0.5-mm depth cutter	A series of depth cuts to determine dentin exposure
				Labial reduction	Round-ended diamond	Follows curvature of original tooth surface
				Proximal reduction	Round-ended diamond	Extended to gingival crest, leaving contact area intact
				Incisal and lingual reduction	Round-ended diamond	None unless incisal margin is extended to lingual to allow lengthening
				Margins	Round-ended diamond	Long chamfer margin
				Finishing	Fine-grit diamonds, carbides, or finishing stones	No sharp internal margins

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9

The Complete Crown Preparation

If metal is used, although esthetic factors can limit its application, the complete crown should always be considered for patients requiring restorations for badly damaged posterior teeth. The longevity of complete crowns is superior to that of all other fixed restorations. Such a crown can be used to restore a single tooth or as a retainer for a fixed dental prosthesis. As its name implies, it covers all axial walls and the occlusal surfaces of the tooth (Fig. 9.1). A complete crown can be made of metal, but increasingly, monolithic zirconia is used.

Preparation for any restoration requires that adequate tooth structure is removed to allow restoring the tooth to its original contours while ensuring sufficient thickness for the restorative material. Whenever possible, tooth structure should be preserved (see Chapter 7), but reduction must be adequate to enable the dentist to fabricate a crown of acceptable strength and optimal contours.

ADVANTAGES

Because all axial surfaces of the tooth are included in the preparation, the complete crown has greater retention than do more conservative restorations on the same tooth (e.g., a seven-eighths or three-quarter crown [see Fig. 7.35]).

Normally, a complete crown preparation has a greater resistance form than does a partial-coverage restoration on the same tooth. If the axial walls of a complete crown have been prepared with reasonable axial wall height and the proper convergence, a significant amount of tooth structure must fail before the crown can be displaced.

In comparison, for a partial veneer crown to rotate off a tooth, only the tooth structure immediately lingual to the occlusal portion of the proximal groove or box needs to fail (see Fig. 7.41). Complete crown strength is superior to that of other restorations. Its cylindrical configuration encircles the tooth and is reinforced by a corrugated occlusal surface. Just as an O-shaped link in a chain resists deformation better than a C-shaped link, this restoration is less easily deformed than its partial-veneer counterpart, which is more conservative of tooth structure.

A complete crown allows the operator, within reason, to modify axial tooth contour. This can be helpful with malaligned teeth, although the extent of possible recontouring is limited by periodontal considerations. Similarly, it is possible to allow improved access for oral hygiene for teeth with furcal involvement through alteration of buccal and lingual wall contours. This is sometimes referred to as *fluting*

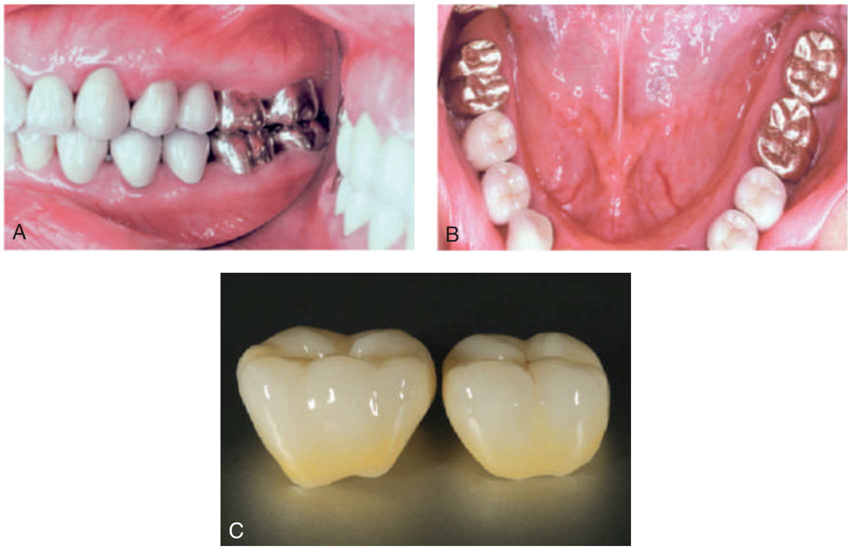


Fig. 9.1 (A and B) Complete cast crowns used to restore molar teeth subject to high loads. The canines and premolars, which are more visible and loaded to a lesser extent because of their more anterior arch position, have been restored with metal-ceramic crowns. (C) Anatomic zirconia crowns.

or *barreling* (Fig. 9.2). When special requirements exist for axial contours—such as when retainers are needed for partially removable dental prostheses in which locations for the heights of the contour are very specific—a complete crown is often the only restoration that allows achieving properly shaped survey lines, guide planes, and occlusal rests in the restored tooth (Fig. 9.3) (see Chapter 21).

Complete crowns facilitate modification of the occlusion, which can prove challenging when a more conservative restoration is made. This is especially important when teeth are supraerupted or when the occlusal plane needs to be reestablished.

DISADVANTAGES

Preparation for complete crowns involves all coronal surfaces. Thus, removal of tooth structure is extensive and can have adverse effects on the pulp and periodontium. Because of the proximity of the margin to the gingiva, inflammation of gingival tissues is not uncommon (although a properly adapted complete crown with good axial contour should minimize this).

When metal is used, the appearance may be objectionable, and in patients with a normal smile line, metal restorations may be restricted to molars. Zirconia complete crowns provide a suitable esthetic alternative.

Fig. 9.2 Fluting of buccal walls of maxillary and mandibular first molars to enable better access to the furcations for plaque control to improve the long-term prognosis of the restorations.

INDICATIONS

The complete crown is indicated on heavily restored teeth that have extensive coronal destruction by caries or trauma. It is the restoration of choice whenever maximum retention and resistance are needed: for instance, in posterior, high-load locations that are not readily visible. To further enhance its prognosis, grooves should be included to further increase resistance form on short clinical crowns or when high displacement forces are anticipated (such as for a retainer of a long-span fixed dental prosthesis).

This restoration is indicated when correction of axial contours is sought but is not achievable with a more conservative technique. Similarly, complete crowns can support a partial removable dental prosthesis. It is occasionally possible to use a partial-coverage restoration, but obtaining the necessary contours is more difficult. Although proximal guide planes can sometimes be prepared through simple enamel modification, obtaining properly oriented reciprocal guide planes and survey contours through enameloplasty is often impractical. The minimum dimensions required for occlusal rests of a partial removable dental prosthetic framework necessitate removing significant amounts of enamel and, if the dentin is exposed, restoring the tooth with a crown.[a]

Complete crowns are indicated on endodontically treated posterior teeth. The superior strength of complete crowns compensates for the loss of tooth structure that results from previous restorations, carious lesions, and endodontic access.

CONTRAINDICATIONS

The complete crown is contraindicated if treatment objectives can be met with a more conservative restoration. For wherever the buccal or lingual wall is intact, the use of a partial-coverage restoration should be considered. If less than maximum retention and resistance are needed (e.g., on a short-span fixed dental prosthesis), a preparation more conservative of tooth structure is indicated. Similarly, if a removable partial denture is planned and an adequate buccal contour exists or can be obtained through enamel modification (enameloplasty), a complete crown is not warranted. If the esthetic need is high (e.g., for anterior teeth or

[a]On mandibular premolars, a rest can sometimes be placed on top of the modified occlusal surface without interfering with the occlusion or articulation.

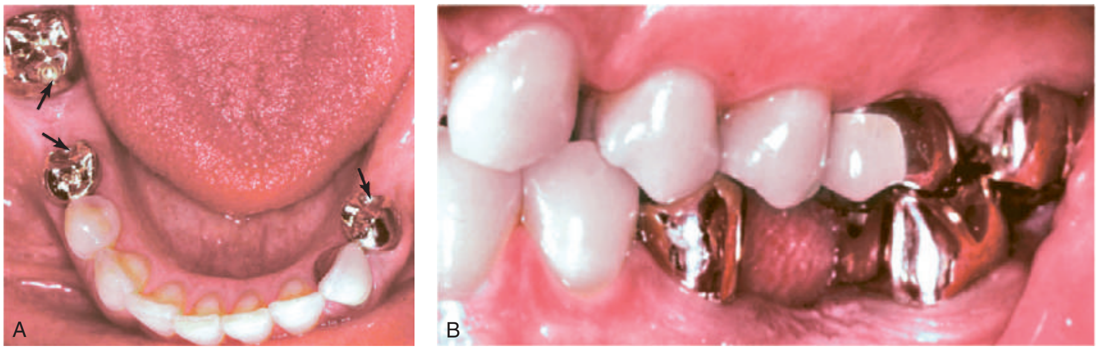


Fig. 9.3 Complete cast crowns used as retainers to accommodate a mandibular partial removable dental prosthesis. Metal-ceramic crowns have been placed on the left mandibular canine (A) and the maxillary first molar (B). Note the occlusal rests (A, *arrows*) and the survey contours (B), which extend to form reciprocating guide planes. (See Chapter 21.)

for posterior teeth in the esthetic zone), a complete metal crown is also contraindicated, although a high-strength zirconia crown with a similar preparation design can normally be substituted.

CRITERIA

The occlusal reduction must allow adequate room for the restorative material from which the crown is to be fabricated. Therefore, the material that is selected to fabricate the restoration has a direct effect on the minimal amount of tooth structure that must be removed. Typically, type III or IV gold casting alloy or its low-gold content equivalent is used for complete cast crown fabrication. Anatomic-contour zirconia crowns (see Chapter 25) offer an esthetic alternative to cast metal crowns. The preparation design for anatomic-contour zirconia is similar to that for cast metal, although additional occlusal clearance, the removal of discolored tooth structure, and foundation restorations are usually required. The difference between occlusal clearance and reduction should be noted: *Clearance* is the amount of space between the completed preparation and the opposing tooth; *reduction* is the amount of tooth structure that is removed to establish the desired clearance (see Chapter 7).

The minimum recommended clearance is 1 mm on nonfunctional (noncentric) cusps and 1.5 mm on functional (centric) cusps. The occlusal reduction should generally follow normal anatomic contours to be as conservative of tooth structure as possible. Axial reduction should parallel the long axis of the tooth but allow for the recommended 6-degree taper or total angle of convergence, which is the angle measured between opposing axial surfaces.

The preparation margin should have a chamfer configuration, and its ideal location is supragingival. The chamfer margin should be smooth and distinct and allow for approximately 0.5 mm of metal thickness at the margin. It is typically an exact replica of half the rotary instrument that was used to prepare it. (The recommended dimensions for reduction are shown in Fig. 9.4.)

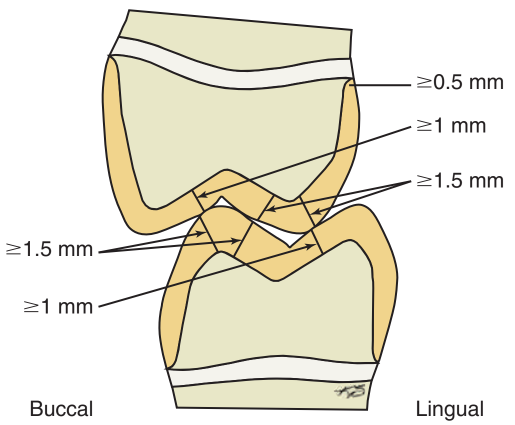


Fig. 9.4 Recommended minimal dimensions for a complete crown. On functional cusps (buccal mandibular and lingual maxillary), occlusal clearance should be 1.5 mm or greater. On nonfunctional cusps, the clearance should be at least 1 mm. The chamfer margin should allow for approximately 0.5 mm of metal thickness at the margin. Note that the buccal wall of the maxillary molar is prepared in two planes.

Special Considerations

Functional (Centric) Cusp Bevel

Reasonably uniform tooth reduction results in a preparation that somewhat mimics the form of the original clinical crown (see Fig. 7.46).

Proper placement of a *functional cusp bevel* achieves this. Because additional reduction is needed for the functional cusps (to provide a minimum of 1.5 mm of occlusal clearance), the functional cusp bevel must be angled flatter than the external surface of the original tooth (Fig. 9.5). On most posterior teeth, the functional cusp bevel is placed at an angle of approximately 45 degrees to the long axis of the prepared tooth.

Nonfunctional (Noncentric) Cusp Bevel

Complete crown preparations should be assessed for adequate reduction at the occlusoaxial line angles of the nonfunctional cusps. In this location, the metal thickness must be at least 0.6 mm for adequate strength. Maxillary molars, in particular, often require additional reduction in this area (Fig. 9.6). Typically, the occlusal half of the buccal wall is reduced to be parallel to the original buccal contour of the original tooth. Without such two-plane buccal reduction, the result can be

Fig. 9.5 The functional cusp bevel is prepared by slanting the rotary instrument at a flatter angle *(dashed line)* than the cuspal angulation. This ensures the necessary clearance over the functional cusp.

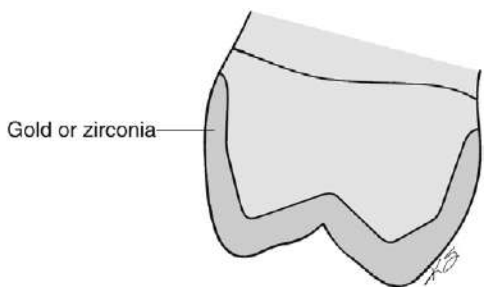


Fig. 9.6 The configuration of the facial wall of the maxillary molars may necessitate a slight additional reduction in the occlusal half to prevent overcontouring of the restoration. This reduction is referred to as a *second plane reduction*. When the tooth is prepared for an anatomic-contour zirconia crown, make sure all the line angles are rounded as sharp internal angles cannot be formed by the milling equipment.

either a restoration that is too thin or, more likely, an overcontoured restoration that does not follow normal anatomic form. Such additional reduction is often unnecessary for mandibular molars, however, because their relatively straight or slightly lingually inclined profile allows for the fabrication of restoration that has good anatomic form and meets minimal material thickness requirements.

Chamfer Margin Width

Adequate chamfer margin width (minimum, 0.5 mm) is important for developing optimum axial contour. Insufficient chamfer margin width forces the dental technician to overcontour the restoration. Such increased faciolingual width of a complete crown is a common error in practice and a leading cause of periodontal disease in association with restorations. On small teeth (e.g., premolars), however, it may be advantageous to prepare a slightly more conservative chamfer margin to preserve tooth structure. This requires increasingly careful manipulation of the wax pattern during fabrication of the restoration and careful assessment at clinical evaluation (see Chapter 29) to ensure that the crown is not overcontoured.

PREPARATION

In addition to the armamentarium (Fig. 9.7 and Table 9.1), the clinical tooth preparation for a complete crown consists of the following steps:

- Occlusal depth grooves
- Occlusal reduction and functional cusp bevel
- Axial alignment grooves
- Axial reduction
- Finishing and evaluation

Step-by-Step Procedure

In this chapter, the tooth preparation steps are described for a mandibular second molar in good alignment. Depending on the tooth to be prepared (e.g., a maxillary molar), the step may vary. Similarly, if a tooth is tipped, the actual depth of these depth grooves will vary from what is described. The recommended sequence remains otherwise identical, however.

Guiding Grooves for Occlusal Reduction

Once the desired reduction depth has been determined, a tapered tungsten carbide or a narrow tapered or small round-ended diamond is recommended for placing the depth grooves for occlusal reduction. Depth grooves are helpful in guiding occlusal reduction only if the tooth is in a good occlusal relationship before preparation. Depth grooves can be placed when a foundation restoration has been placed during the mouth preparation phase of the treatment (see Chapter 6). When this is not practical (e.g., for correcting occlusal discrepancies such as supraeruptions or for replacing an existing crown), a reduction guide can be made from a diagnostic waxing procedure [see Figs. 2.41 and 7.62], which can be used during the tooth preparation to evaluate whether optimal reduction has been achieved.)

1. Place depth holes approximately 1 mm deep in the central, mesial, and distal fossae, and connect them so that a channel runs the length of the central groove and extends into the mesial and distal marginal ridge.
2. Place depth grooves in the buccal and lingual developmental grooves and in each triangular ridge; they should extend approximately from the cusp tip to the center of its base (Figs. 9.8 and 9.9).

TABLE 9.1 Armamentarium for a Complete Cast Crown

Instrument	Use
Tapered tungsten carbide bur or diamond	Occlusal guiding grooves Additional retentive features
Round-ended diamond	Occlusal guiding grooves
Narrow, round-ended, tapered diamond (regular grit) (0.8 mm)	Occlusal reduction Axial alignment grooves Axial reduction Chamfer margin preparation
Wide, round-ended, tapered diamond (fine grit) (1.2 mm)	Finishing
Utility wax and wax caliper Occlusal reduction gauge	Verification of occlusal clearance
High- and low-speed friction grip contra-angle handpieces	

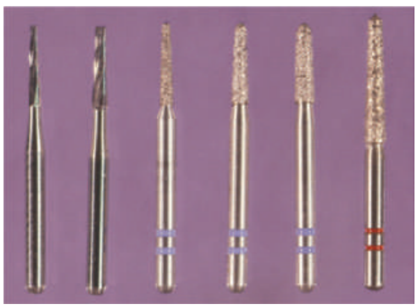


Fig. 9.7 Armamentarium for the complete crown preparation.

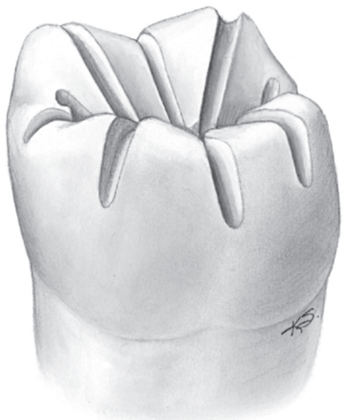


Fig. 9.8 Guiding grooves are placed on the occlusal surface. They are deeper on the functional cusp and for the functional cusp bevel. They diminish in depth from the cusp tip to the cervical margin.

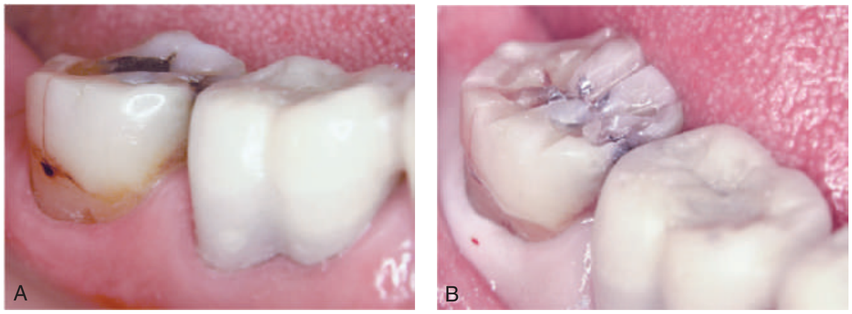


Fig. 9.9 (A) A complete cast crown is indicated on this mandibular second molar with occlusal, proximal, and cervical lesions, as well as a buccal longitudinal fracture. (B) Initial depth grooves placed for occlusal reduction. Note that they have not yet been extended onto the buccal surface, where the functional cusp bevel will be placed.

3. To ensure that the centric or functional cusp will be protected by an adequate thickness of metal, place depth grooves for the functional cusp bevel in the area of occlusal contact with the opposing tooth. The depth of these grooves should be slightly less than 1.5 mm (to allow for smoothing) in the area of the centric stop and should gradually diminish in a cervical direction.
4. Use the depth grooves to ensure that occlusal reduction generally follows anatomic configuration and thus minimizes the loss of tooth structure while ensuring adequate clearance, as dictated by the mechanical properties of the alloy from which the restoration will be fabricated. Depth grooves must be placed with accuracy; the practitioner should concentrate on the position, depth, and angulation of each groove. Mesiodistally, a groove should be placed in the low point and high point of each cusp. The low points are the central and developmental grooves; the high points are the cusp tips and triangular ridges. To achieve correct depth—0.8 mm for the central groove and nonfunctional cusps and 1.3 mm for the functional cusps (allowing approximately 0.2 mm for preparation finishing and smoothing)—the clinician must know the dimensions of the instruments being used. Memorizing the diameters of the rotary instruments allows the practitioner to properly assess the adequacy of the reduction during preparation. If necessary, a periodontal probe can be used to measure the extent of the reduction. Correct groove angulation is necessary to ensure that the occlusal reduction will allow appropriate crown form and thickness. On the nonfunctional cusp, depth grooves parallel the intended cuspal inclination; on the functional cusp, they should be angled slightly flatter to ensure additional clearance that must be achieved on the functional cusp.

Occlusal Reduction

Once the depth grooves have been deemed satisfactory, the remaining tooth structure between the grooves is removed with the tungsten carbide or the narrow, round-ended, tapered diamond. Proper placement of the grooves automatically results in adequate occlusal clearance.

5. Complete the occlusal reduction in two stages (Fig. 9.10). Half the occlusal surface is reduced first so that the other half can be maintained as a reference. When the necessary reduction of the first half has been accomplished, reduction of the remaining half can be completed (Fig. 9.11).
6. On completion, verify that a minimum clearance of 1.5 mm has been established on functional cusps and one of at least 1.0 mm on nonfunctional cusps in the occluded position. These clearances must also be verified in all excursive movements that the patient can make. If any uncertainty remains, as is often the case in evaluations of clearance on the lingual aspect of a tooth preparation, the patient should be asked to close into several layers of dark-colored utility wax in maximum intercuspation (Fig. 9.12A).
7. Remove the wax from the mouth and evaluate it for thin spots, which can be measured with wax calipers (see Fig. 9.12B). Alternatively, the thickness of the wax can be measured intraorally before removal with a periodontal probe.
8. Place the wax back in the patient's mouth and ask the patient to close. Guide the patient's mandible into protrusive and excursive positions. On removal, the thickness of the utility

Half of the occlusal reduction is performed; the other half is maintained for reference purposes.

Fig. 9.10 After the guiding grooves are placed, the occlusal reduction is performed. Either the mesial or the distal half is maintained initially as a reference to facilitate the evaluation of the adequacy of the reduction.

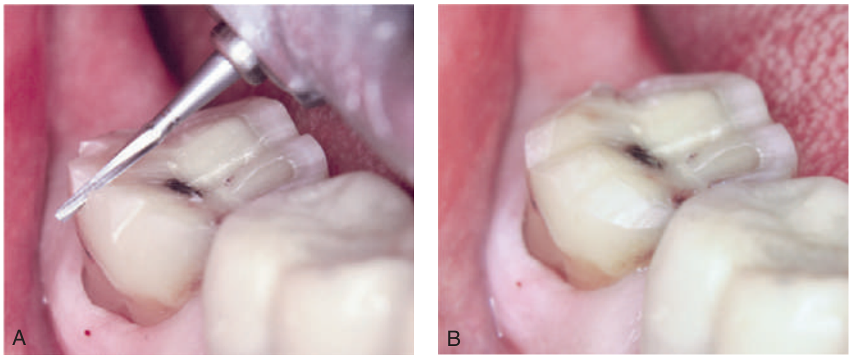


Fig. 9.11 (A) Note the angulation of the bur as the functional cusp bevel is placed, angled slightly flatter than the original cusp angle to provide more clearance for the centric cusp than for the axial wall. (B) Completed occlusal reduction. Note that it follows normal occlusal form. Three distinct slopes can be seen buccolingually.

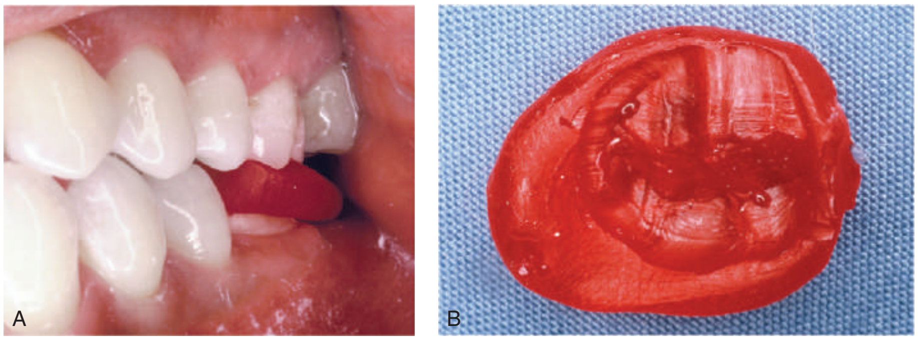


Fig. 9.12 Evaluation of the adequacy of occlusal clearance. (A) The patient closes the teeth into softened wax. (B) After the wax has been removed from the mouth, its thickness is assessed visually and measured with wax calipers.

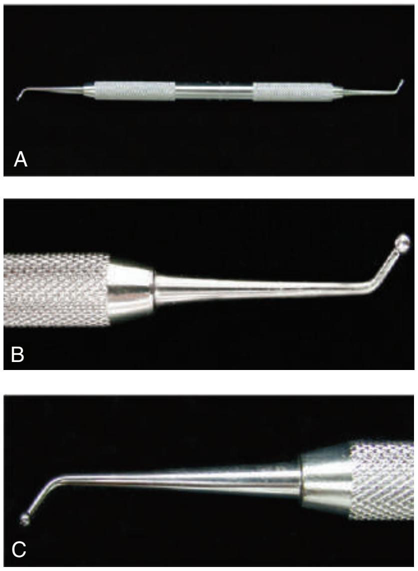


Fig. 9.13 Occlusal clearance can be judged intraorally with a reduction gauge. This instrument (A) has two spherical tips: one that is 1.5 mm in diameter (B) and one that is 1.0 mm in diameter (C).

wax is again evaluated, this time to verify that adequate clearance exists throughout the dynamic range, as was previously verified in maximum intercuspation. A convenient alternative method is to use an occlusal reduction gauge (Hu-Friedy Mfg. Co.) (Fig. 9.13).

Alignment Grooves for Axial Reduction

Once the occlusal reduction has been completed, alignment grooves are placed in each buccal and lingual wall with a narrow, round-ended, tapered diamond. On molars, one alignment groove may be placed in the center of the wall and one in each mesial and distal transitional line angle (Fig. 9.14).

1. As these alignment grooves are placed, verify that the shank of the diamond is parallel to the proposed path of placement for the restoration. Such positioning automatically produces a convergence between the axial walls of the alignment grooves that is identical to the taper of the diamond. If a diamond with a 6-degree taper is used, the identical 6-degree axial convergence will result on the preparation wall.
2. The diamond tip should not cut into the tooth beyond its midpoint; otherwise, a "lip" of tooth enamel will be unsupported (see Fig. 7.24). Gingivally, the depth of the alignment grooves should therefore be no more than half the width of the tip of the diamond. Occlusocervically, the position of the tip of the diamond rotary instrument determines the location of the margin (Fig. 9.15).
3. Note that the alignment grooves determine the path of placement for the restoration. They should be placed parallel to the proposed path of placement, which is typically the long axis of the tooth.
4. Use a periodontal probe to assess the relative parallelism of the alignment grooves with one another and with the proposed path of placement of a secondary retainer if the

prepared tooth is to serve as an abutment for a fixed dental prosthesis. When the correct placement of alignment grooves is uncertain (as is likely on abutments for long-span fixed dental prostheses), an impression made with irreversible hydrocolloid alginate (see Chapter 2) is especially helpful. This can be poured in rapid-setting stone, and the resulting cast can be analyzed with a dental surveyor (see Fig. 7.63). The same cast can be used to fabricate the interim restoration (see Chapter 15). At this time, corrections may still be made in a straightforward manner before irreversible, unnecessary tooth reduction has occurred. Alternatively, an assessment can be done after intraoral scanning.

Axial Reduction

The technique for axial reduction is similar to that for occlusal reduction. The residual islands of tooth structure between the alignment grooves are removed; concurrently, the chamfer margin is created, and the same narrow, round-ended diamond is used for the procedure (Figs. 9.16 and 9.17).

5. Like the occlusal reduction, the axial reduction may be performed for half the tooth at a time, while the other half is maintained as a reference to simplify assessing the adequacy of the reduction.
6. When breaking interproximal contact, pay special attention to prevent unintentional damage to the adjacent teeth. This often results if the practitioner attempts to force the diamond into the proximal aspect too rapidly. Sufficient time must be allowed for the cutting instrument to create space for its passage (Fig. 9.18). Typically, if the proper cervical placement of the margin has been selected with the correct axial alignment of the instrument, a "lip" of tooth enamel is maintained between the diamond and the adjacent tooth, protecting the latter from iatrogenic damage (Fig. 9.19).
7. If desired, protect the adjacent teeth by placing a metal matrix band. The interproximal areas most difficult to reduce are those with significant buccolingual dimension and on teeth with root proximity. However, the challenging area is typically only a few millimeters in length.

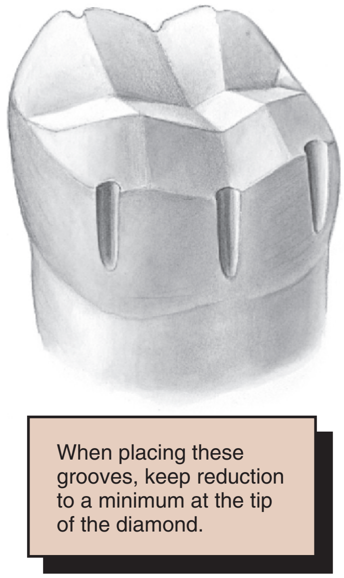


Fig. 9.14 Alignment grooves for axial reduction are placed in the buccal and lingual surfaces parallel to the long axis of the tooth buccolingually and mesiodistally. Note that they are deep occlusally but shallower toward the cervical margin.

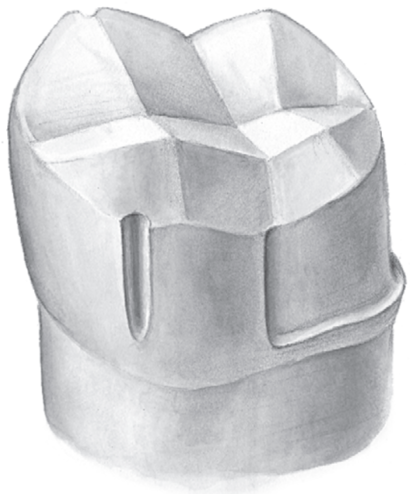


Fig. 9.16 If an axial reduction is completed first on either the distal or the mesial half of the tooth, evaluation is simplified because the remaining intact half of the tooth can serve as a reference.

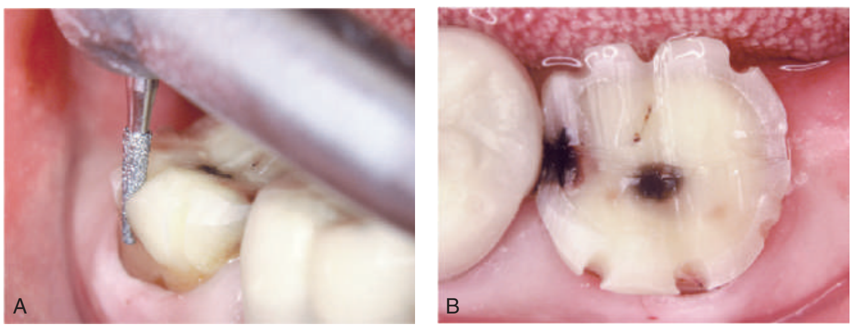


Fig. 9.15 (A) The diamond is aligned parallel to the long axis of the tooth as the buccal guiding grooves for axial alignment are placed. (B) All six grooves have been placed.

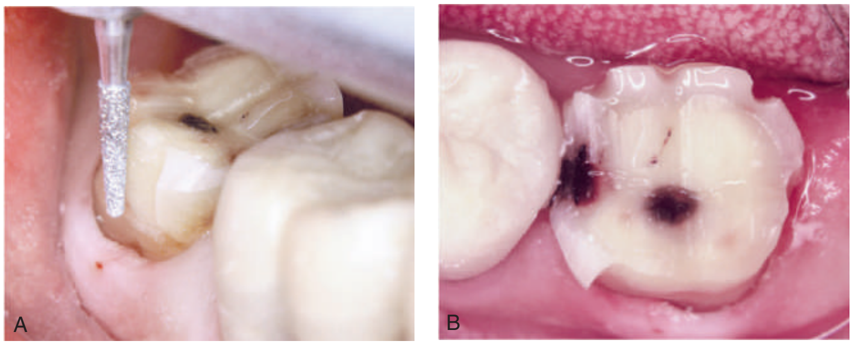


Fig. 9.17 (A) Note the alignment of the diamond as tooth structure between the alignment grooves is removed. (B) Axial reduction. The distobuccal axial reduction has been completed.

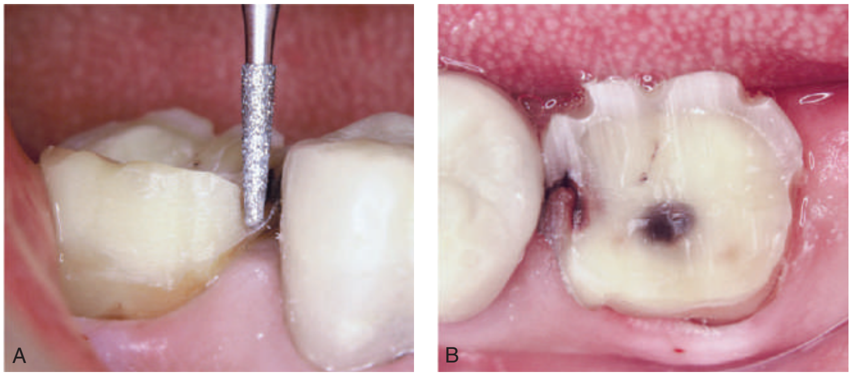
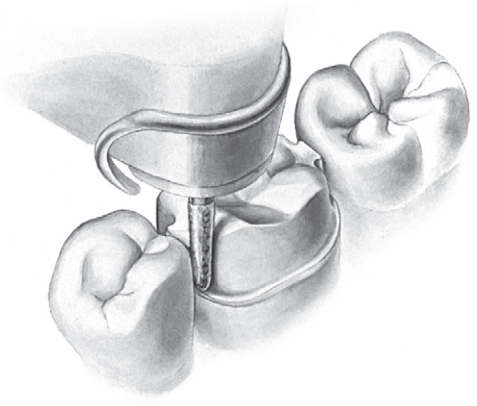


Fig. 9.18 (A) As the mesiobuccal axial surface is reduced, a cervical chamfer margin is placed. (B) The chamfer margin should be of relatively even width and maintain the somewhat rectangular preparation outline form to enhance resistance form.

Fig. 9.19 A "lip" of enamel *(arrow)* protects the adjacent tooth from iatrogenic damage as the axial reduction is completed.

8. Cut into the proximal area from both sides until only a few millimeters of interproximal island remain (Fig. 9.20). If necessary, this area can then be removed (and proximal contact broken) by using thinner, tapered diamonds. If the adjacent proximal surface is accidentally damaged, it must be polished with white stones, silicone points, and prophylaxis paste before impression making. Ideally, a fluoride application is given to improve caries resistance and to prevent demineralization of the surface enamel.
9. Place the cervical chamfer margin concurrently with axial reduction. The finished chamfer margin width should be approximately 0.5 mm, which allows for adequate bulk of metal at the margin. The chamfer margin must be smooth and continuous mesiodistally, and a distinct resistance against vertical displacement should be detected when the margin is probed with the tip of an explorer. The chamfer margin must be at least 0.6 mm from the proximal surface of the adjacent tooth (Fig. 9.21); more distance will simplify



As the axial reduction is performed, eventually a small island of tooth structure will remain in the interproximal area. When removing this, maintain a narrow "lip" of tooth structure between the diamond and the adjacent tooth to protect the latter from damage.

Fig. 9.20 Breaking proximal contact.

subsequent technique steps. Unsupported enamel cannot be tolerated on the chamfer margin because it is likely to fracture when the restoration is evaluated or cemented, which, if undetected, will result in an open margin and premature restoration failure.

Finishing

A smooth surface finish and continuity of all prepared surfaces aid most phases of fabrication of the restoration. Smooth transitions blend occlusal and axial surfaces. This facilitates many subsequent laboratory steps such as impression making, waxing, investing, and casting because the risk of bubble formation is reduced (Fig. 9.22). A smooth surface finish and blending of occlusal and axial surfaces are especially important for anatomic-contour zirconia crowns. These are milled in a computer-controlled unit (see Chapter 25), and the milling tools cannot accurately shape sharp internal angles.

1. Use a fine-grit diamond or tungsten carbide rotary instrument of slightly greater diameter to finish the chamfer margin. This should be done as smoothly as possible, with a high-speed handpiece operating at reduced speed (see Summary Chart). Some clinicians favor using a low-speed

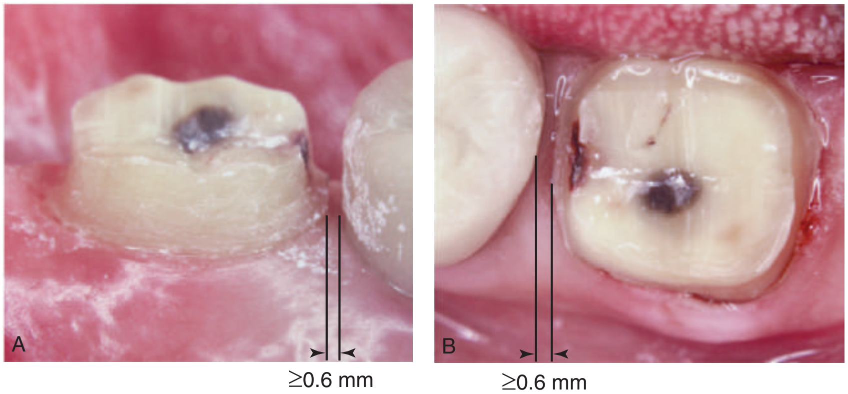


Fig. 9.21 (A) Note that adequate clearance (≥0.6 mm) exists between the external surface of the proximal chamfer margin and the adjacent tooth. (B) Occlusal view of the preparation.

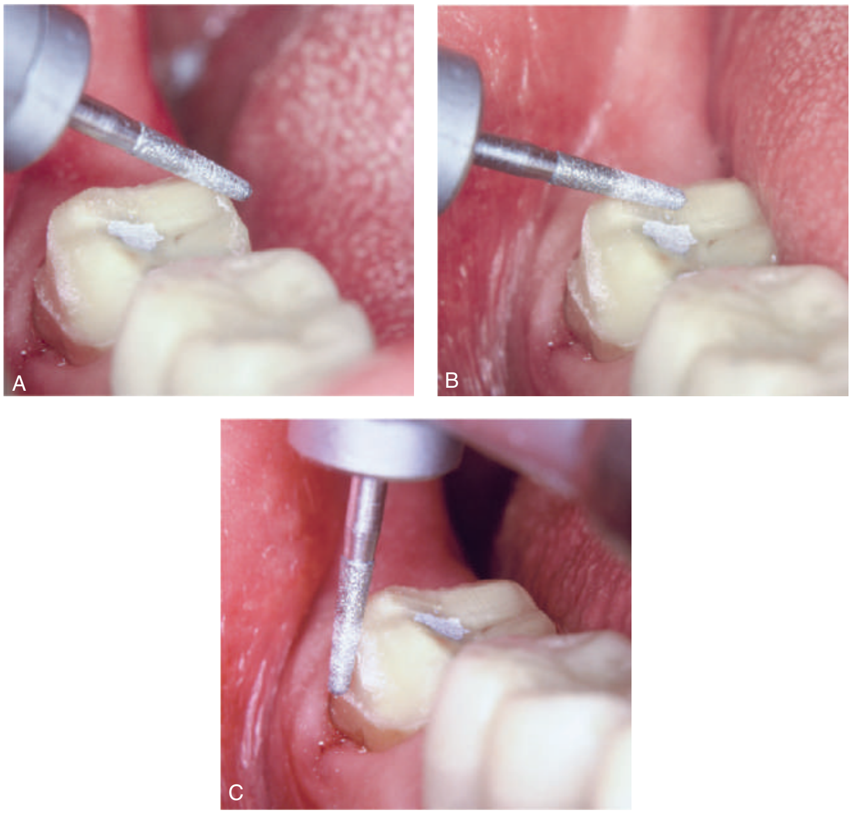


Fig. 9.22 (A) The transition from lingual to occlusal surfaces is rounded with a fine-grit diamond. (B) All sharp line angles between occlusal reduction and functional cusp bevel are similarly rounded. (C) The margin is refined, and any remaining irregularities are removed.

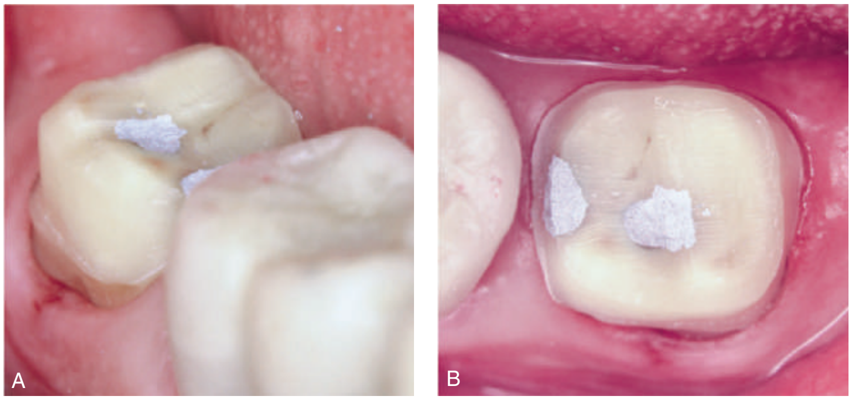


Fig. 9.23 Completed preparation. The carious lesions have been excavated, and the resulting irregularities have been restored with amalgam. If an anatomic contour zirconia crown is to be used, the foundation restorations should be tooth-colored to prevent affecting the esthetics of the restoration. (A) Buccal appearance. (B) Occlusal appearance.

contra-angle handpiece for the finishing steps. A properly finished margin should be smooth as glass, as verified with a touch by the tip of an explorer.

2. Finish all prepared surfaces and slightly round all line angles. During margin finishing, the use of air cooling alone is recommended to improve visibility. However, when only air cooling is used, a water spray should be applied from time to time to prevent the tooth from dehydrating, to avoid the possible development of pulpal damage, and to wash away debris. The larger diamond is recommended because it will eliminate any unwanted ripples that were created during axial reduction while any unsupported enamel at the margin was eliminated (Fig. 9.23).
3. Place additional retentive features as needed (e.g., grooves or boxes) with the tapered tungsten carbide bur and the slow-speed handpiece (Fig. 9.24).

The criteria used to determine the need for such features to enhance retention and resistance are described in Chapter 7.

Evaluation

Upon completion, the preparation is evaluated to verify that all the criteria have been met (Fig. 9.25). The following sequence is recommended:

1. Verify that adequate occlusal clearance has been achieved.
2. View the preparation from the buccal and lingual aspects to verify that an appropriate mesiodistal taper exists. It is helpful to view from both directions to reduce the chance of missing a possible undercut.
3. View the preparation from the mesial aspect: This allows evaluation of the buccolingual path of placement. Depending on the original alignment of the tooth, the lingual wall should be perpendicular to the occlusal plane or have a slight lingual inclination. Evaluate the buccolingual angle of convergence next, followed by the angulation of the functional cusp bevel. Lastly, in this mesial view, evaluate that the occlusal reduction is adequate next to the marginal ridges of the adjacent teeth.
4. View the preparation from the occlusal aspect to evaluate that concentricity has been achieved between the outline form of the cervical and occlusal aspects of the axial walls (see Figs. 7.30 and 7.31). If more vertical wall is visible on one side of the preparation, the preparation is probably over-tapered. Conversely, if it is impossible to see part of the axial wall in the occlusal view, an undercut may be present.

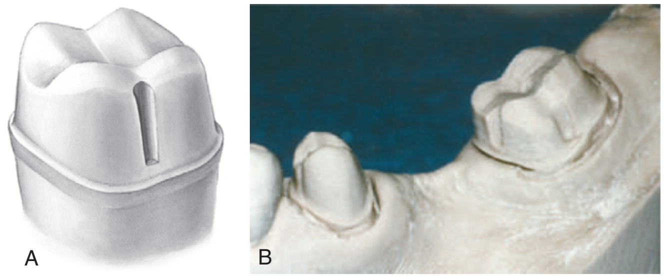


Fig. 9.24 (A) When opposing axial walls are excessively tapered, internal features such as this buccal groove can be used to improve resistance form. (B) Mesially tipped molars and short premolars often benefit from grooves or boxes, or both, incorporated in the preparation design.

Fig. 9.25 The completed preparation is characterized by a smooth, even chamfer margin; a 6-degree taper; and gradual transitions between all prepared surfaces.

A common error in complete crown preparations is over-tapering of the opposing axial walls. This significantly reduces retention and resistance of the completed restoration. If a tooth preparation has been inadvertently overreduced through excessive tapering of axial walls, it should be carefully evaluated to determine how it can be corrected. If a band of several millimeters of tooth structure can be prepared circumferentially with a restricted taper of approximately 6 degrees, it is probably unnecessary to modify the preparation further to compensate for areas of excessive reduction in the occlusal third. If this is not the case, an approach slightly less conservative of tooth structure may be warranted: (1) uprighting overtapered axial walls to obtain the mechanical advantage of increased retention or (2) using grooves, boxes, or pinholes as needed.

No undercuts between any opposing axial walls are acceptable. When the diamond is placed against the axial surface of the prepared tooth, parallel to the path of placement, it should be possible to move the instrument around the tooth so that the entire height of the preparation is touching the diamond at all times. The tip of the diamond should rest on the chamfer margin throughout this movement, and no light should be visible between the instrument and the axial surface.

5. Evaluate margin width, smoothness, and continuity. An explorer moved circumferentially along a properly finished chamfer margin should not encounter any bumps or irregularities, whereas when it is pushed in an apical direction, distinct resistance to vertical displacement of the instrument should be felt. The margin must be placed sufficiently apically to result in adequate proximal clearance (see Fig. 9.21). It may be necessary to extend the preparation farther apically to achieve the minimally required clearance from the adjacent proximal walls.

Any noted deficiencies must be corrected before fabrication of the interim restoration (Fig. 9.26) and the definitive impression. On occasion, it can prove helpful to evaluate the thickness of a properly contoured interim restoration with a thickness gauge to verify that reduction was indeed adequate in the completed preparation.

SUMMARY

The complete crown, an entirely metal or high-strength ceramic restoration often used on a single posterior tooth or as a retainer for a fixed dental prosthesis, provides greater strength, retention, and resistance than any other type of restoration. It is not indicated for every restorative circumstance, however. It is unnecessary if the buccal or lingual walls of a tooth are intact or if less than maximum retention is needed. The rather extensive removal of tooth structure required in its preparation can have adverse pulpal and periodontal effects. The high strength of the complete crown makes it especially suitable for restoring second molars and endodontically treated posterior teeth, although in patients who find visible metal a significant drawback, the metal-ceramic or a more conservative partial-coverage restoration may be preferred.

A well-organized approach to preparation for a complete crown should be based on the selective use of depth and alignment grooves of predetermined dimensions correlated with specific properties of the selected restorative material. Adequate occlusal reduction is necessary, in accordance with normal anatomic tooth form, and axial reduction should also conform to the normal configuration of the tooth, with minimum taper (6 degrees). Under no circumstances should undercuts remain in the proximal walls. These must be removed by additional tooth preparation or blocked out with a suitable material. The chamfer margin is the margin of choice for a complete crown. It must be distinct and of adequate width. No enamel should be left unsupported. Occlusocervically, the margin ideally should be supragingival, and it should be smooth and continuous circumferentially. When the dentist assesses the adequacy of the chamfer margin, an explorer or a periodontal probe should encounter distinct resistance against vertical displacement.

Fig. 9.26 (A) Acrylic resin interim restoration is cemented. (B and C) Complete cast crown is cemented.

STUDY QUESTIONS

1. What are the indications for and contraindications to complete crowns?
2. What are the advantages and disadvantages of complete crowns?
3. What is the recommended armamentarium, and in what sequence should a mandibular molar be prepared for a complete crown?
4. What are the minimum criteria for each step described in question 3?

SUMMARY CHART

Complete Crown

Indications	Contraindications	Advantages	Disadvantages	Preparation Steps	Recommended Armamentarium	Criteria
• Extensive destruction from caries or trauma • Endodontically treated teeth • Existing restoration • Necessity for maximum retention and strength • To provide contours to receive a removable appliance • Other recontouring of axial surfaces (minor corrections of malinclinations) • Correction of occlusal plane	• No need for maximum retention • Esthetics if metal used	• Strong • High retentive qualities • Usually easy to obtain adequate resistance form • Option to modify form and occlusion • Acceptable esthetics if zirconia used	• Removal of large amount of tooth structure • Adverse effects on tissue • Vitality testing not readily feasible • Display if metal used	Depth grooves for occlusal reduction	Tapered tungsten carbide or diamond	Minimum clearance on noncentric cusps: 1 mm
				Functional cusp bevel	Tapered tungsten carbide or diamond	Minimum clearance on centric cusps: 1.5 mm
				Occlusal reduction (half at a time)	Regular-grit, round-ended diamond	Flatter than cuspal plane, to allow additional reduction at functional cusp
				Alignment grooves for axial reduction	Tapered diamond	Following normal anatomic configuration of occlusal surface
				Axial reduction (half at a time)	Tapered diamond	Chamfer margin allows 0.5 mm of thickness of wax at margins
				Finishing of chamfer margin	Tapered diamond	Reduction performed parallel to long axis
				Additional retentive features if needed	Wide, round-ended diamond or tungsten carbide	Smooth mesiodistally and buccolingually; resistance to vertical displacement by tip of explorer or periodontal probe
				Finishing	Tapered tungsten carbide; fine-grit diamond or finishing tungsten carbide	Grooves, boxes, and pinholes as described for partial-coverage restorations Rounding of all sharp line angles to facilitate impression making, die pouring, waxing, and casting

The Ceramic-Veneered Crown Preparation

In many dental practices, the metal-ceramic crown remains one of the most widely used fixed restorations. This restoration offers a predictable esthetic result, coupled with sound physical properties. Metal-ceramic crowns consist of a complete-coverage metal crown (or substructure) that is veneered with a layer of fused porcelain to mimic the appearance of a natural tooth. The extent of the veneer can vary. In recent years, ceramic materials such as zirconia reinforced lithium silicate and sintered zirconia have gained in popularity over metal cast substructures (see Chapters 19 and 25). However, the use of metal may be advantageous when fabricating a fixed partial denture (FPD), since ceramic FPDs require larger connectors than needed when metal is used, lest connector fracture occurs.

In comparison with the tooth preparation for cast or monolithic zirconia crowns, successful veneered crown preparations require substantial additional tooth reduction wherever the substructure is to be veneered with dental porcelain. Only when a crown is sufficiently thick can the veneer duplicate the appearance of a natural tooth, and if metal is used, can its darker color be masked. The porcelain veneer must have a certain minimum thickness for esthetics. Consequently substantial tooth reduction is necessary, and the ceramic veneered preparation is one of the methods least conservative of tooth structure (Fig. 10.1).

Historically, attempts to veneer metal restorations with porcelain faced several problems. A major challenge was the development of an alloy and a ceramic veneering material with physical properties sufficiently compatible to provide adequate bond strength. In addition, it was initially difficult to obtain a natural appearance.

The technical aspects of the fabrication of metal substructures and their subsequent veneering are discussed in detail in Chapters 19 and 24 and the fabrication of zirconia-based restorations in Chapter 25. Here, only a brief summary is provided: The metal substructure is fabricated in a special alloy that has a higher fusing range and a lower thermal expansion than do conventional gold alloys. After preparatory finishing procedures, this substructure, or framework, is veneered with multiple layers of dental porcelain. The porcelain is fused onto the framework in much the same manner as household articles are enameled. Modern dental porcelains fuse at a temperature of about 960°C (1760°F). Because conventional gold alloys would melt at this temperature, the special alloys are necessary. Similarly, the sintering temperature of zirconia is significantly higher than the fusing temperature of the feldspathic veneering porcelains. As for metal, this enables their use for substructure fabrication. However, since zirconia does not possess the outstanding translucency that can be achieved with feldspathic porcelain, the latter permits the fabrication of restorations that combine the strength of a strong substructure with the excellent esthetics of the more lifelike veneer.

INDICATIONS

Ceramic-veneered crowns are indicated on teeth that require complete coverage and for which esthetic demands are significant (e.g., the anterior teeth). If esthetic considerations are a priority, however, a ceramic crown (see Chapters 11 and 25) has cosmetic advantages over the metal-ceramic restoration. However, the metal-ceramic crown may be a better choice to serve as a retainer for FPDs because its metal substructure can accommodate cast or soldered connectors. Particularly for long-span FPDs, metal-ceramic crowns offer a more predictable prognosis than what can be achieved with ceramic prostheses, which are generally not efficacious for long spans. Also, ceramic restorations cannot as predictably accommodate occlusal rests for a removable prosthesis. Metal-ceramic crowns may successfully be modified to incorporate occlusal and cingulum rests and milled proximal and reciprocal guide planes in their metal substructure (see Chapter 21).

Typical indications are similar to those for metal complete crowns with the addition of an esthetic concern: extensive tooth destruction—as a result of caries, trauma, or existing previous restorations—that precludes the use of a more conservative restoration; the need for superior retention and strength; an endodontically treated tooth in conjunction with a suitable supporting structure (a post-and-core); and the need to recontour axial surfaces or correct minor malinclinations. Within certain limits, ceramic-veneered restorations can also be used to alter the occlusal plane.

CONTRAINDICATIONS

Contraindications for the ceramic-veneered crown, as for all fixed restorations, include the presence of active caries or untreated periodontal disease. In young patients with large pulp chambers, the ceramic-veneered crown is contraindicated because of the high risk of pulp exposure (see Fig. 7.5). If possible, a more conservative restorative option such as a composite resin or porcelain laminate veneer (see Chapter 25) or a ceramic crown with less axial reduction (see Chapter 11) is preferred.

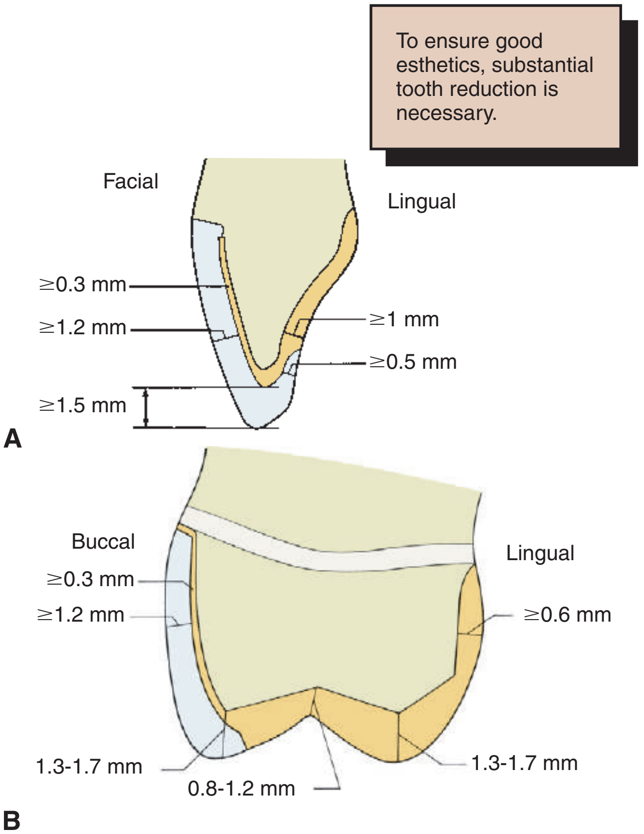


Fig. 10.1 Recommended *minimum* dimensions for a ceramic-veneered restoration on an anterior tooth (A) and a posterior tooth (B). Note the significant reduction needed in comparison with that for a complete cast or partial veneer crown (see Fig. 9.4).

A ceramic-veneered restoration should not be considered when a more conservative retainer is feasible, unless maximum retention and resistance form are needed, as for a long-span FPD. If the facial or buccal wall is intact, the dentist should consider if involving all axial tooth surfaces in the proposed restoration is truly necessary. Although perhaps technically more demanding and time consuming, a more conservative solution that satisfies the patient's needs while providing superior long-term service can usually be found.

ADVANTAGES

The ceramic-veneered restoration combines, to a large degree, the strength of its substructure with the esthetics of ceramics. The underlying principle is to reinforce a brittle, more cosmetically pleasing material through support derived from the stronger substructure. Natural appearance can be matched closely by good technique and, if desired, through characterization of the restoration with internally or externally applied stains. Retentive qualities are excellent because all axial walls are included in the preparation, and it is usually straightforward to achieve adequate resistance form in the tooth preparation. The complete-coverage aspect of ceramic-veneered crowns enables easy correction of axial form. In general, the degree of difficulty of a ceramic-veneered preparation is comparable with that of preparing a posterior tooth for a complete cast crown.

DISADVANTAGES

The ceramic-veneered crown preparation requires significant tooth reduction to provide sufficient space for the restorative materials. To achieve a superior esthetic result, the facial margin of an anterior restoration is often placed subgingivally, which increases the potential for periodontal disease. However, a supragingival margin can be used if significant cosmetic concerns do not preclude its use or if the restoration incorporates a porcelain labial margin (see Fig. 10.1A and Chapter 24).

In comparison with ceramic restorations, metal-ceramic crowns may have slightly inferior esthetics: they may appear slightly grayish in comparison with the translucency that can be achieved with ceramic crowns. Also, with ceramic crowns, a somewhat greater range of brightness can be achieved. However, the superior strength of the metal-ceramic crowns allows their use in higher stress situations and on teeth that would not provide adequate support for a ceramic restoration.

Because of the glasslike nature of the veneering material, ceramic-veneered crowns are subject to brittle fracture (although such failure is usually attributable to poor substructure design or poor fabrication technique). A frequent problem is the difficulty of accurate shade selection and its communication to the dental laboratory technician (see Chapter 23). The difficulty in achieving an accurate shade match is often underestimated by novice dentists. Because many procedural steps are required for fabrication of a metal substructure and porcelain application, laboratory costs generally render the metal-ceramic restoration among the more expensive of dental procedures. In comparison, monolithic ceramic restorations can often be fabricated at a lesser cost.

PREPARATION

The recommended preparation sequence is described for a maxillary right central incisor (Fig. 10.2); however, the same step-by-step approach can be applied to other teeth (Fig. 10.3). As with all tooth preparations, a systematic and organized approach to tooth reduction saves time.

Armamentarium

The instruments needed to prepare teeth for a ceramic-veneered crown (Fig. 10.4) include the following:

- Round-ended rotary diamonds (regular grit for bulk reduction, fine grit for finishing) or tungsten carbide burs
- Football- or wheel-shaped diamond (for lingual reduction of anterior teeth)
- Flat-ended, tapered diamond (for shoulder margin preparation)
- Finishing stones
- Explorer and periodontal probe
- Off-angle hatchets (see Fig. 10.4B–D)

The actual sequence of steps can be varied slightly, depending on the operator's preference.

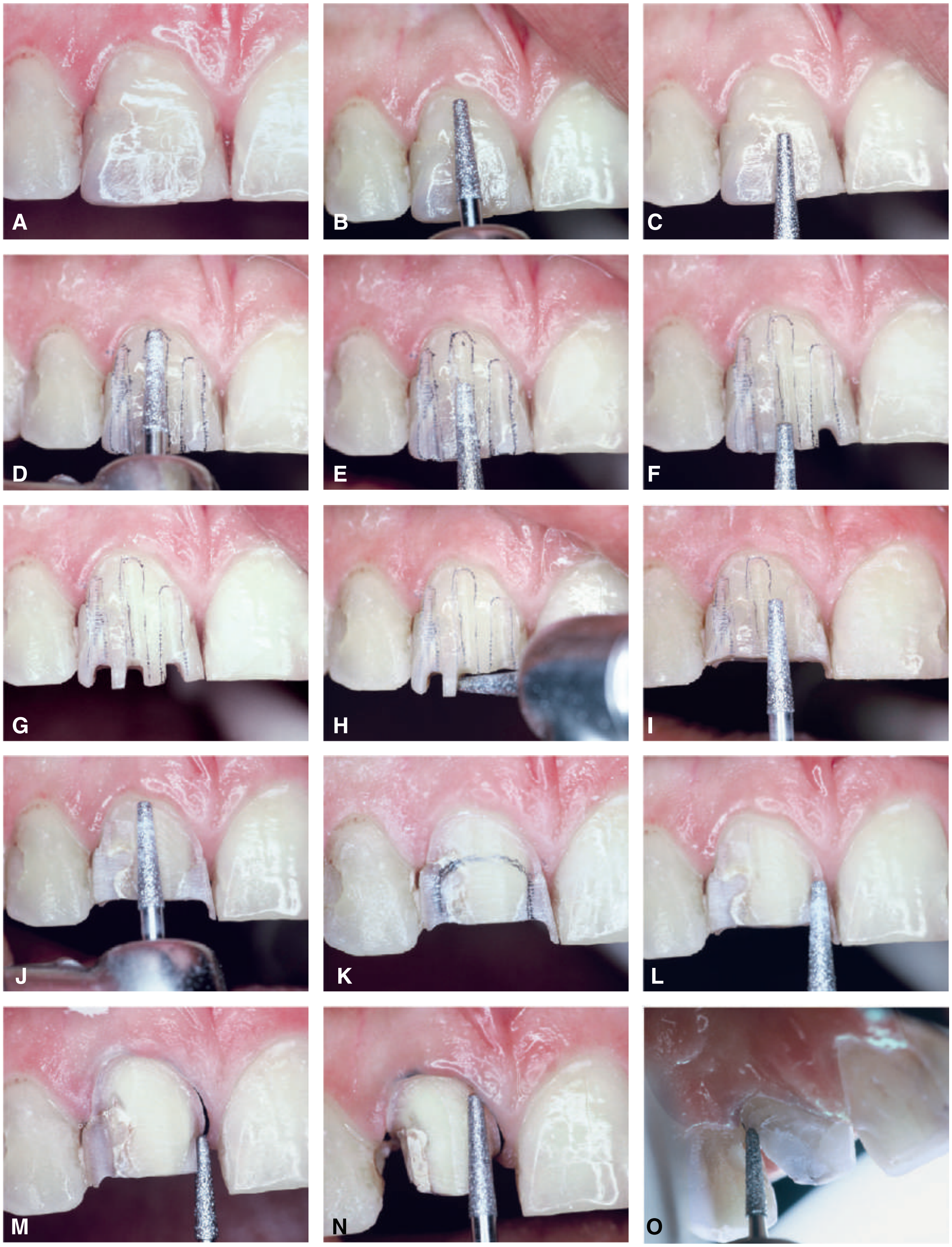


Fig. 10.2 Preparation of a maxillary incisor for a ceramic-veneered crown. (A) Heavily restored maxillary central incisor. (B and C) Rotary instrument aligned with the cervical one third and incisal two thirds to gauge correct planes of reduction. (D and E) Placement of depth grooves in two planes. The cervical groove is made parallel to the path of placement, which usually coincides with the long axis of the tooth. The secondary facial depth groove is prepared parallel to the facial contour of the tooth. (F and G) Placement of incisal depth grooves. (H) Incisal edge reduction. (I–K) Facial reduction accomplished in two planes. (L) Breaking proximal contact, maintaining a "lip" of enamel to protect the adjacent tooth from inadvertent damage. (M and N) Proximal reduction. (O) Placing a 0.5-mm lingual chamfer margin.

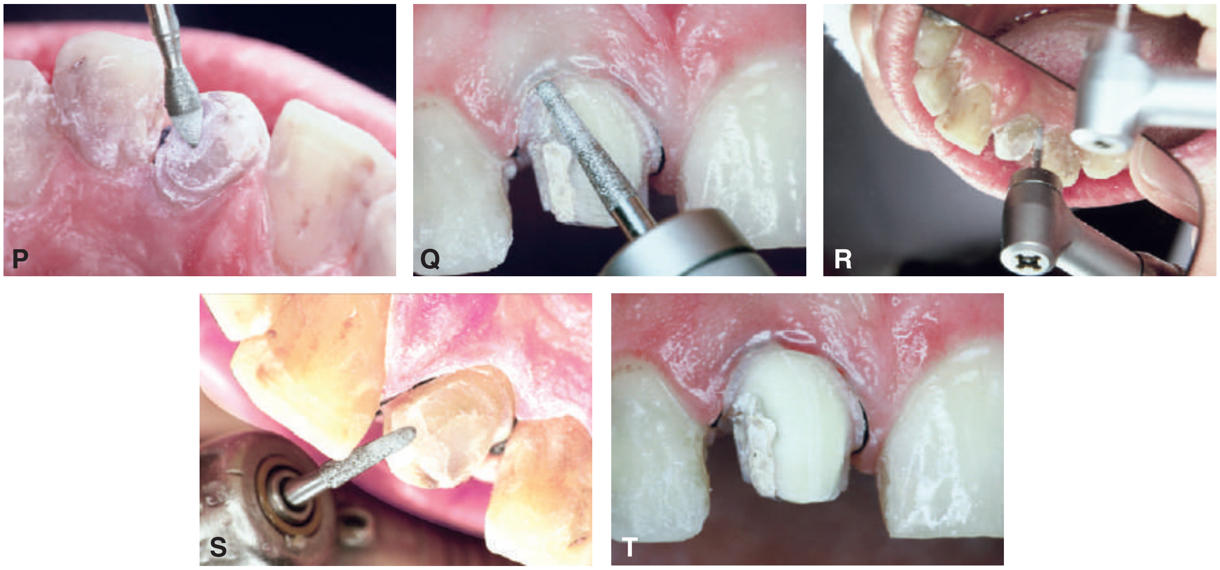


Fig. 10.2 Cont'd (P) Lingual reduction of anterior teeth with a football-shaped diamond. (Q–S) Finishing the preparation with a fine-grit diamond. (T) The completed preparation.

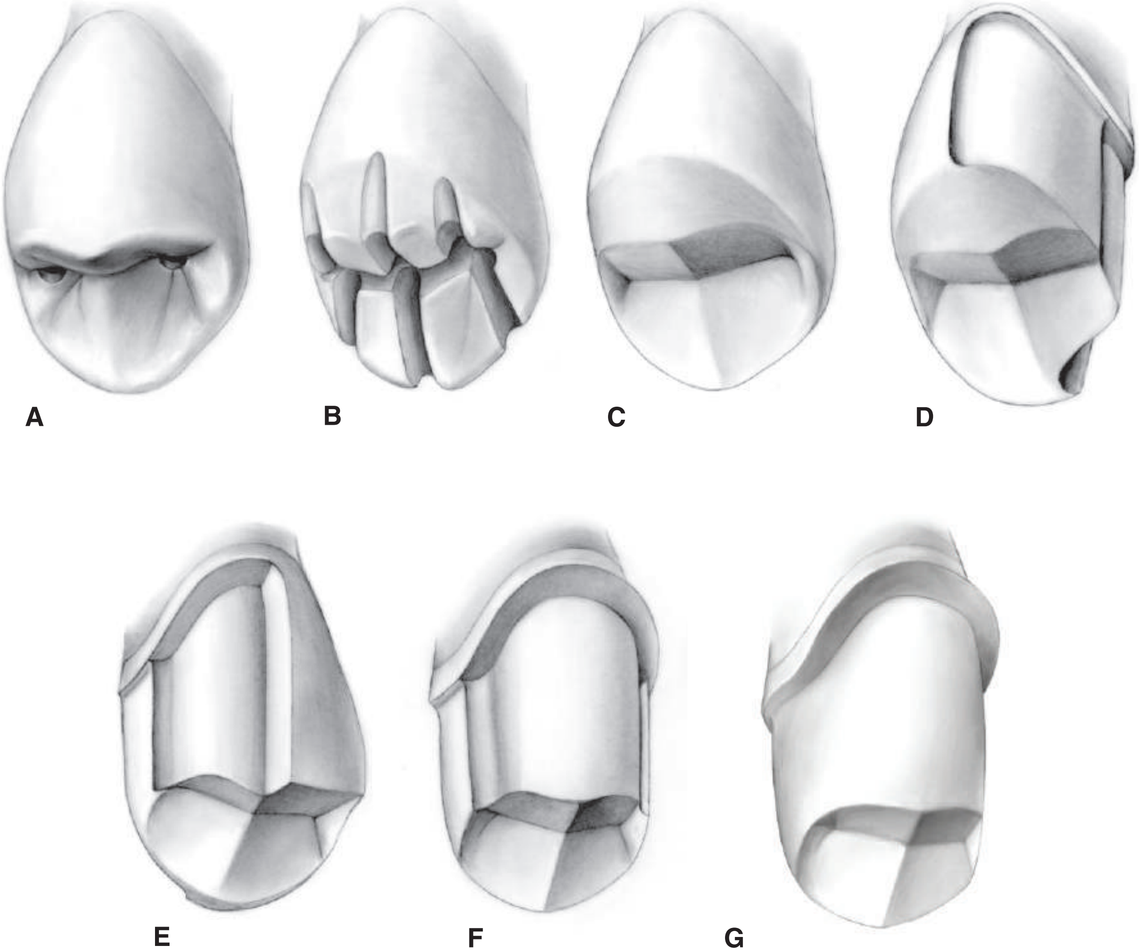


Fig. 10.3 Preparation of a maxillary premolar for a metal-ceramic crown. (A) Depth holes. (B) Occlusal depth cuts. (C) Completed occlusal reduction. Lingual chamfer margin (D) and facial shoulder margin (E) are prepared on half the tooth. (F and G) Completed preparation. The proximal wings are often eliminated for ceramic-veneered crowns (see also Fig. 10.19) but can prove advantageous on short teeth when non-adhesive luting procedures will be used.

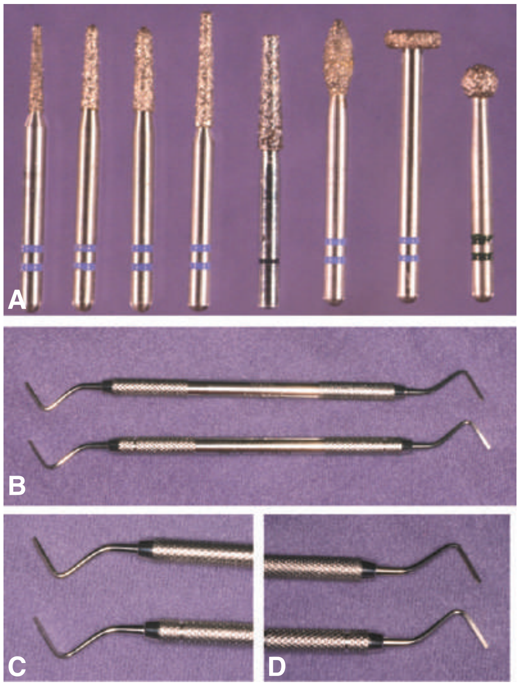


Fig. 10.4 Armamentarium for the ceramic-veneered crown preparation. (A) Diamond rotary instruments. (B–D) Off-angle hatchets. These are useful for smoothing the shoulder margins of ceramic-veneered crown preparations.

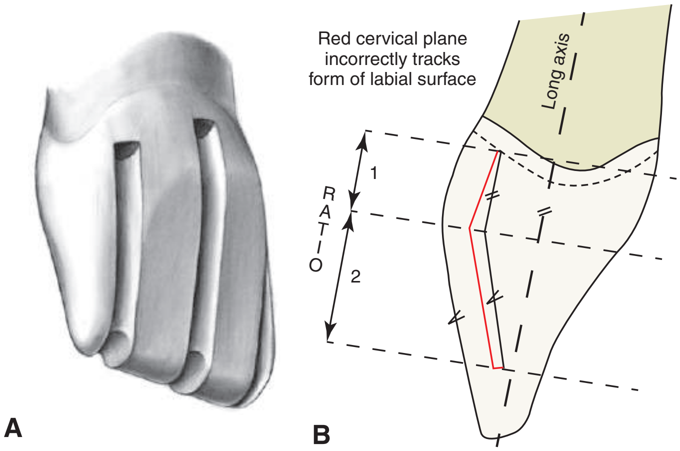


Fig. 10.5 (A) Depth grooves in the facial wall are placed in two directions: incisally, parallel to the tooth contour, and cervically, parallel to the long axis of the tooth (i.e., the path of placement). The grooves should be prepared initially to a depth of about 1.3 mm. (B) A common fault is to place the cervical groove at too labial an angle *(red line)*. This will lead to inadequate space for porcelain and may create an undercut.

Step-by-Step Procedure

The preparation is divided into five major steps: depth grooves, incisal or occlusal reduction, labial or buccal reduction in the area to be veneered with porcelain, axial reduction of the proximal and lingual surfaces, and final finishing of all prepared surfaces.

Depth Grooves

1. Place three depth grooves (Fig. 10.5), one in the center of the facial surface and one each in the approximate locations of the mesiofacial and distofacial line angles (see Fig. 10.2A–E). These are placed in two planes: The cervical portion parallels the long axis of the tooth, and the incisal (occlusal) portion follows the normal facial contour (see Fig. 10.2D and E).
2. Perform the facial reduction in the cervical and incisal planes. The cervical plane determines the path of placement of the completed restoration. The incisal or occlusal plane provides the space needed for the porcelain veneer; facial reduction should be uniform and approximately 1.3 mm deep, in the understanding that some additional reduction will occur during finishing. The incisal portion of the facial grooves usually extends half to two thirds of the way down the facial surface, depending on the shape of the tooth. The cervical third of the facial reduction parallels the long axis of the tooth. Slight adjustments to these guidelines are feasible; for example, a slight labial inclination can improve retention on a tooth with little cingulum height. On small teeth, it may be advisable to keep the cervical grooves somewhat shallower than 1.3 mm near the margin: 1.0 mm labial reduction in the cervical third still allows the fabrication of an esthetically acceptable restoration.
3. In order to achieve the necessary 2-mm clearance on the incisal aspect of an anterior tooth, place three depth grooves (about 1.8 mm deep) in the incisal edge of an anterior tooth, if it is normally aligned (see Fig. 10.2F and G). Verify groove depth with a periodontal probe. On a posterior tooth, if the occlusal surface is to be established in porcelain, clearance must be a minimum of 2 mm. If posterior occlusion is to be established in metal, the same minimum clearances are needed as for a complete cast crown. On maxillary teeth, posterior occlusal reduction incorporates a functional cusp bevel on the lingual cusp, similar to that for a complete cast crown. When the diamond is initially positioned for anterior teeth, it is helpful to observe the long axis of the opposing tooth in maximum intercuspation and to orient the instrument perpendicular to that axis (Fig. 10.6). The grooves must not be too deep, to avoid an overreduced and possibly undulating surface.

Incisal (Occlusal) Reduction

The completed reduction of the incisal edge on an anterior tooth should allow 2 mm of clearance for adequate material thickness to achieve translucency in the completed restoration. Posterior teeth may still be restorable with less reduction because esthetics is not as critical. Caution must be used during the occlusal preparation phase because excessive occlusal reduction will shorten the axial preparation walls and thus is a common cause of inadequacies in mechanical retention and resistance form in the completed preparation. Loss of retention form can be especially problematic on anterior teeth (on which, as a consequence of tooth form, most mechanical retention is derived from the proximal walls).

4. Remove the islands of remaining tooth structure. On anterior teeth, access is usually unrestricted, and the thickest portion of the cutting instrument can be used to maximize cutting efficiency (see Fig. 10.2H). On posterior teeth, the same protocol is followed as in preparing depth grooves for

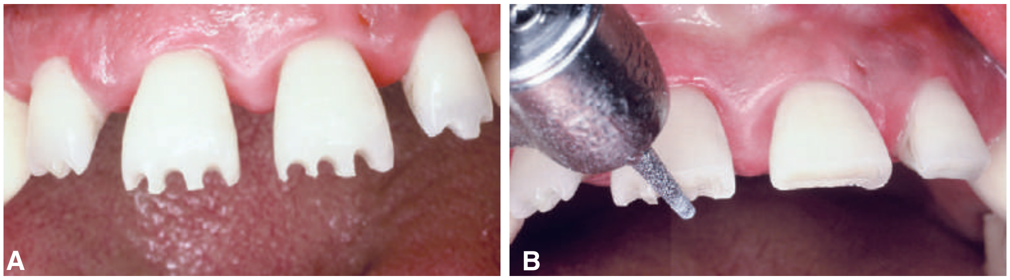


Fig. 10.6 (A) Depth grooves 1.8 mm deep placed in the incisal edges to ensure adequate and even reduction. (B) Incisal reduction completed on the left central and lateral incisors. Note the angulation of the diamond, perpendicular to the direction of loading by the mandibular anterior teeth.

a complete cast crown (see Chapter 9). This includes the use of a functional cusp bevel, although additional occlusal reduction is needed where the porcelain is to be applied (see Fig. 10.3A–C).

Labial (Buccal) Reduction

When completed, the facial reduction should have produced sufficient space to accommodate the substructure and porcelain veneer. A minimum of 1.2 mm is necessary for the ceramist to produce a restoration with satisfactory appearance (1.5 mm is preferable). This requires significant tooth reduction. For comparison, the cervical diameter of a maxillary central incisor averages between 6 and 7 mm.

In the cervical area of small teeth, obtaining optimal reduction is not always feasible (see Fig. 7.4). A compromise is often made with less reduction in the area of the cervical shoulder margin.

5. Remove the tooth structure that remains between the depth grooves (see Fig. 10.2I–L), creating a shoulder margin at the cervical margin (Fig. 10.7). If a restoration with a narrow subgingival metal collar is to be fabricated and sulcular depth is sufficient, place the shoulder margin approximately 0.5 mm apical to the crest of the free gingiva at this time. Additional finishing will place the margin further subgingivally. Use adequate water spray during the entire phase of preparation because a significant amount of tooth structure is being removed and copious irrigation (along with intermittent strokes) expedites the preparation process while reducing the risk of pulpal trauma. The resulting shoulder margin should be approximately 1 mm wide and should extend well into the proximal embrasures when viewed from the incisal (occlusal) side (Fig. 10.8). Where access allows, refining this shoulder margin from the proximal gingival crest toward the middle of the facial wall is preferred. This minimizes the risk of preparing the initial shoulder margin too close to the epithelial attachment. If the margin is prepared from the facial to proximal aspects, there is a tendency to "bury" the instrument and encroach on the epithelial attachment. Proper margin position must be maintained in relation to the crest of the free gingiva (see Fig. 7.65). The location and specific configuration of the facial margin depend on several factors: the type of ceramic-veneered restoration selected, the cosmetic expectations of the patient, and the operator's preference.

To reduce the risk of periodontal disease, a supragingival margin is preferable. Its application is restricted, however, because of mechanical and esthetic considerations, unless a

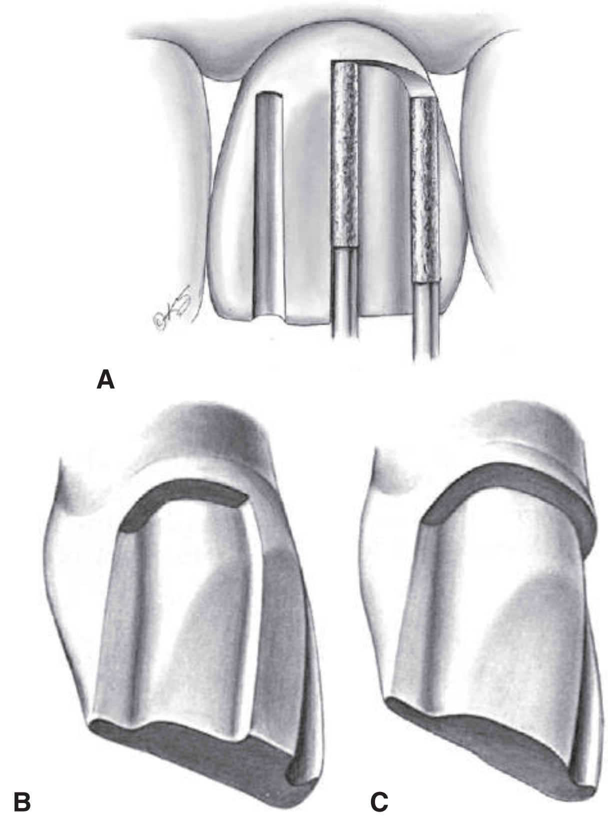


Fig. 10.7 (A) The cervical shoulder margin is established as the tooth structure between the depth grooves is removed. The rotary instrument is moved parallel to the intended path of placement during this procedure. (B) The facial reduction should be completed in two phases; initially, one half is maintained intact for evaluation of the adequacy of reduction. Note the two distinct planes of reduction on the facial aspect. The proximal aspect parallels the cervical reduction on the facial wall. (C) Facial reduction completed. A 6-degree taper has been established between the proximal walls.

zirconia substructure is used. It may be necessary to extend the preparation farther in an apical direction to ensure adequate vertical wall height. Patients often object to the sight of a visible metal collar or discolored root surface. Such objections are common, even when the gingival margin is not visible during normal function, as in patients with a low lip line. In general, this esthetic drawback limits the use of metal supragingival margins to posterior teeth (Fig. 10.9) and to undiscolored anterior teeth

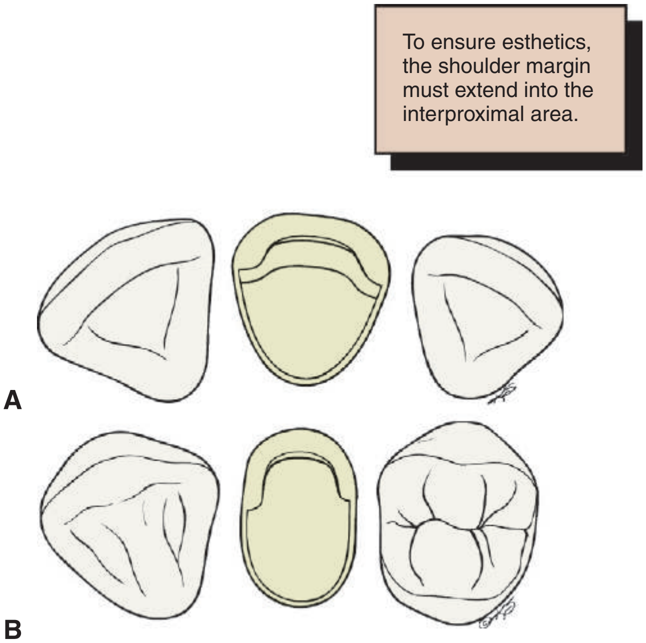


Fig. 10.8 (A) The facial shoulder margin preparation should wrap around into the interproximal embrasure and extend at least 1 mm lingual to the proximal contact. (B) The shoulder margin preparation extends adequately to the lingual side of the proximal contact. Note that on the mesial (visible) side, the preparation extends slightly farther than on the distal (cosmetically less critical) side.

Fig. 10.9 Supragingival margins on the maxillary premolars. They were possible because of a favorable lip line hiding the cervical aspect of these posterior teeth. The subgingival margins on the mandibular premolars were prepared only because of previously existing restorations.

(in which case a ceramic substructure or a porcelain labial margin is indicated; see Chapter 24). The optimum margin location should be carefully determined with the full cooperation of the patient. Where a subgingival margin is to be placed, careful tissue manipulation is essential; otherwise, the resulting soft-tissue damage can readily lead to permanent gingival recession and subsequent exposure of the tooth-restoration interface. This is most effectively avoided through meticulous gingival displacement with a cord before margin finishing (Fig. 10.10). The configuration of the margin is also finalized at this time (Fig. 10.11).

Axial Reduction of the Proximal and Lingual Surfaces

Sufficient tooth structure must be removed to provide a distinct, smooth chamfer margin of about 0.5 mm in width

Fig. 10.10 (A) Gingival displacement cord (under tension) is placed in the interproximal sulcus. (B) A second instrument can be used to prevent the cord from rebounding from the sulcus after it has been packed. (C) The preparation margin is extended apically. The cord must not engage with the diamond rotary instrument because extensive tissue trauma would result.

(see Fig. 10.2M–P), although a slightly wider margin is desirable for the zirconia reinforced lithium silicate substructures.

6. Reduce the proximoaxial and linguoaxial surfaces with the diamond held parallel to the intended path of placement of the restoration. These walls should converge slightly from cervical to incisal or occlusal. A taper of approximately 6 degrees, measured as the angle between opposing axial walls, is recommended. On anterior teeth, a lingual concavity is prepared for adequate clearance for the restorative materials. Typically, a 1-mm thickness is required if the centric contacts in the completed restoration are to be located on metal. When contact is planned on porcelain, additional reduction is necessary. For anterior teeth, usually only a single depth groove is placed in the center of the lingual surface. For molars, three grooves can be placed in a manner similar to that described for the metal complete cast crown (see Chapter 9).
7. Make a lingual alignment groove by positioning the diamond parallel to the cervical plane of the facial reduction. When the round-ended diamond of appropriate size and shape is aligned properly, it is submerged almost halfway into the tooth structure. Verify the alignment of the resulting orientation groove, and carry the axial reduction from the groove along the lingual surface into the proximal aspect; maintain the originally selected alignment of the diamond at all times.

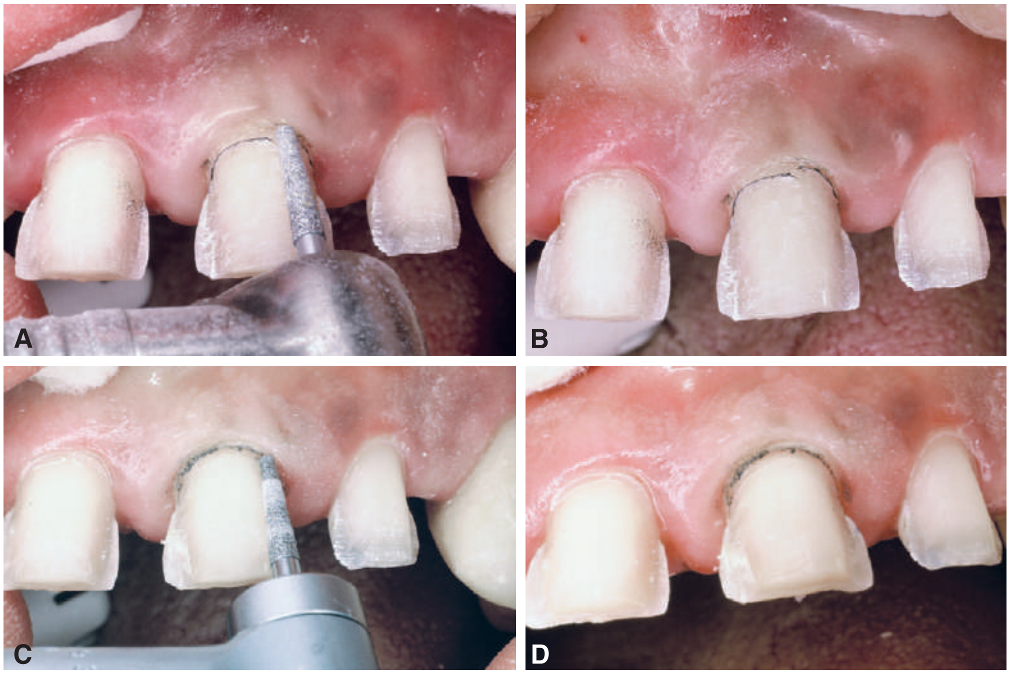


Fig. 10.11 (A) After tissue displacement, the facial margin is extended apically. Caution is needed because if the diamond inadvertently grabs the cord, it may be ripped out of the sulcus and injure the epithelial attachment. (B) Note the additional apical extension of the shoulder margin on the distal aspect. (C) The entire facial shoulder margin is placed at a level that will be subgingival after the tissue rebounds. (D) The facial margin has been prepared to the level of the previously placed cord.

Fig. 10.12 A lingual chamfer margin is prepared to allow adequate space for the substructure. The transition from interproximal shoulder margin to chamfer margin must be smooth.

8. As the lingual chamfer margin is developed, extend it buccally into the proximal area to blend with the interproximal shoulder margin that was placed earlier (Fig. 10.12). Alternatively, a facial approach may be used. Although this is slightly more difficult initially, after some practice it should be easy to eliminate the lingual orientation groove and to perform the proximal and lingual axial reduction in one step; however, this requires the diamond to be held freehand, parallel to the path of placement. The proximal flange that resulted from the shoulder margin preparation can be used as a reference for judging alignment of the rotary instrument (Fig. 10.13). The interproximal margin should not be inadvertently placed too far subgingivally and thereby infringe on the attachment apparatus. It must follow the soft tissue contour (see Chapter 7). On posterior teeth, occlusally, the lingual wall reduction blends into the functional cusp bevel placed during the occlusal reduction. Anterior teeth require an additional step: After preparation of the cingulum wall, one or more depth grooves are placed in the lingual surface. In teeth that are well aligned and in occlusal contact, these depth grooves are approximately 1 mm deep.
9. Use a football-shaped diamond to reduce the lingual surface of anterior teeth (see Fig. 10.2P). When half this reduction has been completed, it is helpful to stop and evaluate clearance in maximum intercuspation and all excursions. The remaining intact tooth structure can serve as a reference. Once clearance is deemed satisfactory, the lingual reduction is then completed.

Finishing. The margin must provide distinct resistance to vertical displacement of the tip of a periodontal probe or an explorer, and it must be smooth and continuous circumferentially. (A properly finished margin should give the dentist a feel similar to running an explorer over a smooth unscratched glass surface.) All line angles should be rounded, and the completed preparation should have a satin finish, free from obvious diamond scratch marks. Tissue displacement is especially helpful when subgingival margins are being finished (Fig. 10.14). Sometimes this step is postponed until just before definitive impression making after initial tissue displacement to reduce the risk of soft tissue trauma (see Chapter 14).

10. Finish the margins with diamonds (see Fig. 10.2Q and R), hand instruments such as off-angle hatchets (see Fig. 10.4B), or tungsten carbide burs. All internal line angles should be

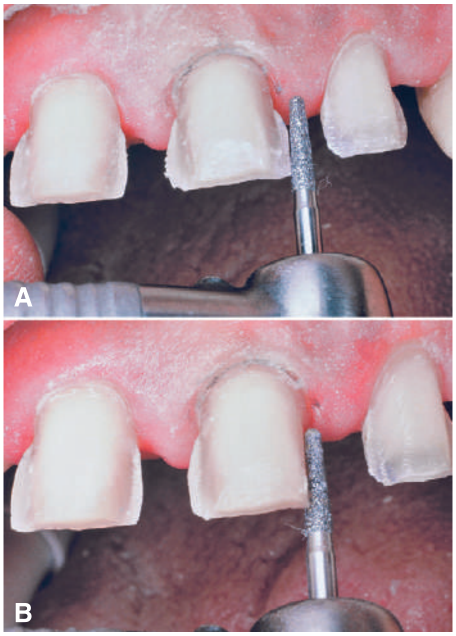


Fig. 10.13 (A) Proximal reduction of the flange with a facial approach. (B) Once sufficient tooth structure has been removed, the cervical chamfer margin is prepared simultaneously with the lingual axial surface. After the distolingual preparation has been completed, the mesial chamfer margin is blended into a smooth transition with the shoulder margin. The dentist must be especially careful not to encroach on the biologic width interproximally. It is easiest to start the margin preparation interproximally and move toward the facial aspect. Preparing from the facial aspect to the proximal aspect may easily lead to margin placement that is too far subgingival.

rounded to facilitate the impression-making and subsequent fabrication steps (see Fig. 10.2S). The finishing steps for the facial margin depend on the design of margin chosen (Figs. 10.15 and 10.16; see also Table 7.2). A shoulder margin for a crown with a porcelain labial margin must be shaped to support the brittle ceramic properly. A shoulder margin with a 90-degree cavosurface angle is recommended. This type of shoulder margin can also be used for a crown with a conventional metal collar and enables the dentist to make a restoration with a narrower metal collar than when a bevel is added to the shoulder margin preparation (see Fig. 7.29). However, if residual unsupported enamel remains, its potential for fracture during cementation may jeopardize the restoration's longevity. For this reason, the margin is often beveled or sloped to create a slightly obtuse cavosurface angle (see Fig. 10.16). A flat-ended diamond in a low-speed handpiece creates the 90-degree shoulder margin. Any unsupported enamel must be removed subsequently by careful planing with a sharp chisel. Care must also be taken to adjust the alignment of the rotary instrument properly as it moves around the tooth if inadvertent undercuts are to be avoided. When a metal-ceramic crown with a metal collar is planned, a 90-degree shoulder margin is less crucial. A sloped shoulder margin has been advocated to ensure the elimination of unsupported enamel and to minimize marginal gap width

Fig. 10.14 Controlled tissue displacement can be helpful when the margin is finished with a fine-grit diamond or another rotary instrument.

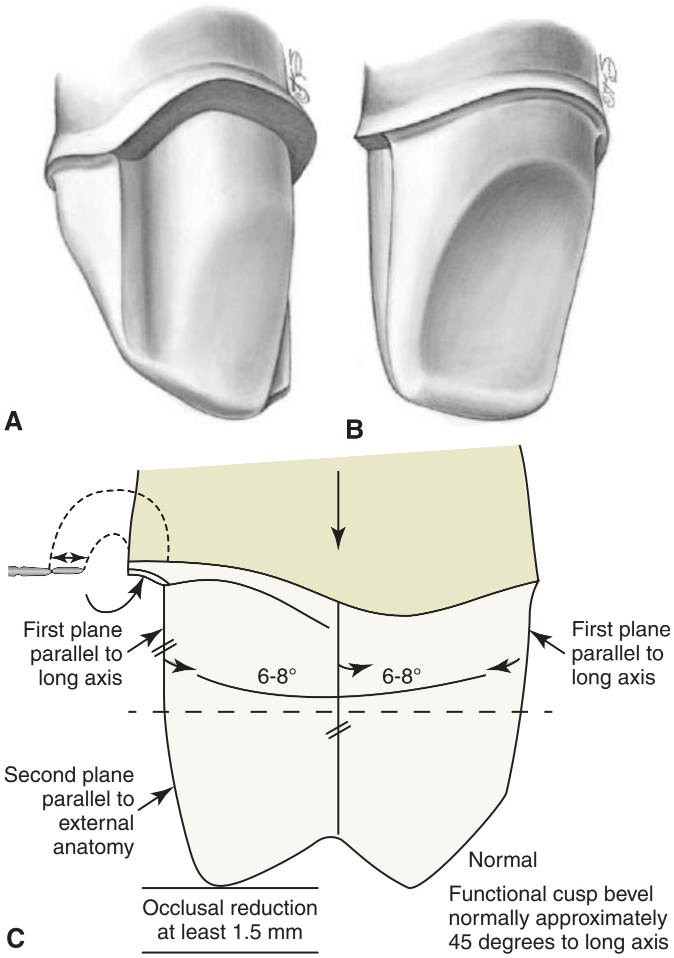


Fig. 10.15 (A) Completed preparation. Note that the transition from incisal to axial walls is rounded, and a distinct 90-degree or slightly sloped shoulder margin has been established. It is important that the proximal axial reduction of both the shoulder and chamfer margins of the preparation are exactly in the same plane. (B) An even chamfer margin width and a smooth transition between lingual and axial surfaces. The chamfer margin is distinct and blends smoothly into the facial shoulder margin. (C) When a maxillary molar is prepared for a metal ceramic crown, note the two-plane facial reduction to provide both adequate retention and space for the ceramic material.

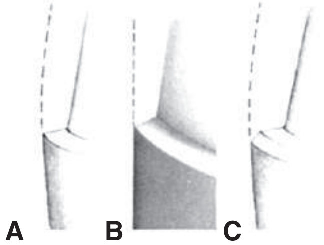


Fig. 10.16 (A) A 90-degree shoulder margin. (B) A 120-degree shoulder margin. (C) A beveled shoulder margin.

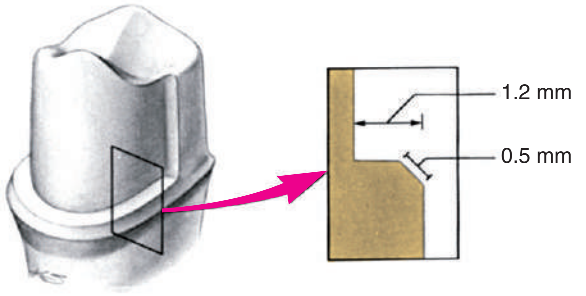


Fig. 10.17 The beveled shoulder margin.

Fig. 10.18 Facial (A) and lingual (B) views of ceramic-veneered preparations.

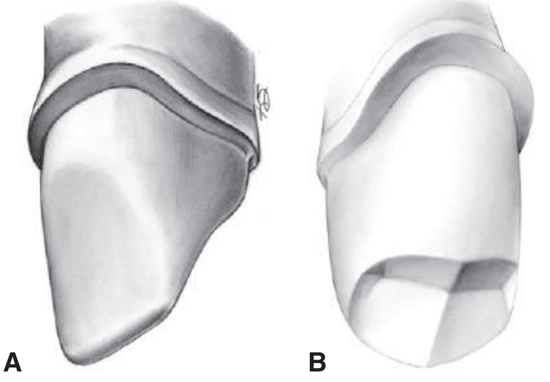


Fig. 10.19 Completed preparations on maxillary central incisor (A) and premolar (B). The "wingless" variation does not exhibit the defined transition from chamfer margin to shoulder margin seen in Fig. 10.15. Rather, the shoulder margin gradually narrows toward the lingual side. Interproximally, the same criteria for minimum extension of the shoulder margin apply as for the wing-type or flange preparation.

(see Chapter 7). Such a shoulder margin (cavosurface angle of about 120 degrees) can be accomplished with a flat-ended diamond by changing its alignment, with particular attention to the configuration of the tooth structure cervical to the margin. Alternatively, a hatchet can be used to plane the margin to the desired angulation. Again, be careful to avoid undercutting the axial wall of the preparation where it meets the shoulder margin during finishing. A beveled shoulder margin is most effectively achieved with a flame-shaped tungsten carbide bur or hand instrument, depending on the length of bevel desired (Fig. 10.17). In general, a short-beveled margin with a cavosurface angle of 135 degrees is advocated, although longer beveled margins have been recommended for improved marginal fit. Special care must be exerted where the beveled margin meets the interproximal chamfer margin. The chamfer and beveled margins should be continuous with each other. Care must be taken not to damage the epithelial attachment during beveling; tissue displacement before preparation of subgingival beveled margins is recommended.

11. After a satisfactory facial margin has been obtained, round all sharp line angles within the preparation (see Fig. 10.2S). This will reduce the risk of fracture of the ceramic crown, and also will facilitate surface wetting and expedites subsequent procedures (e.g., elastomeric impression making, cast fabrication, and additional laboratory procedures). A fine-grit diamond operating at low speed is particularly useful. However, where access allows, a slightly larger tapered diamond may be preferred because the greater diameter of its tip prevents "lipping" of the chamfer margin (see Fig. 7.24). Blend all surfaces together, and remove any sharp transitions (Figs. 10.18 and 10.19; see also Fig. 10.2T).

Evaluation. Areas often missed during finishing are the incisal edges of anterior preparations and the transition from occlusal to axial wall of posterior preparations. Incisally or occlusally, a 2-mm reduction should allow adequate clearance. If an occlusal surface is planned in metal, reduction may be more conservative. Clearances should be verified in the static occluded position, as well as in all excursive positions of the mandible.

Axial walls should exhibit a restricted angle of convergence. Restricted taper between the proximal walls, particularly on anterior teeth, contributes significantly to mechanical retention form, whereas resistance is usually achievable on most anterior teeth because of their relatively small diameter. If a metal-ceramic retainer is planned on a short posterior tooth, a wing-type preparation offers some mechanical advantage because it has better resistance form than its wingless counterpart. For ceramic-veneered crowns, wings are usually not incorporated in the completed preparation as they can complicate some of the fabrication procedures (e.g., milling).

The facial and buccal walls on maxillary teeth in the esthetic zone should exhibit two plane reductions. On incisors and canines, the cervical plane is typically about one third of the preparation height, whereas the second plane is approximately two-thirds of the preparation height and follows the geometry of the desired anatomic form in the completed restoration. On premolars and molars, cervical and occlusal planes often approximate each other in height. Care is also needed to avoid creating an undercut between the facial and lingual walls. This aspect of the preparation should be thoroughly evaluated. Excessive convergence should also be avoided because this may lead to pulpal exposure.

The completed chamfer margin should provide 0.5 mm of space for a metal margin and slightly more for a ceramic margin. The chamfer margin must be smooth and continuous, and when it is evaluated, the dentist should feel distinct resistance to vertical displacement of the tip of an explorer or periodontal probe. The chamfer margin should be continuous with the interproximal shoulder margin or beveled shoulder margin. The cavosurface angle of the chamfer margin should be slightly obtuse or 90 degrees. Under no circumstances should any unsupported tooth structure remain, especially at the facial margin. All residual debris is removed with thorough irrigation. (Various examples of metal-ceramic preparations are shown in Fig. 10.20.)

Fig. 10.20 (A) Failing, nonesthetic restorations. (B–D) Existing restorations have been removed and teeth re-prepared after foundation restorations were placed. (E–J) Completed ceramic-veneered crowns after delivery.

STUDY QUESTIONS

1. What are the indications for and contraindications to ceramic-veneered crowns?
2. What are the advantages and disadvantages of ceramic-veneered crowns?
3. What is the recommended armamentarium, and in what sequence should a maxillary central incisor be prepared, for a ceramic-veneered crown?
4. What are the minimal criteria for steps 1, 2, and 3? Why?
5. Discuss how to determine the buccolingual position of a proximal groove to precisely obtain the desired position of the facial finish line.

SUMMARY CHART

Ceramic-Veneered Crown

Indications	Contraindications	Advantages	Disadvantages
• Esthetics • If monolithic ceramic crown is contraindicated • Gingival involvement • Esthetics	• Large pulp chamber • Intact buccal wall • When more conservative retainer is technically feasible • Large pulp chamber	• Superior esthetics in comparison with complete cast crown • Superior esthetics in comparison with complete cast crown	• Removal of substantial tooth structure • Subject to fracture because porcelain is brittle • Difficulty obtaining accurate occlusion in glazed porcelain • Shade selection can be difficult • Expensive • Removal of substantial tooth structure

Preparation Steps	Recommended Armamentarium	Criteria
Incisal (occlusal) reduction guide grooves	Tapered, round-ended diamond	1.5–2 mm of clearance in intercuspal positions and all excursions
Incisal (occlusal) reduction	Tapered, round-ended diamond	1.2–1.5 mm of reduction for metal or ceramic framework and porcelain (see Fig. 10.1)
Labial reduction guide grooves (two planes)	Tapered, round-ended diamond	6 degrees of convergence, measured as the angle between opposing axial walls
Labial reduction (two planes)	Tapered, flat-ended diamond	Should provide 1 mm of clearance in all excursions and intercuspal positions (1.5 mm if occlusal surface is porcelain)
Axial reduction	Tapered, round-ended diamond	Shoulder margin must extend at least 1 mm lingual to proximal contact area; beveled margin, if selected, should be as far incisally as possible in relation to epithelial attachment
Lingual reduction	Football-shaped diamond	All line angles rounded and preparation surfaces smooth
Finishing of shoulder (or beveled shoulder) margin	Tapered, flat-ended diamond	—
Finishing	Hand instrument Tapered, round-ended diamond or tungsten carbide bur	—

11

The Cast Partial Veneer Crown, Inlay, and Onlay Preparations

An extracoronal metal restoration that covers only part of the clinical crown is considered a partial veneer crown. It can also be referred to as a *partial-coverage restoration*. An intracoronal cast metal restoration is called an *inlay*, or an *onlay* if one or more cusps are restored. Examples of these restorations are presented in Fig. 11.1. Partial veneer crowns generally include all tooth surfaces except the buccal or labial wall in the preparation. Therefore these restorations preserve more of the tooth's coronal tissue than does a complete crown. However, the preparation is more demanding and is not routinely provided by practitioners. Buccolingual displacement of the restoration is prevented by internal features (e.g., proximal boxes and grooves). Partial veneers can be used as single-tooth restorations or as retainers for a fixed partial denture (FPD). Although more often used on posterior teeth today, they can be used on both anterior and posterior teeth. Because they cover less of the coronal surface, partial coverage restorations tend to be less retentive than complete crowns and also less resistant to displacement. Inlays and onlays are even less retentive than partial veneer crowns. However, they provide the advantage of material strength (i.e., resistance to deformation) and preservation of tooth structure. Margins are generally more accessible, allowing improved finishing by the dentist, and cleaning by the patient. When carefully executed, inlays and onlays can be exceptionally long-lasting restorations (see Fig. 11.1).

PARTIAL VENEER CROWNS

Over time, several types of cast partial veneer restorations have been used: for posterior teeth, these include three-quarter, modified three-quarter, and seven-eighths crowns; for anterior teeth, three-quarter crowns and pinledges (Fig. 11.2). In the presence of more esthetic contemporary materials cast partial veneer crowns are primarily used on posterior teeth, rather than in the esthetic zone.

Indications

Partial veneer crowns can be used to restore posterior teeth that have lost moderate amounts of tooth structure if the buccal wall of the abutment is intact and well supported by sound tooth structure. They provide adequate retention to be used as retainers for an FPD or where restoration or alteration of the occlusal surface is needed. Anterior cast partial veneers are rarely used today but can be used as retainers. They may offer a conservative approach to reestablish anterior guidance and can be used to splint teeth. They are particularly suitable for teeth with sufficient bulk since those can accommodate the necessary retentive features.

Contraindications

Partial veneer restorations are contraindicated on teeth with short clinical crowns because retention may be inadequate. They are also contraindicated as retainers for long-span FPDs. They are rarely suitable for endodontically treated teeth as insufficient tooth structure remains after the endodontic treatment to accommodate the retentive features. Often, on endodontically treated posterior teeth the buccal cusps are weakened by the access cavity. They are not suitable for teeth with extensively damaged crowns, and as is true of all cast restorations, partial veneer restorations are contraindicated in the presence of active caries or periodontal disease.

The shape and alignment of teeth are important determinants of the feasibility of partial veneer crowns. The alignment of axial surfaces should be evaluated carefully, and partial veneer crowns should not be prepared on teeth that are proximally bulbous. Making the necessary proximal grooves on such teeth will leave unsupported enamel. Similarly, it is often not possible to prepare adequate grooves on thin teeth with restricted faciolingual dimension.

Partial veneer crowns are usually prepared parallel to the long axis of the tooth, and poorly aligned abutment teeth are a contraindication since problems with unsupported enamel often result.

Advantages

The primary advantage associated with partial veneer crowns is conservation of tooth structure. Another advantage is reduced pulpal and periodontal insult during tooth preparation. Access to supragingival margins is rather easy, and the operator can perform selected finishing procedures that are more difficult or impossible with complete coverage restorations. Access is also better for oral hygiene. Because less of the margin approximates the soft tissues subgingivally, there is less gingival involvement than with complete crowns.

During cementation of a partial veneer, excess luting agent can escape more easily than during cementation of complete cast crowns, which facilitates seating of the restoration. Because of direct visibility, verification of seating and cement removal are simple. When the restoration is in service, the remaining intact facial or buccal tooth structure enables vitality testing.

Fig. 11.1 (A) Partial veneer crowns serving as retainers on the premolars for a four-unit fixed partial denture replacing the maxillary first molar. (B) This two-surface inlay, photographed after more than 50 years of service, eventually lasted for 63 years. (C) Maxillary premolars restored with gold inlays, and a molar restored with a gold onlay. At the time this photograph was made, these restorations had served for approximately 35 years.

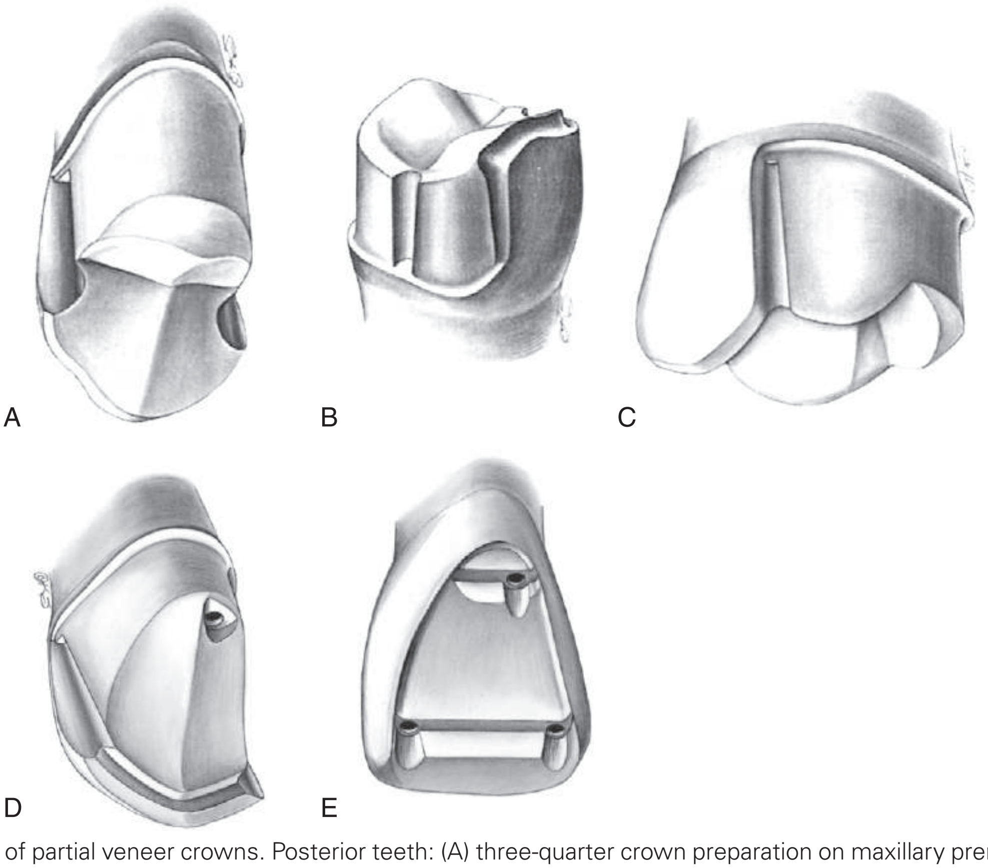


Fig. 11.2 Examples of partial veneer crowns. Posterior teeth: (A) three-quarter crown preparation on maxillary premolar. (B) Modified three-quarter crown on mandibular premolar. (C) seven-eighths crown maxillary molar. Anterior teeth: (D) three-quarter crown on maxillary canine. (E) Pinledge preparation on central incisor.

Disadvantages

Partial veneer restorations have less retention and resistance than do complete cast crowns. Tooth preparation is more challenging because only limited adjustments can be made in the path of placement. The preparation of grooves, boxes, and pinholes requires dexterity of the operator. Some metal is displayed in the completed restoration, which may be unacceptable to patients.

Preparation

The teeth most commonly prepared for partial veneer restorations include maxillary and mandibular molars. Cast partial veneers are rarely applied anymore on anterior teeth because of the difficulty in achieving an esthetic result and have been replaced by ceramic alternatives. The technique illustrated is suitable for posterior teeth. Meticulous care and precision are required if partial veneer restorations are to be a successful (conservative) alternative to complete-coverage restorations.

Armamentarium

The necessary instruments for a partial veneer crown preparation include the following (Fig. 11.3):

- Narrow (approximately 0.8 mm), round-ended, tapered diamond (regular or coarse grit)
- Regular-size (approximately 1.2 mm), round-ended, tapered diamond (fine grit) or tungsten carbide bur
- Football-shaped or wheel-shaped diamond (regular grit)
- Tapered and straight tungsten carbide fissure burs
- Small, round tungsten carbide bur
- Small-diameter twist drill
- Inverted-cone tungsten carbide bur
- Finishing stones
- Mirror
- Explorer and periodontal probe
- Chisels

The regular- or coarse-grit diamonds are used for bulk reduction, and the fine-grit diamonds or tungsten carbide burs for finishing. If pinholes are required, they can be prepared with the twist drill and then shaped with a tapered tungsten carbide fissure bur. The tungsten carbide fissure burs are recommended for preparing boxes and ledges, and the inverted-cone tungsten carbide bur is useful for preparation of offsets. Hand instruments can be used to finish proximal flares and bevels. A periodontal probe is invaluable for assessing the alignment and dimension of the various preparation features.

Fig. 11.3 Armamentarium for a partial veneer crown preparation.

Posterior Partial Veneer Crown Preparations

Maxillary Premolar Three-quarter Crown

The step-by-step preparation of a three-quarter crown is illustrated on a maxillary premolar (Fig. 11.4). Except for a narrow bevel or chamfer margin placed along the bucco-occlusal line angle, the buccal surface of the abutment remains intact. The other surfaces (including the occlusal surface) are prepared to accommodate a casting in the same manner as a complete crown preparation (see Chapter 8), differing only in the need for proximal axial grooves to develop resistance form.

Occlusal reduction. Upon the completion of occlusal reduction, the clearance on the functional cusp should be at least 1.5 mm, and those on the nonfunctional cusp and in the central groove should be at least 1.0 mm. Simultaneously, the tooth should be prepared so that metal display is minimal; the original outline form of the buccal wall should be preserved as well as possible.

1. Before starting the preparation, mark the proposed margin location of the completed restoration on the tooth with a pencil (Fig. 11.5).
2. Place depth grooves for the occlusal reduction. These may be made with a tapered tungsten carbide bur or a narrow diamond in the developmental grooves of the mesial and distal fossae and on the crest of the triangular ridge. In the central groove, they should be kept slightly shallow to allow for finishing; similarly, on the functional (lingual) cusp, they should be slightly less than 1.5 mm deep in the location of the occlusal contacts.
3. Place three depth grooves on the lingual incline of the buccal cusp. Initially, these should be kept somewhat shallow as they approach the buccal cusp ridge (see Fig. 11.4B). In the area of occlusal contact, groove depth should accommodate at least 1 mm of clearance after finishing.
4. Verify groove depth with a periodontal probe. When acceptable, remove the islands of tooth structure remaining between the grooves (see Fig. 11.4C and D).
5. Assess the amount of occlusal clearance in maximum intercuspation (Fig. 11.6) and in all excursive movements of the mandible. Concave preparation of the lingual incline of the buccal cusp is helpful for obtaining sufficient clearance while maintaining the original occlusocervical dimension of the buccal tooth surface (Fig. 11.7).

Axial reduction

6. Depth grooves for axial alignment are prepared in the center of the lingual surface and in the mesiolingual and distolingual transitional line angles. These parallel the long axis of the tooth and should initially be kept shallow to avoid inadvertently creating a lip of unsupported enamel at the margin.
7. Because the path of placement of a partial veneer is critical, the orientation grooves must be critically evaluated when correction is still feasible. A common mistake is to angle the

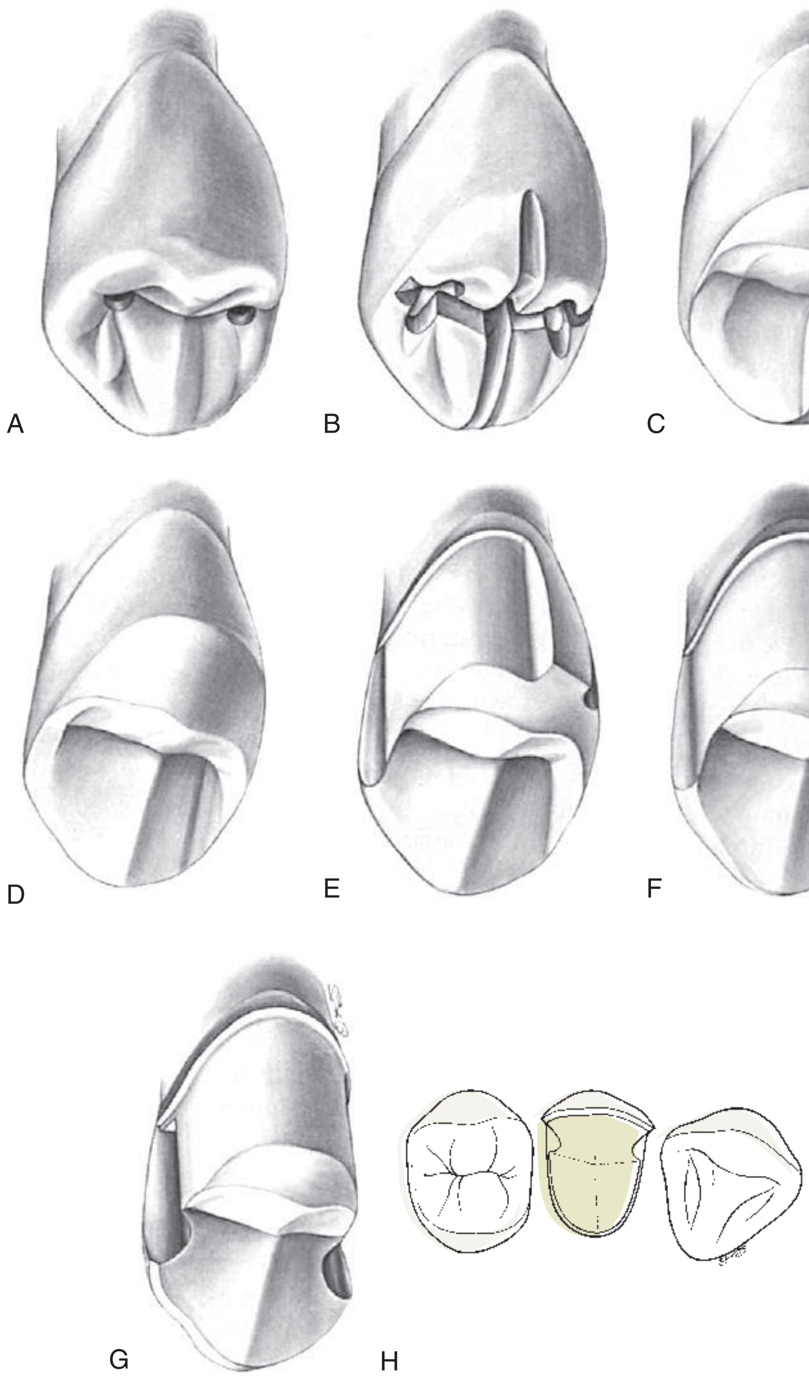


Fig. 11.4 The maxillary premolar three-quarter crown. (A) Initial depth holes approximately 0.8 mm deep are placed in the mesial and distal fossae. (B) They are connected by a guiding groove that extends through the central groove. Additional guiding grooves similar to those for a complete cast crown (see Fig. 8.8) are placed on the lingual cusp. The depth cut placed on the triangular ridge of the buccal cusp becomes shallower as it approaches the cusp tip. (C) Half the occlusal reduction is completed. Note the functional cusp bevel. The occlusocervical height of the buccal surface is not reduced at this stage. (D) Occlusal reduction completed. (E) After guiding grooves are placed in the lingual surface of the tooth parallel to the proposed path of placement, the proximoaxial and linguoaxial reductions are initiated. Simultaneously, a smooth and even-width cervical chamfer margin is created. (F) When the axial reduction of the first half is considered acceptable, reduction of the other half can begin. (G) Proximal grooves are placed perpendicular to the prepared surface, and the buccal wall of each groove is flared to leave no unsupported enamel. The proximal flares are connected with a narrow contrabevel. After rounding of the line angles, the preparation is complete. (H) The interproximal clearance in relation to adjacent teeth extends both cervically and near the occlusal aspect of the buccal flares of the proximal grooves.

Fig. 11.5 The anticipated location of the completed preparation is marked with a sterilized pencil.

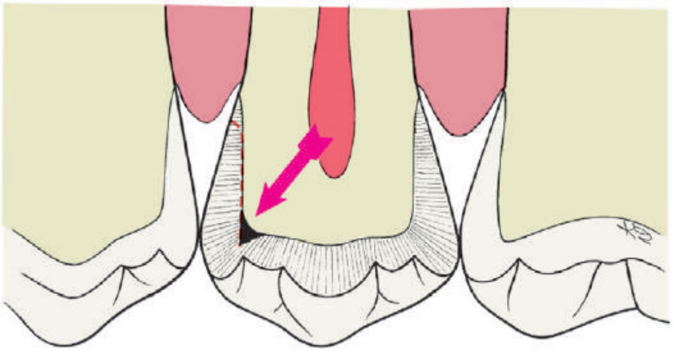


Fig. 11.6 A common error is insufficient reduction of tooth structure in the buccolingual center of the marginal ridge area *(arrow)*.

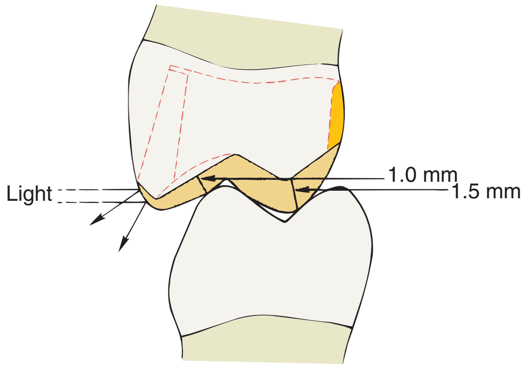


Fig. 11.7 Recommended minimum clearances for reduction of a partial veneer crown preparation. Slight hollow grinding of the lingual incline of the buccal cusp can result in acceptable clearance while resulting in the least metal display. Also, the final restoration retains the normal contours of the cuspal ridge; thus, incident light is not reflected and the restoration is less evident.

Fig. 11.8 Proximal and linguoaxial reduction is performed with a round-ended diamond. The proximal reduction is stopped short of the proposed location of the buccal margin.

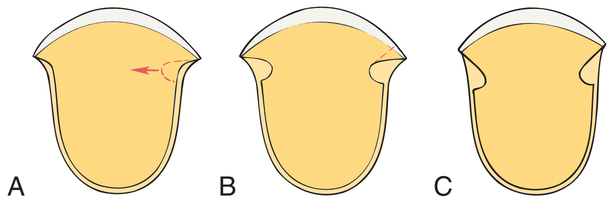


Fig. 11.9 (A) Upon completion of the proximoaxial reduction, a groove is placed perpendicular to the prepared surface. (B) Note that some unsupported tooth structure remains at the cavosurface angle. (C) After the buccal wall of the proximal groove is flared, no unsupported tooth structure remains. *Note:* It is important to anticipate the influence of the buccal extent of the proximoaxial reduction (A) on the ultimate location of the margin (C).

path of placement toward the buccal aspect. This reduces retention, leads to excessive display of metal, or both. A periodontal probe placed in each groove should be carefully viewed in both mesiodistal and buccolingual planes. It often helps to pour an irreversible hydrocolloid (alginate) impression in fast-setting plaster and to evaluate the cast with a dental surveyor; this is particularly useful if multiple partial veneers are being used as retainers for an FPD.

8. After alignment verification and, if necessary, correction, the tooth structure between the orientation grooves is removed with a smooth continuous motion, simultaneously with development of a cervical chamfer margin (Fig. 11.8).
9. Carry the diamond into the proximal embrasure to reduce the proximal wall (see Fig. 11.4E and F). For proper extension of the proximal reduction of the axial tooth surface, it is critical to understand the factors that affect the correct position of the proximal groove. A proximal groove is placed parallel to the path of placement. Normally, unsupported tooth structure remains on the buccal side of the groove, and this side is flared to remove it. Fig. 11.9 illustrates the relationship among the initial axial reduction, groove placement, and location of the cavosurface angle where the flare meets the intact buccal wall. The cavosurface angle is especially significant when a tooth is prepared for a cast partial veneer that should display a minimum of metal; the farther to the buccal aspect the margin is, the more visible it will be. A subtle but important variable that affects the final location of the buccal margin is the apical extension of the

preparation. As the cervical chamfer margin is placed closer to the cementoenamel junction, more axial tooth structure must be removed because of the normal anatomical shape of the abutment. Consequently, the deepest portion of the groove (its pulpal wall) is then located slightly closer to the mesiodistal center of the tooth. This results in a flare that will extend farther onto the facial or buccal surface than may be desirable. Marking the planned location of the intended facial flare on the tooth with a sterilized pencil before initiating the proximoaxial reduction is helpful. The intersection of this mark with the reduced proximal surface is a convenient reference point (see Fig. 11.5).

10. Stop the proximal reduction well short of the pencil mark and usually slightly short of breaking the proximal contact (Fig. 11.10). The resulting flange should parallel the linguoaxial preparation, with the chamfer margin placed sufficiently cervical to provide at least 0.6 mm of clearance with the adjacent tooth and adequate axial wall height, to permit subsequent placement of a proximal groove that is at least 4 mm long occlusocervically (see Fig. 11.4F and G).

Groove placement. The proximal grooves are best prepared with a tapered tungsten carbide bur.

11. Position the bur against the interproximal flange parallel to the path of placement and make a groove perpendicular to the axial surface. The groove need not be deeper than 1 mm at its cervical end but may be deeper near its occlusal end (Fig. 11.11). During this stage, the bur must be held precisely parallel to the selected path of placement. Allowing it to tip axially results in excessive taper between opposing proximal grooves, a common error. The criteria that need to be met consist of the following:
   - The grooves should resist lingual displacement of a periodontal probe or explorer (Fig. 11.12).
   - The walls of the grooves should not be undercut in relation to the selected path of placement.
   - The walls should be flared toward the intact buccal surface of the tooth (see Fig. 11.4G and H).

Depending on available access, it may be feasible to complete the flaring with the same rotary instrument that was used to place the groove (Fig. 11.13). However, removing the last "lip"

Fig. 11.10 The distal proximal reduction is stopped before proximal contact is broken. After groove placement and subsequent flaring, interproximal clearance results.

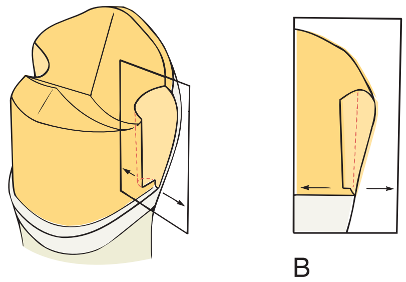


Fig. 11.11 Because of the rotary instrument's taper, the proximal groove is deeper near the occlusal table (A). The floor of the groove should be flat and smooth. The proximal chamfer margin often extends slightly cervically to the floor of the groove. If only minimal difference exists (B) the cervical margin adjacent to the groove can be beveled. The recommended occlusocervical height for a proximal groove is 4 mm.

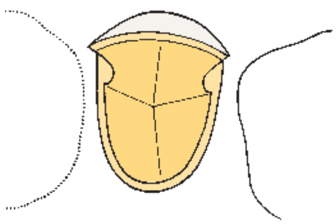


Fig. 11.12 The 90-degree angle between the lingual walls of the proximal grooves and the axial walls resists lingual displacement. Because the buccal aspect of the grooves has been adequately flared, no unsupported tooth structure remains.

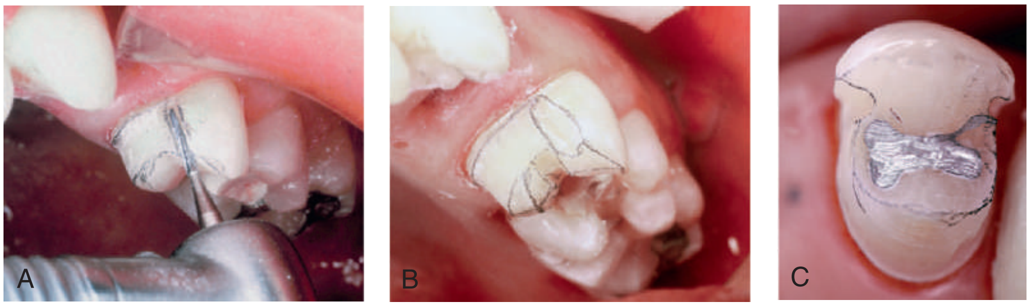


Fig. 11.13 (A) Initial preparation of the mesioproximal groove. Note that the tungsten carbide bur is oriented parallel to the path of placement as dictated by the lingual surface of the tooth. (B) Initial flaring has resulted in elimination of most unsupported tooth structure. (C) Hand or rotary instruments are used to refine these proximal flares and remove all unsupported enamel.

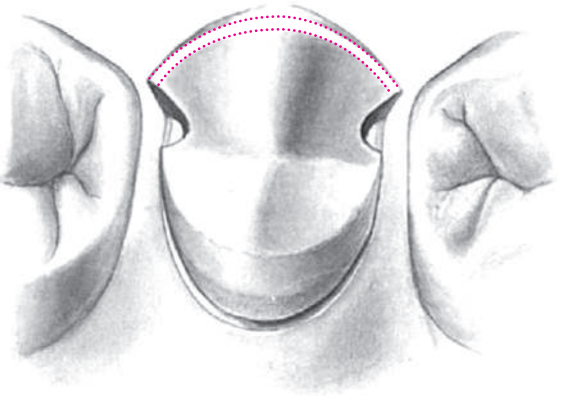


Fig. 11.14 The bucco-occlusal contrabevel remains within the curvature of the cusp tip rather than extending onto the buccal surface.

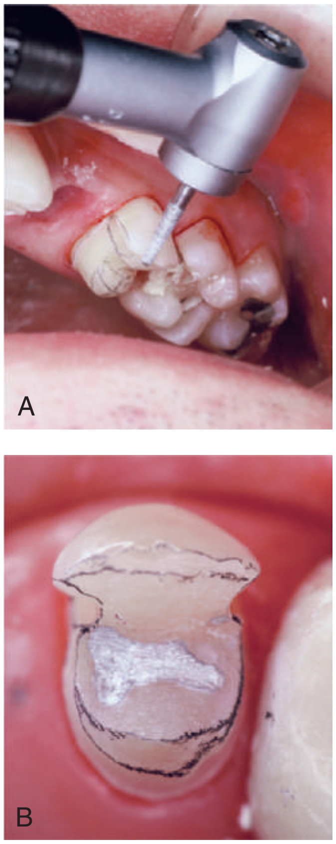


Fig. 11.15 (A and B) A fine-grit diamond in a low-speed contra-angle handpiece is used to place the bucco-occlusal contrabevel that connects the mesioproximal and distoproximal flares.

of unsupported tooth structure with a chisel is often a better option because this minimizes the risk of damage to the adjacent tooth.

Bucco-occlusal contrabevel

12. Connect the mesial and distal flares with a narrow contrabevel that follows the buccal cusp ridges. This can be placed with a diamond, a tungsten carbide bur, or even a hand instrument. Its primary purpose is to remove any unsupported enamel and thereby protect the buccal cusp tip from chipping during function. If group function is planned (as opposed to a mutually protected occlusion), a heavier bevel, a chamfer margin, or an occlusal offset is needed because tooth contact occurs in this area during excursive movement. The bevel should remain within the curvature of the cusp tip, rather than extend onto the buccal wall (Fig. 11.14). This results in a convex shape of the restoration, and light is prevented from reflecting back to a casual observer (see Fig. 11.7). Thus the restoration is less obvious, and the outline form of remaining buccal enamel is perceived as the shape of the tooth.

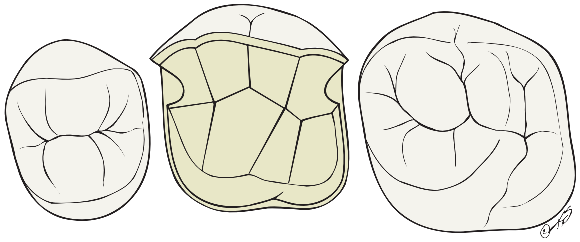


Fig. 11.16 The three-quarter crown preparation on a maxillary first molar.

Finishing

13. With the exception of the junction between grooves and proximal walls, round all sharp internal line angles to facilitate subsequent procedures. A fine-grit diamond or tungsten carbide bur can be used to blend the surfaces (Fig. 11.15).
14. Reevaluate the flares, paying particular attention to any remaining undercuts, which must be removed. The flares should be monoplane, straight, and smooth, with sufficient clearance between them and the adjacent tooth. A minimum clearance of 0.6 mm is recommended. The mesial flare cannot extend beyond the transitional line angle. However, because the distal margin is less visible, it may extend slightly farther to the buccal margin, allowing easier access (Fig. 11.16). Fig. 11.17 shows the step-by-step sequence of a three-quarter cast partial veneer crown on a maxillary molar.

Examples of Other Cast Partial Veneer Crowns

Although largely surpassed in popularity by adhesively bonded ceramic restorations—at least for restoration of single teeth—a few clinical examples of other types of cast partial veneer crowns are illustrated to help understand the geometry of their preparation designs and since they still may be encountered clinically. Fig. 11.18 shows the design of a seven-eighths crown on a maxillary molar and a clinical example. A modified three-quarter crown used as a retainer for a three-unit FPD is illustrated in Fig. 11.19.

With the advent of metal-ceramic and ceramic restorations, the use of partial veneer restorations on anterior teeth has become rare. Nevertheless, two anterior partial veneer

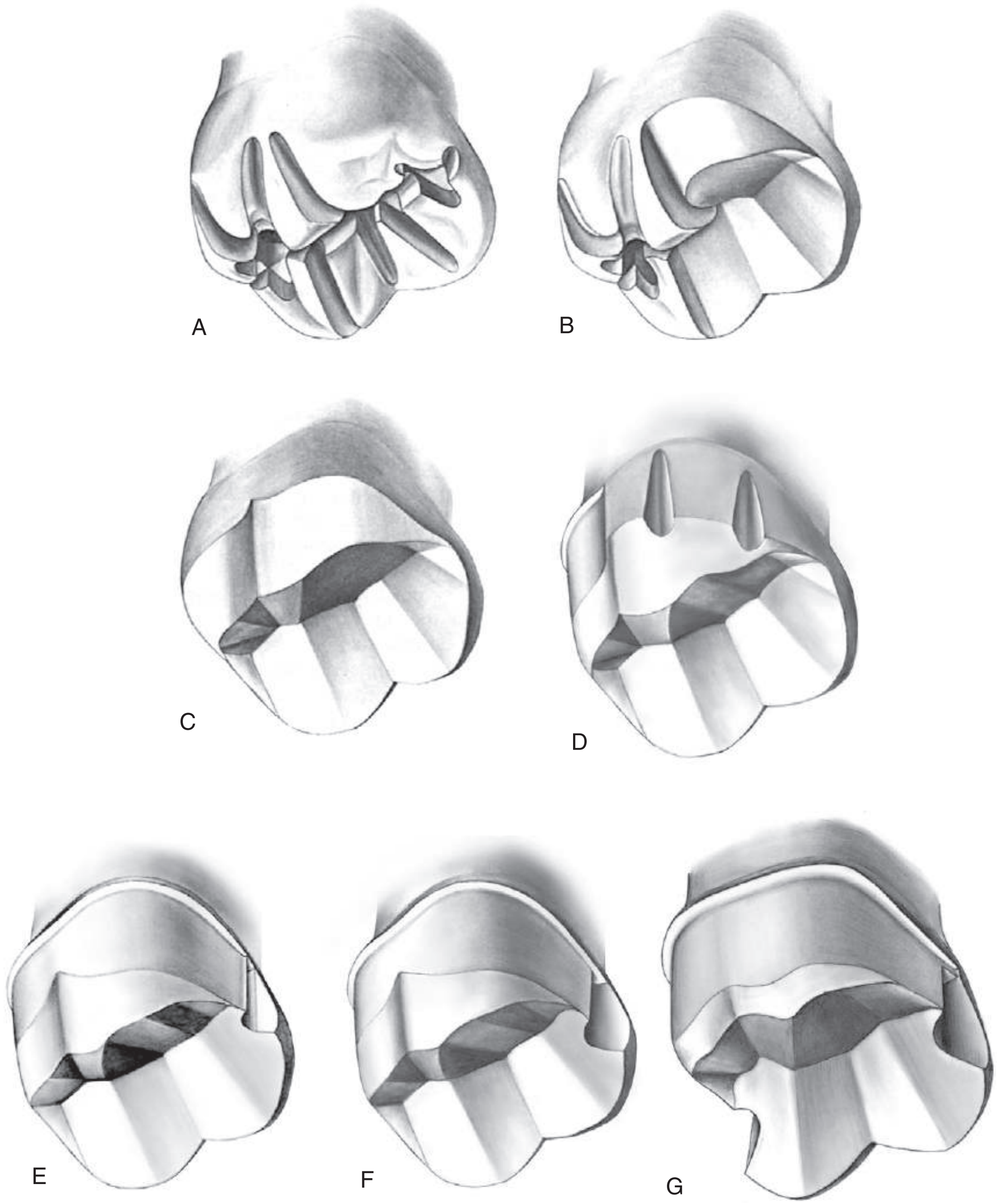


Fig. 11.17 The maxillary molar three-quarter crown preparation. (A) Occlusal depth grooves. On the lingual aspect of the mesiobuccal cusp, they are identical to grooves for any functional cusp. On the buccal aspect, note their difference from grooves placed on the triangular ridges. The mesial groove becomes shallower as it approaches the cuspal ridge. (B) Occlusal reduction is partially completed. A semblance of normal occlusal form can be recognized in the reduced area. (C) Completed occlusal reduction. (D) Distal half of the axial reduction is completed, comparable with the preparation for a complete cast crown. The rotary instrument is moved parallel to the guiding grooves placed in the lingual tooth surface. (E) Mesial half of the axial reduction is completed, and a proximal groove is placed. (F) The proximal grooves are then flared. Note the monoplane of the flare, extending from the deepest portion of the groove to the cavosurface angle. (G) Lingual view of the completed preparation.

crown preparations, the maxillary canine three-quarter crown and the pinledge, are worthy of study. Few preparations are as technically demanding as the three-quarter crown preparation on a maxillary canine (Fig. 11.20) which stems from the proximal curvature that this tooth exhibits. This challenge is illustrated in Fig. 11.21. A clinical example is shown in Fig. 11.22.

Although always considered technically challenging, pinledge preparations (Fig. 11.23) were used on intact anterior teeth and encompassed minimal tooth reduction while providing adequate mechanical support for short-span FPDs or splints (Fig. 11.24). They are of interest because their clinical application enhanced our understanding of optimal placement of pinholes in anterior teeth (Fig. 11.25).

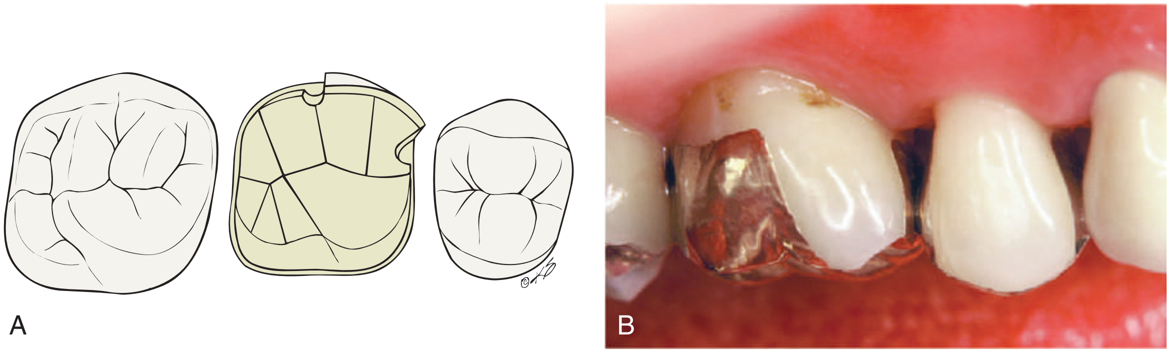


Fig. 11.18 (A) The seven-eighths crown preparation. Note that adequate clearance has been established. From this perspective, it is evident why little or no flaring is necessary for the buccal groove, as opposed to the considerable flaring needed for the mesial groove. (B) Seven-eighths crown restoring maxillary molar.

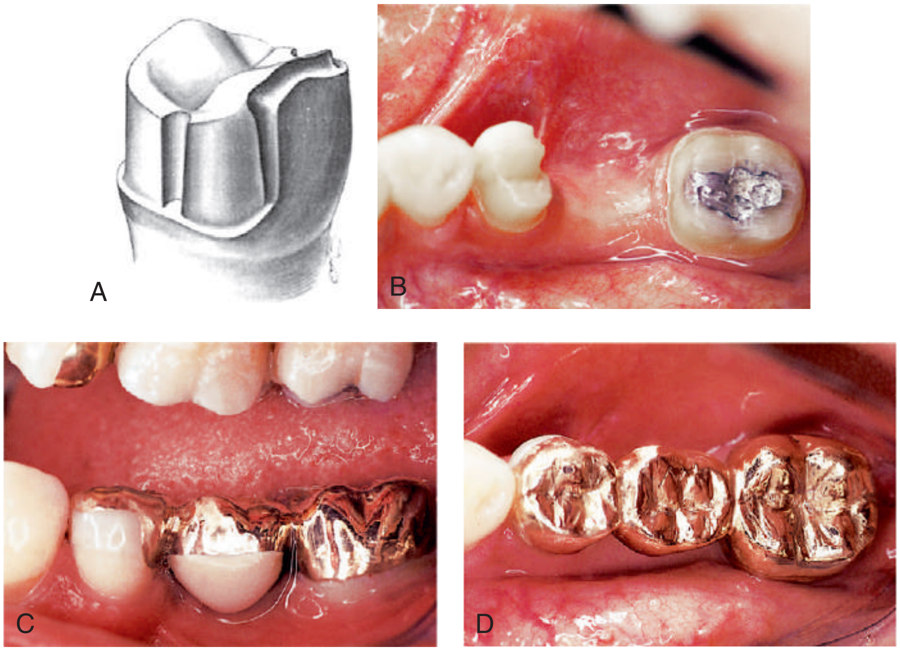


Fig. 11.19 (A) Modified three-quarter crown preparation on mandibular premolar. Note that the distal groove is positioned close to the bucco-lingual center of the tooth to preserve the strength of the distobuccal aspect of the preparation. The extension of the preparation onto the buccal surface of the tooth (but kept distal to the visible mesial part of the tooth) compensates for the relatively short clinical crowns of mandibular premolars compared with maxillary premolars. Also note the considerable width of the chamfer margin on the functional cusp. (B) The modified three-quarter crown on the second premolar serves as the anterior retainer for a three-unit fixed partial denture (C). Because the distobuccal modification remains in the distal fourth of the buccal preparation, it is hidden behind the normal height of contour of the buccal tooth surface (D). Note the considerable thickness of gold that protects the buccal cusp.

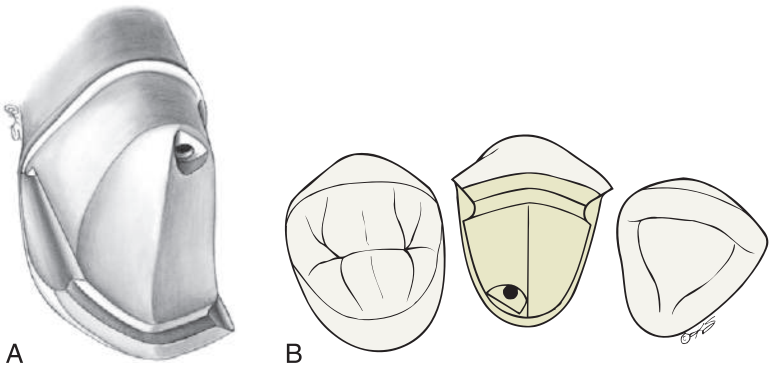


Fig. 11.20 Maxillary canine three-quarter crown: (A) Note the lingual pinhole that is surrounded by adequate dentin and the horizontal ledge that is prepared before pinhole placement. The incisal offset that provides additional strength near the somewhat fragile incisal edge. (B) Completed three-quarter crown preparation. Note the location of the labial margin in relation to the adjacent teeth. Sufficient interproximal clearance has been established, but unnecessary display of metal is avoided.

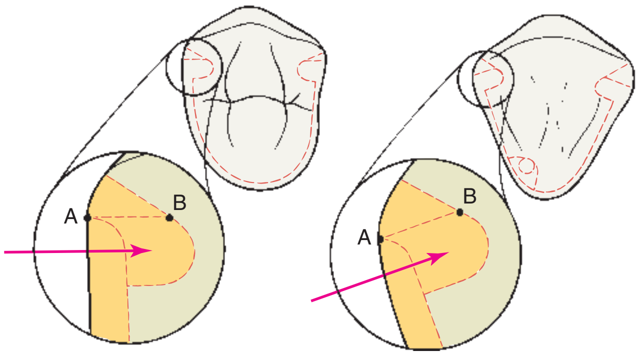


Fig. 11.21 Differences between the proximal flares on premolars *(left)* and canines *(right)*. In both images, label (A) designates where the initial proximal reduction is halted. Because a facial component is present in the direction of groove placement on the canine, as opposed to the premolar, the starting point (B) for the flare is located farther to the facial aspect. In conjunction with the greater degree of proximal curvature of canines, it is crucial that the initial proximal axial reduction not be carried too far facially; otherwise, the final margin will extend too far onto the labial surface of the tooth and result in excessive display of metal.

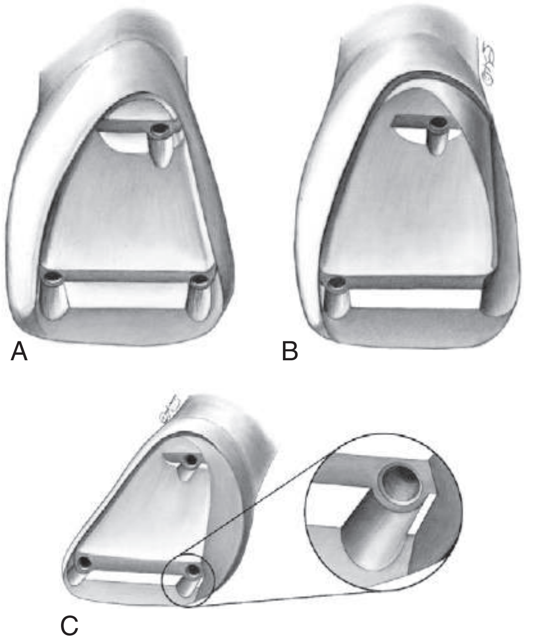


Fig. 11.23 Pinledge preparations. (A) Pinholes are prepared to a depth of 2 mm. The junction between the ledge and the pinholes has been countersunk. (B) When used as a retainer the preparation can be modified by adding a proximal groove, the path of which is compatible with that of the pinholes or (C) by adding a proximal slice.

Fig. 11.22 (A) Caries-free canine: excellent candidate for anterior partial veneer crown serving as anterior retainer of a three-unit fixed partial denture (FPD). (B) Satisfactory esthetic appearance with minimal display of metal although some light reflection from the connector is visible (C).

Fig. 11.24 (A) Periodontally compromised but caries-free teeth of adequate buccolingual width are excellent candidates for a pinledge retained fixed splint. (B) The definitive cast. (C) Pinledge splint consisting of six separate castings that were soldered together and seated. (D) As a result, display of metal is minimal. The pinledge preparations allow retention of the intact labial enamel of all six anterior teeth.

INLAYS AND ONLAYS

Indications

An inlay can be used instead of amalgam for patients with a low caries rate who require a small interproximal restoration in a tooth with ample supporting dentin. It is among the least complicated cast restorations to make and can be very durable when done carefully. An onlay allows a damaged occlusal surface to be restored with a casting in the most conservative manner. It should be considered in the restoration of a severely worn dentition when the teeth are otherwise minimally damaged or for the replacement of a mesio-occlusal–distal (MOD) amalgam restoration when sufficient tooth structure remains for retention and resistance form.

Contraindications

Because these restorations rely on intracoronal (wedging) retention, inlays and onlays are contraindicated unless there is sufficient bulk to provide resistance and retention form. MOD inlays may increase the risk of cusp fracture and are generally not recommended. Extensive onlays, required where caries or existing restorations extend beyond the facial or lingual line angles, are contraindicated unless pins are used to supplement retention and resistance.

Advantages

Cast inlays and onlays can be extremely long-lived restorations because of the excellent mechanical properties of the gold alloy (see Fig. 11.1). Low creep and corrosion mean that if inlay or onlay margins are accurately cast and finished, they will not deteriorate. The lack of corrosion may also offer an esthetic advantage. Gold does not lead to the tooth discoloration sometimes associated with dental amalgam. Unlike an inlay or amalgam, an onlay can support cusps, reducing the risk of tooth fracture.

Disadvantages

In the restoration of a small carious lesion, an inlay is not very conservative of tooth structure. This is because additional tooth removal is necessary after minimal proximal extension to achieve a cavity preparation without undercuts and to enable access for impression making. This extension may lead to additional display of metal and to gingival encroachment, which is undesirable for periodontal health. Because inlays do not encircle the tooth, the bulk of the buccal and lingual cusps must provide resistance and retention form. Of concern is that high occlusal force may lead to cusp fracture as a result of wedging from the inlay.

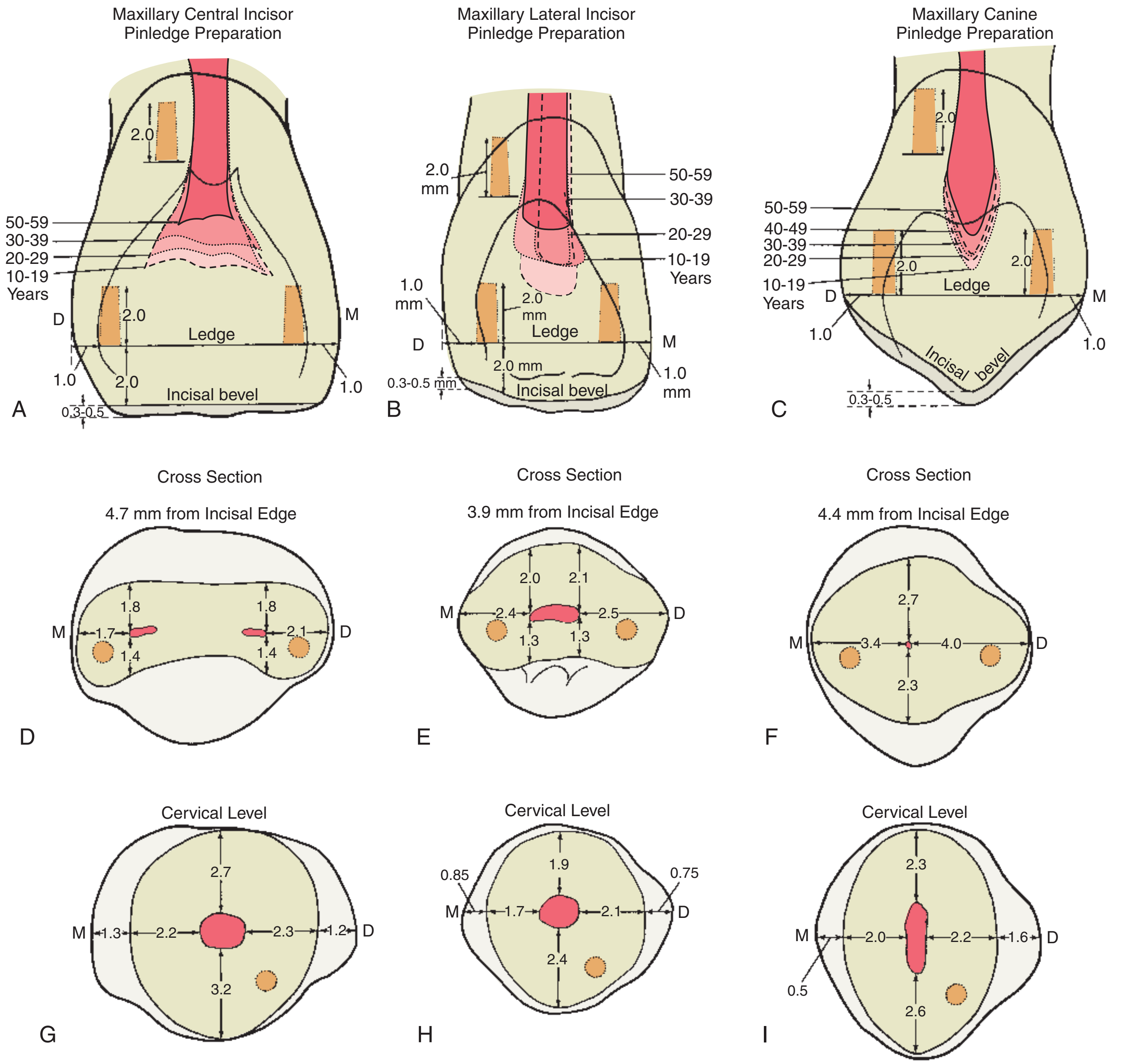


Fig. 11.25 Relationship between pinhole placement and pulp configuration. (A–C) Lingual views. (D–F) Cross-sectional views through incisal pinholes. (G–I) Cross-sectional views through cervical pinholes. *Dashed lines* show the mean pulp chamber sizes of various age groups. *D*, Distal; *M*, mesial. (Data from Ohashi Y. Research related to anterior abutment teeth of fixed partial denture. *Shikagakuho*. 1968;68:726.)

Preparation

Armamentarium

Tungsten carbide burs are usually used for inlay or onlay preparations (Fig. 11.26), but diamonds can be substituted if preferred:

- Tapered tungsten carbide burs
- Round tungsten carbide burs
- Cylindrical tungsten carbide burs
- Finishing stones
- Mirror
- Explorer and periodontal probe

Fig. 11.26 Armamentarium for inlays and onlays.

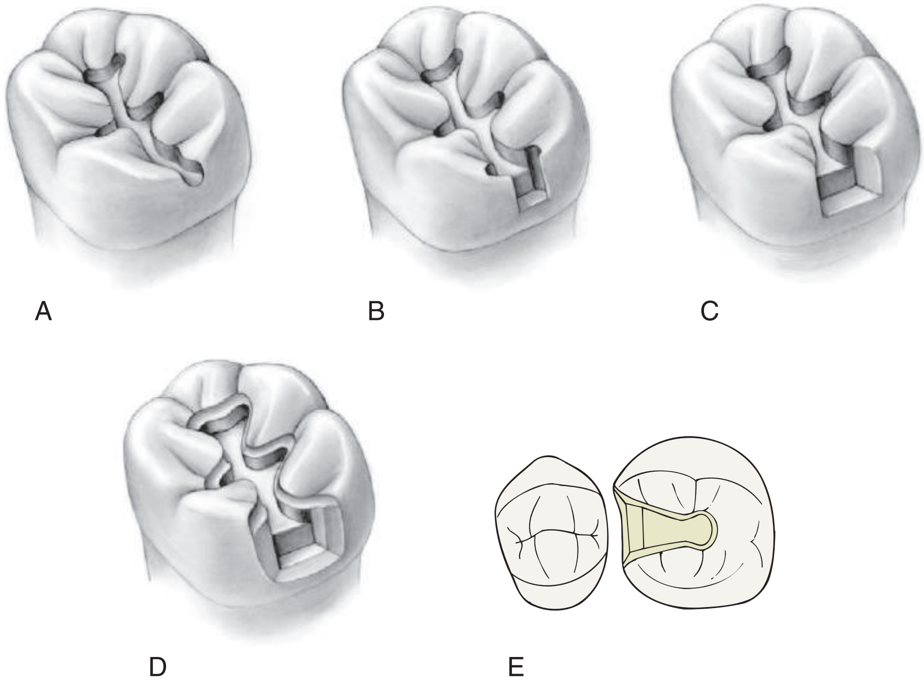


Fig. 11.27 The mesio-occlusal inlay preparation. (A) An occlusal outline is prepared, following the central groove and extending proximally. (B) Gingival extension undermines the marginal ridge during caries removal. (C) Unsupported enamel is removed, and the walls of the proximal box are defined. This is easily accomplished with hand instruments. (D) An occlusal bevel or chamfer margin completes the preparation. (E) Occlusal view of the completed preparation.

- Chisels
- Hatchet
- Gingival margin trimmers
- Excavators
- High- and low-speed handpieces
- Articulating film

Mesio-occlusal or Distal-occlusal Inlay Preparation

The MO or DO inlay preparation follows a series of steps (Fig. 11.27).

Occlusal Analysis

1. Carefully assess the occlusal contact relationship and mark it with articulating film. The margins of the restoration should not be too close (≥1.0 mm) to a centric contact; otherwise, there will be damaging stresses at the gold-enamel junction.
2. Apply rubber dam. Because good visibility and moisture control are essential during tooth preparation and caries excavation, the use of a rubber dam is strongly recommended.

Outline Form

3. Penetrate the central groove just to the depth of the dentin (typically about 1.8 mm) with a small round or tapered tungsten carbide bur held in the path of placement of the inlay. In general, this is perpendicular to an imaginary line connecting the buccal and lingual cusps, not necessarily perpendicular to the occlusal plane. For example, on mandibular premolars, it is angled toward the lingual aspect.
4. Extend the occlusal outline through the central groove with the tapered tungsten carbide bur. The bur should be held in the same path of placement and kept at the same depth: just into dentin. The buccolingual extension should be as conservative as possible to preserve the bulk of the buccal and lingual cusps. Resistance to proximal displacement is achieved with a small occlusal dovetail or pinhole. The outline should avoid the occlusal contacts.
5. Extend the outline proximally, undermining the marginal ridge, and stop it at the height of contour of the ridge (Fig. 11.28A).
6. Advance the bur cervically to the carious lesion and then lingually and buccally, taking care to hold it in the precise path of placement. A thin layer of enamel should remain between the side of the bur and the adjacent tooth (see Fig. 11.28B). This prevents accidental damage. The bur should move parallel to the original unprepared proximal surface, creating a convex axial wall in the interproximal preparation or box. The opposing buccal and lingual walls contribute significantly to retention; therefore, great care must be taken not to tilt the bur during this step. It should be held in the path of placement throughout. The width of the gingival floor of the box should be about 1.0 mm (mesiodistally). Correct cervical, lingual, and buccal extension at this stage is just beyond the proximal contact area. The completed inlay will require a minimum proximal clearance of 0.6 mm to allow an impression to be made, but some of this will be achieved with the proximal flares and gingival

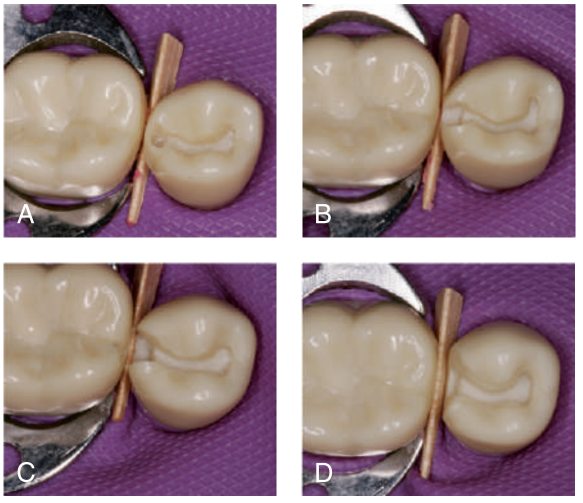


Fig. 11.28 Preparation of a mandibular premolar tooth for a disto-occlusal inlay. (A) Occlusal outline. (B) Proximal box initiated. (C) Proximal box extended to remove contact. (D) Completed preparation. (Courtesy Dr. H. Bowman.)

bevels. Sharp line angles between the occlusal outline and proximal box are rounded at this time (see Fig. 11.28C).

Caries Excavation

7. Identify and remove any caries not eliminated by the proximal box preparation, with the use of an excavator or a round bur in the low-speed handpiece.
8. Place a cement base to restore the excavated tissue in the axial wall, pulpal floor, or both. If necessary, the preparation can be extended buccally or lingually. An inlay is not a suitable restoration for extensive caries and carrying it beyond the line angles will lead to a significant loss of retention and resistance form.

Axiogingival Groove and Bevel Placement

9. Prepare a small, well-defined groove at the junction of the axial and gingival walls at the base of the proximal box to enhance resistance form and prevent distortion of the wax pattern during manipulation. It is easily placed with a gingival margin trimmer held in contact with the axial wall to prevent creating an undercut.
10. Place a 45-degree gingival margin bevel with a thin, tapered tungsten carbide bur or a fine-grit diamond. Correct orientation is achieved by holding the instrument parallel to the gingival third of the proximal surface of the adjacent tooth. The bur should not be tilted buccally or lingually to the path of placement; otherwise, an undercut will be created at the corners of the box (a common error in inlay preparations).
11. Prepare proximal bevels on the buccal and lingual walls with the tapered bur oriented in the path of placement. There should be a smooth transition between the proximal and gingival bevels.
12. Place an occlusal bevel to improve marginal fit and allow finishing of the restoration. When the cuspal anatomy is steep, a conventional straight bevel produces too little metal near the margin for strength and durability. A hollow-ground bevel or chamfer margin is normally preferred and can be conveniently placed with a round bur or stone.
13. As a final step, smooth the preparation where necessary, paying particular attention to the margin (see Fig. 11.28D).

Fig. 11.29 shows some outstanding clinical examples of conservative cast inlays.

Mesio-occlusal–distal Onlay Preparation

The occlusal outline and proximal boxes of an onlay preparation (Fig. 11.30) are similar to those of an inlay. The additional steps are the occlusal reduction and a functional (centric) cusp ledge.

Outline Form

1. Prepare the occlusal outline with a tapered tungsten carbide bur just beyond the enamel-dentin junction (approximately 1.8 mm deep) and extend it through the central groove, incorporating any deep buccal or lingual grooves. Existing amalgam restorations are removed as part of this step (Fig. 11.31A).
2. Extend the outline both mesially and distally to the height of contour of the marginal ridge. As with an inlay, prepare the boxes with an MOD onlay by advancing the bur gingivally and then buccally and lingually, always holding it in the precise path of placement of the preparation. If a thin section of proximal enamel remains as the bur advances, damage to the adjacent tooth will be prevented (see Fig. 11.31B). Correct gingival, buccal, and lingual extension of the preparation normally depends on the contact area with the adjacent tooth. A minimum clearance of 0.6 mm is needed for impression making. Sometimes existing restorations or caries necessitate that a box be extended beyond optimal. However, if a box requires extension beyond the transitional line angle, the preparation will have little resistance form, and an alternative restoration, such as a complete crown, should be considered. Preparing the boxes is a key step when an onlay is fabricated (see Fig. 11. 31C and D). The tapered bur should be held precisely in the planned path of placement throughout. Tilting, often caused by attempts to advance the bur too quickly, is common and is difficult to correct.
3. Round sharp line angles between the occlusal outline and proximal boxes.

Caries Excavation

4. Remove any remaining caries by using an excavator or a round bur in the low-speed handpiece.
5. Place a cement base to restore the excavated tissue. Good judgment is needed to ensure that sound dentin on the axial walls is adequate for providing retention and resistance.

Occlusal Reduction

6. Place depth grooves on the functional cusps. To provide additional clearance at the cusp tip, the bur must be oriented more horizontally than the intended restoration

Fig. 11.29 (A–F) Examples of posterior quadrants restored with cast gold inlays. Note the replication of normal embrasure form, the outstanding finish and marginal adaptation. Note that on the first molars in C, D, and E the oblique ridge was kept intact, resulting in conservation of tooth structure and strength, in contrast with the MODL inlay in B. (Courtesy of Dr. R.V. Tucker.)

cusp. The grooves should be 1.3 mm deep, allowing 0.2 mm for smoothing (see Fig. 11.31E).

7. Place 0.8-mm grooves on the nonfunctional cusps. The bur is oriented parallel to the cuspal inclines. As with all depth grooves, it is assumed that the tooth is in good occlusal relation before preparation. If it is not, a vacuum-formed matrix made from the diagnostic waxing procedure is recommended as a guide.
8. Connect the grooves to form the occlusal reduction, maintaining the general contour of the original anatomy.
9. Prepare a 1.0-mm functional cusp ledge with the cylindrical tungsten carbide bur (see Fig. 11.31F). This provides the restoration bulk in a high-stress area, preventing deformation during function. The ledge should be placed about 1 mm apical to the opposing centric contacts. It extends into the proximal boxes but should not be positioned too

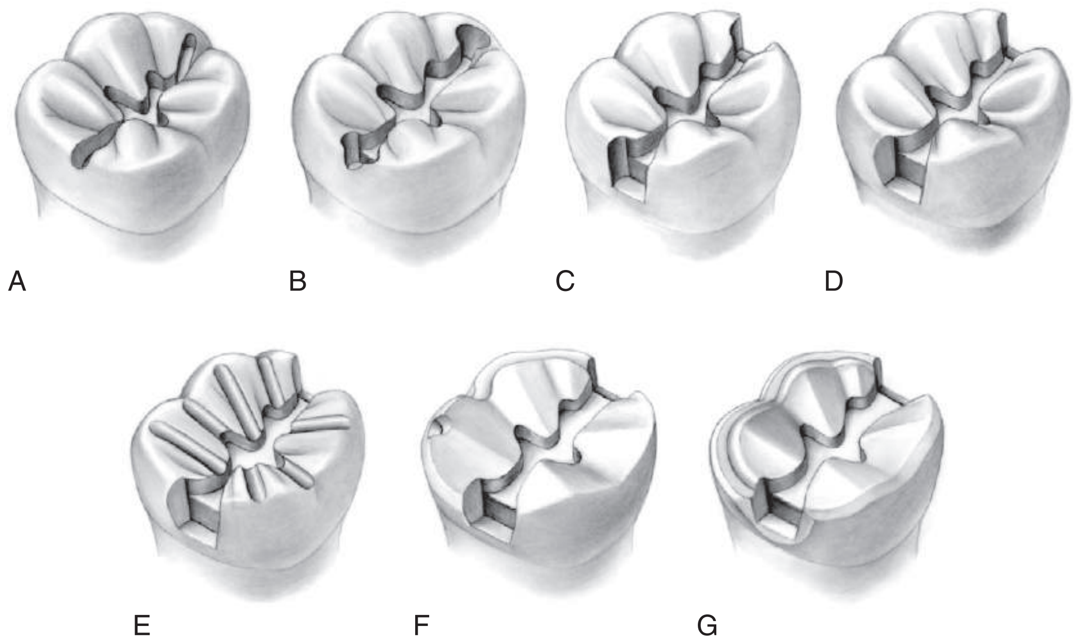


Fig. 11.30 The mesio-occlusal–distal (MOD) onlay preparation. (A) An occlusal outline is prepared to follow the central fossa. (B) The marginal ridges are undermined. (C and D) The proximal boxes are refined. They should extend just beyond the proximal contact area. (E) Depth grooves are placed for occlusal reduction: 0.8 mm on the nonfunctional cusp and 1.3 mm on the functional cusp. (F) Note the buccal functional cusp bevel as part of the completed occlusal reduction. A buccal shoulder margin is prepared, approximately at the level of the pulpal floor. (G) A continuous bevel completes the preparation. The bevel on the buccal shoulder margin makes a smooth transition into the proximal bevel of the box. A small contrabevel is placed on the lingual cavosurface margin.

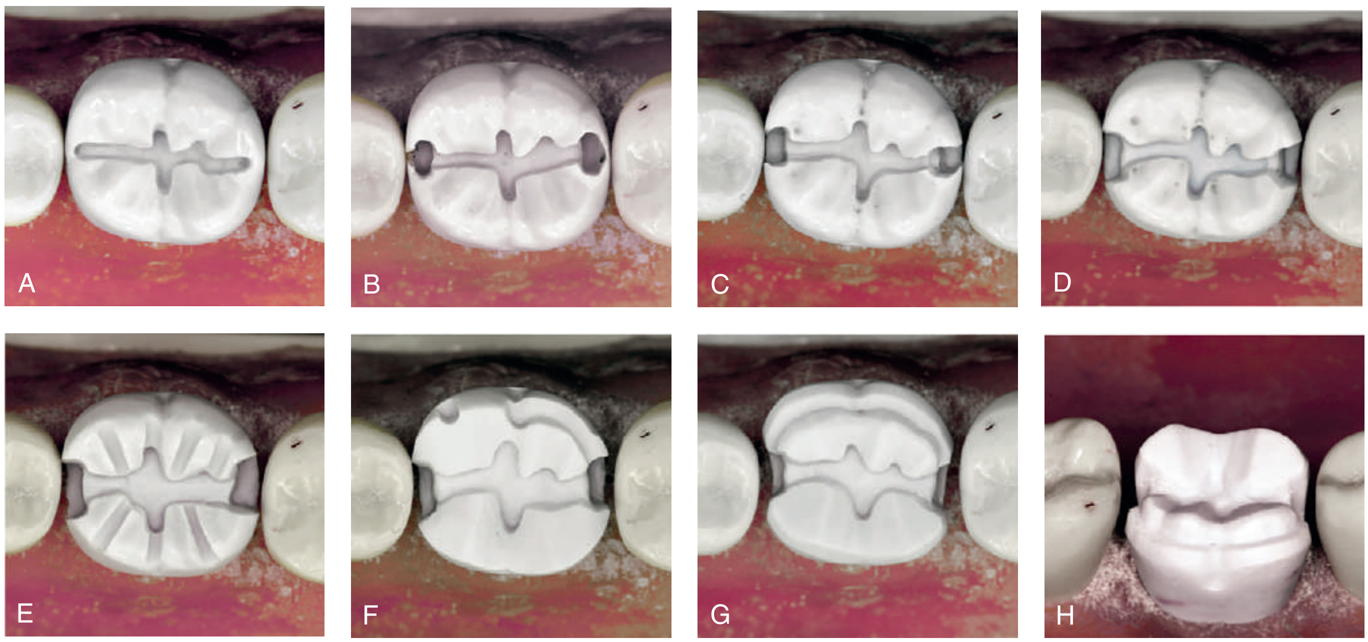


Fig. 11.31 Preparation of a mandibular molar tooth for a mesio-occlusal–distal (MOD) onlay. (A) Preparation outline. (B) Proximal boxes are extended to remove contacts. (C) Unsupported enamel is removed with hand instruments. (D) Proximal boxes are extended to form a 90-degree cavosurface angle. (E) Occlusal reduction grooves. (F) Functional cusp ledge is placed for distal half. (G and H) Completed preparation. (Courtesy Dr. H. Bowman.)

far apically; otherwise, the resistance form from the boxes will be lost.

10. Round any sharp line angles, particularly at the junction of the ledge and occlusal surface.
11. Check for adequate occlusal reduction by having the patient close the jaws into soft wax and measuring with a thickness gauge.

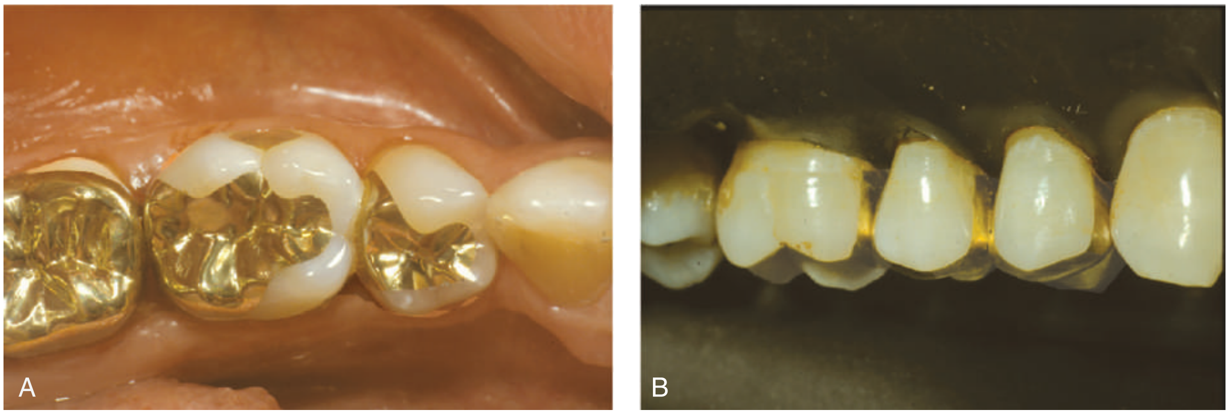


Fig. 11.32 (A) Onlays were used to provide cuspal protection on the second molar and the DL cusp of the first molar. (B) Onlays restore both premolars. Note the minimal light reflection that results from additional curvature having been imparted to the cast alloy (see also Fig. 11.7). (Courtesy of Dr. R.V. Tucker.)

Margin Placement

12. Establish a smooth, continuous bevel on all margins. The gingival bevel is placed, as for an inlay, with the thin tungsten carbide bur or diamond held at a 45-degree angle to the path of placement, or approximately parallel to the adjacent tooth contour. This will blend smoothly with the buccal and lingual bevels, which have been prepared with the bur held in the path of placement.
13. Bevel the nonfunctional and functional cusps. Where additional bulk at the margin is needed, a chamfer margin should be substituted for the straight bevel margin. This can be placed with a round-ended diamond.
14. Complete the preparation by rechecking the occlusal clearance in all excursions and assessing for smoothness (see Fig. 11.31G and H).

Clinical examples of onlay restorations are shown in Fig. 11.32.

STUDY QUESTIONS

1. What are the indications for and contraindications to partial veneer crowns?
2. What are the advantages and disadvantages of partial veneer crowns?
3. What is the recommended armamentarium, and in what sequence should a maxillary premolar be prepared, for a partial veneer crown?
4. What are the minimal criteria for each step just described?
5. What are the indications for and contraindications to inlay/onlay restorations?
6. What are the advantages and disadvantages of inlay/onlay restorations?
7. What is the recommended armamentarium, and in what sequence should a mandibular molar be prepared, for an inlay/onlay restoration?
8. What are the minimal criteria for steps 5, 6, and 7? Why?

SUMMARY CHART

Partial Veneer Crown Preparation

Indications	Contraindications	Advantages	Disadvantages
Posterior Teeth			
• Sturdy clinical crown of average length or longer • Intact buccal surface not in need of contour modification and well supported by sound tooth structure • No conflict between axial relationship of tooth and proposed path of placement	• Short teeth • Extensive caries • Extensive destruction • Poor alignment • Bulbous teeth • Thin teeth	• Conservation of tooth structure • Easy access to margins • Less gingival involvement than with complete cast crown • Easy escape of cement and good seating • Easy verification of seating • Electric vitality test feasible	• Less retentive than complete cast crown • Limited adjustment of path of withdrawal • Some display of metal
Anterior Teeth			
• Sturdy clinical crown of average length or longer • Intact labial surface that is not in need of contour modification and that is supported by sound tooth structure • No discrepancy between axial relationship of tooth and proposed path of placement of FPD	• Short teeth • Nonvital teeth • Extensive caries • Extensive destruction • Poor alignment with path of withdrawal of FPD • Cervical caries • Bulbous teeth • Thin teeth	• Conservation of tooth structure • Easy access to margins for finishing (dentist) and cleaning (patient) • Less gingival involvement than with complete cast crown • Easy escape of cement and good seating • Easy verification of complete seating • Electric vitality test feasible	• Less retentive than complete cast crown • Limited adjustment of path of insertion • Some display of metal • Not indicated on nonvital teeth

FPD, Fixed partial denture.

Preparation Steps	Recommended Armamentarium	Criteria
Depth grooves for occlusal reduction	Tapered tungsten carbide fissure bur or tapered, round-ended diamond	Clearance of 0.8 mm on nonfunctional cusps, 1.3 mm on functional cusps
Occlusal reduction	Round-ended diamond	Clearance of 1 mm on nonfunctional cusps, 1.5 mm on functional cusps
Depth grooves for axial reduction	Round-ended diamond	Chamfer margin depth of 0.5 mm (no more than half the width of diamond)
Axial reduction	Round-ended diamond	Axial reduction parallel to long axis of tooth
Chamfer margin finishing	Large, round-ended diamond	Smooth and continuous to minimize marginal length and facilitate finishing; distinct resistance to vertical displacement by periodontal probe
Proximal groove	Tapered tungsten carbide fissure bur	Distinct resistance to lingual displacement by probe; parallel to path of placement of restoration; 90-degree angle between prepared axial wall and buccal or lingual aspect of groove
Buccal and occlusal bevel margins (maxilla), chamfer margins (mandible)	Round-ended diamond	Maxillary teeth: bevel extends just beyond cusp tip but remains within curvature of cusp tip
Finishing	Large, round-ended diamond or tungsten carbide bur	Mandibular teeth: minimum of 1 mm of cast gold in area of centric stops
Depth grooves for lingual reduction	Round-ended diamond	All sharp internal line angles (except grooves) rounded to smooth transitions
Lingual reduction	Football-shaped diamond	Should allow for 1 mm of clearance
Incisal bevel	Round-ended diamond	Should have 1 mm of clearance
Depth grooves for axial reduction	Round-ended diamond	Allows for metal thickness $\geq$0.7 mm
—	Round-ended diamond	Allows for 0.5 mm of metal thickness at margin
Axial reduction	Tapered tungsten carbide fissure bur and half-round bur	Extends into interproximal about 0.4 mm lingual of contact area; parallel to incisal two-thirds of labial surface
Retention form (proximal grooves and lingual pinhole)	Fine-grit, tapered diamonds (large and small) or tungsten carbide bur	Grooves parallel to incisal two-thirds of labial surface; should resist lingual displacement; pinhole should be between 2 and 3 mm deep
Finishing and flare	Fine-grit, tapered diamonds or finishing stones.	Lingual wall of groove meets proximoaxial wall at angle of 90 degrees
		All surfaces smooth; buccal wall of groove flared to break proximal contact; resulting cavosurface angle is 90 degrees; no unsupported enamel remaining

SUMMARY CHART

MO or DO Inlay Preparation

Indications	Contraindications	Advantages	Disadvantages	Preparation Steps	Recommended Armamentarium	Criteria
• Small carious lesion in otherwise sound tooth • Adequate dentinal support • Low caries rate • Patient's request for gold instead of amalgam or composite resin	• Extensive caries • Poor plaque control • Small teeth • Adolescents • MOD restorations • Poor dentinal support necessitating a wide preparation	• Superior material properties • Longevity • No discoloration from corrosion • Least complex cast restoration	• Less conservation of tooth structure than amalgam • May display metal • Gingival extension beyond ideal • "Wedge" retention summary chart	Occlusal outline	Tapered tungsten carbide bur	Includes central groove, avoids centric contacts, includes dovetail or pinhole for resistance; approximately 1.8 mm deep
				Proximal box	Tapered tungsten carbide bur	Follows curvature of original tooth surface
				Caries removal	Excavator or round bur	Tissue replaced with base
				Axiogingival groove	Gingival margin trimmer	Detectable with explorer tip (0.2 mm deep)
				Gingival and proximal bevels	Thin, tapered tungsten carbide bur or diamond	Placed at 45 degrees to tooth surface; approximately 0.8 mm wide
				Occlusal bevel	Round tungsten carbide bur or finishing stone	Hollow ground, avoid centric contacts

MOD, Mesio-occlusal–distal.

SUMMARY CHART

MOD Onlay Preparation

Indications	Contraindications	Advantages	Disadvantages	Preparation Steps	Recommended Armamentarium	Criteria
• Worn or carious teeth with intact buccal and lingual cusps • Need to replace MOD amalgam • Low caries rate • Patient's request for gold instead of amalgam	• Extensive caries • Poor plaque control • Short clinical crown or extruded teeth • Lesions extending beyond transitional line angles	• Support of cusps • High strength • Longevity	• Lacks retention • Less conservation of tooth structure than amalgam • May display metal • Gingival extension beyond ideal	Occlusal outline	Tapered tungsten carbide bur	Includes central, buccal, and lingual grooves; about 1.8 mm deep
				Proximal boxes Caries removal	Tapered tungsten carbide bur Excavator or round bur	Follows curvature of original tooth surface Tissue replaced with base
				Occlusal reduction	Tapered tungsten carbide bur	Adequate dentin for resistance and retention
				Centric cusp ledge	Tapered tungsten carbide bur	Following anatomic contours
				Gingival and proximal bevels	Thin, tapered tungsten carbide bur	1.5-mm functional cusp; 1.0-mm nonfunctional cusp About 1.0 mm wide (before beveling) About 1.0 mm apical to centric contact at 45-degree angle; about 0.8 mm wide

MOD, Mesio-occlusal–distal.

12

Restoration of the Endodontically Treated Tooth

An endodontically treated tooth should have a good prognosis. It can resume full function and serve satisfactorily as an abutment for a fixed or removable dental prosthesis. However, special techniques are needed to restore such teeth. Usually, a considerable amount of tooth structure has been lost because of caries, the placement of previous restorations, and the endodontic treatment. This loss of tooth structure complicates subsequent restoration and increases the likelihood of fracture during function.

Two factors influence the choice of technique: the type of tooth (whether it is an incisor, a canine, a premolar, or a molar) and the amount of remaining coronal tooth structure. The latter is probably the most important indicator of prognosis.

A number of different clinical techniques have been proposed to solve these problems, and opinions and preferences vary. Experimental data have improved the understanding of the difficulties inherent in restoring endodontically treated teeth. This chapter offers a rational and practical approach to the challenge.

TREATMENT PLANNING

Because of extensive caries or periodontal disease, tooth removal may make more sense than treating it endodontically, although such a severely damaged tooth occasionally can be restored after orthodontic repositioning or root resection (Fig. 12.1). This should be done if loss of the tooth will significantly jeopardize the patient's occlusal function or the overall treatment plan, particularly when dental implants are not an option. The decision to treat the tooth endodontically can be made only after its restorability has been confirmed. Before being restored, teeth that have been endodontically treated must be evaluated carefully for the following[1]:

- Good apical seal
- No sensitivity to pressure
- No exudate
- No fistula
- No apical sensitivity
- No active inflammation

Inadequate root fillings should be re-treated before fixed prosthodontic treatment is begun. If any doubt about their adequacy remains or if the tooth remains sensitive after such re-treatment, it should be observed for several months until there is definite evidence of success or failure of treatment.

If the coronal structures are largely intact and loading is favorable, as on anterior teeth that are farther removed from the fulcrum than are molars (see Chapter 4), a simple restoration can be placed in the access cavity (Fig. 12.2A). However, if a substantial amount of coronal structure is missing, a post-and-core restoration is indicated instead (see Fig. 12.2B). Molars are often restored with amalgam or composite resin, and a post is rarely needed (see Fig. 12.2C and D). Placing a parallel-sided post in a molar may risk perforation.[2]

Although one-piece post crowns were once made, such prostheses are of only historical interest, although the idea has been reintroduced for the restoration of posterior teeth with computer-aided design and computer-aided manufacturing (CAD-CAM) ceramic or polymer-infiltrated ceramic-network (PICN) restorations.[3,4] Typically, dentists use a two-step technique (Fig. 12.3) consisting of initial placement of a post-and-core foundation restoration, followed by placement of a separately fabricated crown. In the past, a metal post was used most often, although esthetic concerns have increased the use of tooth-colored glass fiber and zirconia ceramic posts,[5,6] which provide the necessary retention for the core. The core replaces any lost coronal tooth structure, enabling optimal tooth preparation geometry. Thus the shape of the residual coronal tooth structure, in combination with the core, should result in an ideal shape for the preparation design that was selected (Fig. 12.4).

Typically, prefabricated posts are used in a two-step procedure in conjunction with a plastic material such as composite resin, resin-modified glass ionomer, or amalgam: First the post is cemented; then the selected core material is applied. After shaping of the core and remaining tooth structure to optimal crown preparation form, an impression is made and a crown fabricated.

A cast post-and-core restoration needs to be slightly undersized in comparison with the canal to achieve optimal internal seating; in contrast, a crown needs to be slightly larger to achieve optimal seating (see Chapter 7). Thus the two-step technique simplifies achieving a satisfactory marginal adaptation because the expansion rate of the two castings can be controlled individually. An added benefit is that it is possible to fabricate a replacement crown, if necessary, without the need for post removal, which can be extremely difficult and can jeopardize the prognosis of the tooth. Finally, making a post-and-core restoration and a separate crown allows selection of a path of placement for the crown that is different from the one selected for the post-and-core restoration. This is often helpful when the tooth is restored to serve as an abutment for a fixed partial denture (FPD).

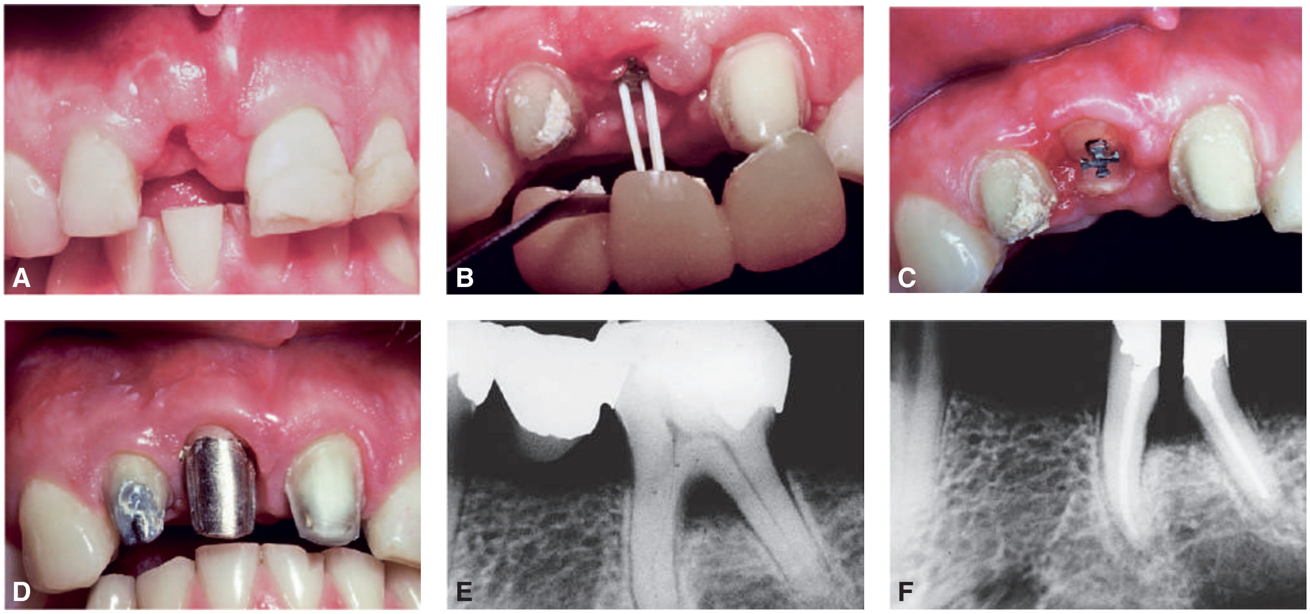


Fig. 12.1 (A and B) A severely damaged tooth can sometimes be retained after orthodontic extrusion (see Chapter 6). (C) Post with retentive head fitted. Elastics were used to extrude the tooth. (D) Cast post and core placed on extruded root. (E and F) Plaque control around periodontally compromised teeth may be improved after hemisectioning (see Chapter 5). (E and F, Courtesy Dr. H. Kahn.)

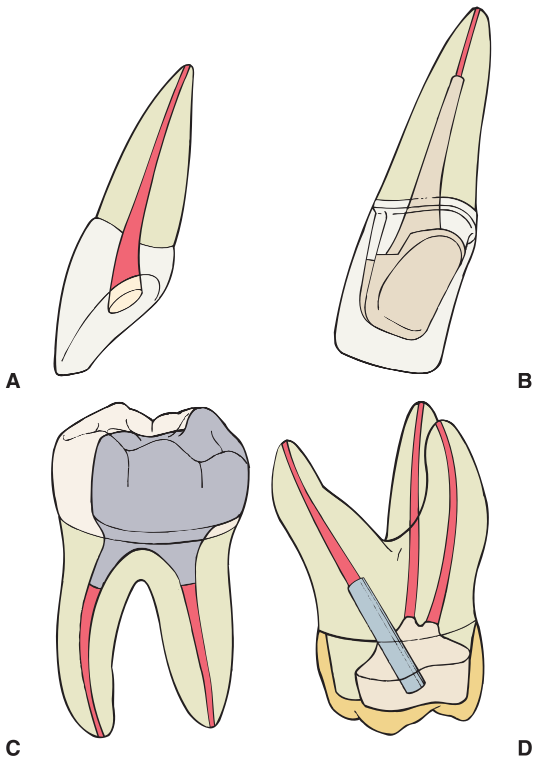


Fig. 12.2 (A) An anterior tooth with an intact clinical crown can be predictably restored with a composite restoration in the access cavity. (B) When most coronal tissue is missing, a cast post-and-core restoration is indicated to obtain optimal tooth preparation form. (C and D) In molars, a composite resin or amalgam foundation is used. Additional retention from posts is rarely needed in molars.

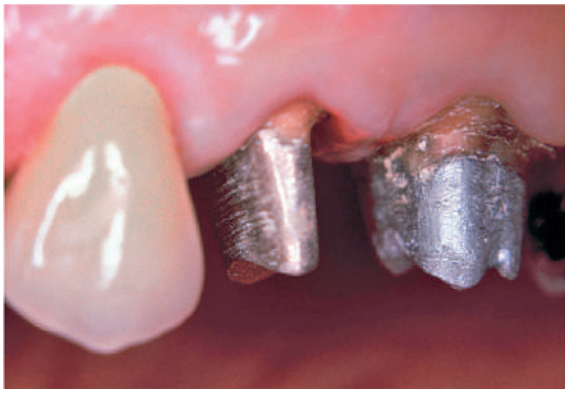


Fig. 12.3 The first molar and second premolar have post-and-core restorations. Note the margins, optimally located on sound tooth structure, cervical to the castings.

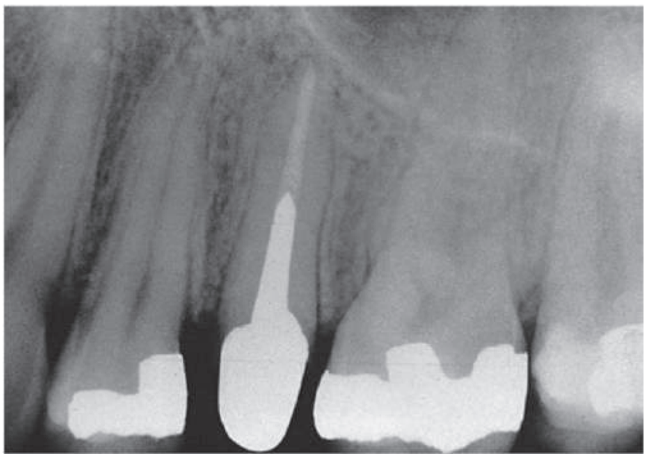


Fig. 12.4 The second premolar has been restored with a cast post-and-core restoration, in preparation for a metal-ceramic crown. (Courtesy Dr. R. Webber.)

Clinical Failure

Because of morphologic and functional differences between anterior teeth and posterior teeth, they must be treated differently after endodontic therapy, mainly because different loading considerations apply.

In one retrospective analysis[7] involving 638 patients, investigators evaluated 788 post-and-core restorations: 456 custom cast post-and-core restorations and 332 foundations restored with prefabricated ParaPosts. Four to 5 years after cementation, reported failure rates were significantly higher in men than in women, and failure rates were three times higher in those older than 60 than for younger patients. Maxillary failure rates (15%) were three times as high as mandibular failure rates (5%) and more prevalent in lateral incisors, canines, and premolars than in central incisors and molars. The failure rate of restorations under FPDs was significantly lower than that of restorations under single crowns. The latter finding may have been caused by load reduction resulting from bracing by the FPD. No correlation was apparent between failure and reduced marginal height of the encasing bone. Custom cast post-and-core restorations exhibited slightly higher failure rates than did amalgam foundations. This observation was also made by Sorensen and Martinoff.[8] However, Torbjörner et al.[7] suggested that custom cast post-and-core restorations tend to be used more often in teeth that already have considerably weakened root structure. Therefore regardless of the technique selected for subsequent restoration, the teeth themselves probably are already more prone to failure. Distal cantilevers appear to contribute to failure of a post-and-core restoration in endodontically treated abutment teeth that support the cantilever.

Most of the failures just discussed are influenced by load. In general, as loading increases, failure rates appear to increase concomitantly. Failure has been shown to occur at lower loads as teeth are loaded obliquely, rather than parallel to their long axes.[9] This suggests that clinical failure occurs more readily under lateral loading. The choice of post material will influence the clinical failure rates: A recent systematic review and meta-analysis reported that the use of glass fiber posts increased the fracture resistance of endodontically treated and restored anterior teeth,[10] findings that conflicted with an earlier review that reported that fiber posts have somewhat higher failure rates than do metal posts.[11]

In the planning of the restoration of endodontically treated teeth, the practitioner must account for the strength of the remaining tooth structure, comparing it carefully against the load to which the restored tooth will be subjected.

Considerations for Anterior Teeth

Endodontically treated anterior teeth do not always need a complete crown, except when the size of plastic restorative materials limits their prognosis (e.g., if the tooth has large proximal composite resin restorations and unsupported labial tooth structure). Many otherwise intact teeth function satisfactorily with a composite resin restoration (see Fig. 12.2A).

Although it is commonly believed that endodontically treated teeth are weaker or more brittle than vital teeth, this has not been demonstrated experimentally. However, their moisture content may be reduced.[12] Laboratory testing[13] has actually revealed that untreated and endodontically treated anterior teeth are similarly resistant to fracture. Nevertheless, clinical fracture does occur, and attempts have been made to strengthen the tooth by removing part of the root canal filling and replacing it with a metal post. In reality, placement of a post requires the removal of additional tooth structure (Box 12.1), which actually weakens the tooth.

Cementing a post in an endodontically treated tooth to enhance its prognosis is a fairly common clinical procedure, despite the paucity of data to support its success. In fact, one laboratory study[14] and two stress analyses[15,16] revealed that no significant reinforcement results. This might be explained by the hypothesis that, when the tooth is loaded, stresses are greatest at the facial and lingual surfaces of the root, and an internal post, being only minimally stressed, does not help prevent fracture (Fig. 12.5). However, results of other studies contradict this assumption.[13,17] Cemented posts may further limit or complicate endodontic re-treatment options, if these are necessary,

BOX 12.1 Disadvantages to the Routine Use of a Cemented Post

- Placing the post requires an additional operative procedure.
- Preparing a tooth to accommodate the post entails removal of additional tooth structure.
- It may be difficult to restore the tooth later, when a complete crown is needed, because the cemented post may have failed to provide adequate retention for the core material.
- The post can complicate or preclude future endodontic re-treatment that may be necessary.

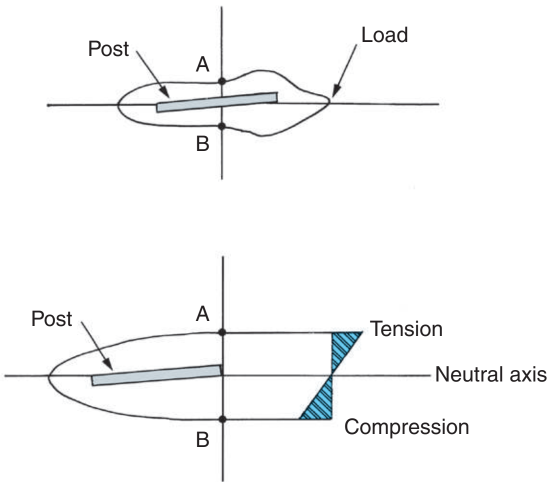


Fig. 12.5 Experimental stress distributions in an endodontically treated tooth with a cemented post. When the tooth is loaded, the lingual surface (A) is in tension, and the buccal surface (B) is in compression. The centrally located cemented post lies in the neutral axis (i.e., is not in tension or compression). (Redrawn from Guzy GE, Nicholls JI. In vitro comparison of intact endodontically treated teeth with and without endo-post reinforcement. *J Prosthet Dent.* 1979;42:39.)

because of the difficulties encountered in removing them. In addition, if additional coronal destruction occurs after the post is cemented, post removal may be necessary to provide adequate support for a future core.

For these reasons, a metal post is not recommended in anterior teeth that do not require complete crowns. This is supported by results of a retrospective study[18] that did not show any improvement in prognosis for endodontically treated anterior teeth restored with a post. In another study, post placement did not influence the position or angle of radicular fracture.[19] A conflicting report, however, suggests that endodontically treated teeth not crowned after obturation were lost six times more frequently than teeth that were crowned after obturation.[20]

Discoloration in the absence of significant tooth loss may be more effectively treated by bleaching[21,22] than by the placement of a complete crown, although not all stained teeth can be bleached successfully. Resorption can be an unfortunate side effect of nonvital bleaching.[23] However, when loss of coronal tooth structure is extensive or the tooth will be serving as an abutment for an FPD, a complete crown is mandatory. Retention and support then must be derived from within the canal because a limited amount of coronal dentin remains once the reduction for complete coverage has been completed. This outcome, coupled with the loss of internal tooth structure necessary for endodontic treatment, causes the remaining walls to become thin and fragile (Fig. 12.6), which often necessitates substantial reduction in height.

Considerations for Posterior Teeth

Posterior teeth are subject to greater loading than are anterior teeth because they are closer to the transverse horizontal axis. This, combined with their morphologic characteristics (having cusps that can be wedged apart), makes them more susceptible to fracture. Careful occlusal reshaping reduces potentially damaging lateral forces during excursive movements. Nevertheless, endodontically treated posterior teeth should receive cuspal coverage to prevent occlusal forces from causing fracture. Possible exceptions are mandibular premolars and first molars with intact marginal ridges and conservative access cavities not subjected to excessive occlusal forces (i.e., posterior disclusion in conjunction with normal muscle activity).

Complete coverage is recommended on teeth with a high risk of fracture. This is especially true for maxillary premolars, which have been shown to have fairly high failure rates if two or three surfaces are restored with amalgam.[24] Complete coverage gives the best protection against fracture because the tooth is completely encircled by the restoration. However, when a metal-ceramic crown is to be used, considerable additional buccal tooth reduction is required, which results in further weakening of the remaining tooth structure. In general, when significant coronal tooth loss has occurred, a cast post-and-core restoration (Fig. 12.7) or an amalgam or composite resin foundation restoration is needed.

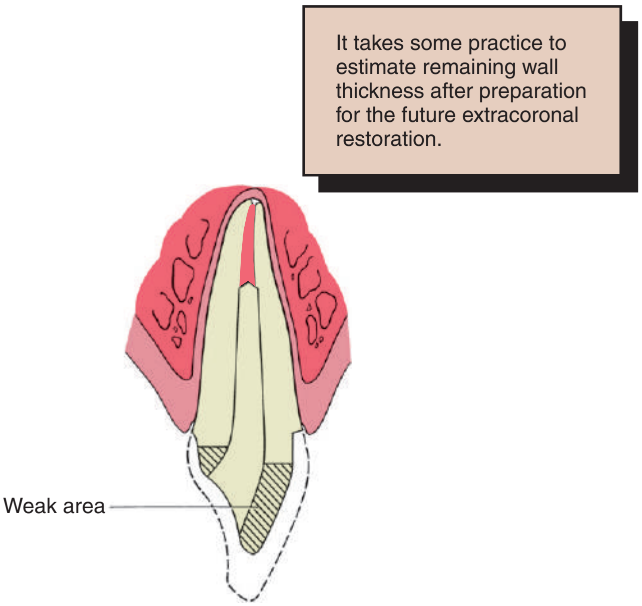


Fig. 12.6 Cross section through a central incisor. The *dashed line* indicates the original tooth contour before preparation for a metal-ceramic restoration. Even with minimum reduction for the extracoronal restoration, the buccal wall is weakened and would not be able to support a prosthesis successfully. The sharp lingual wall would complicate pattern fabrication.

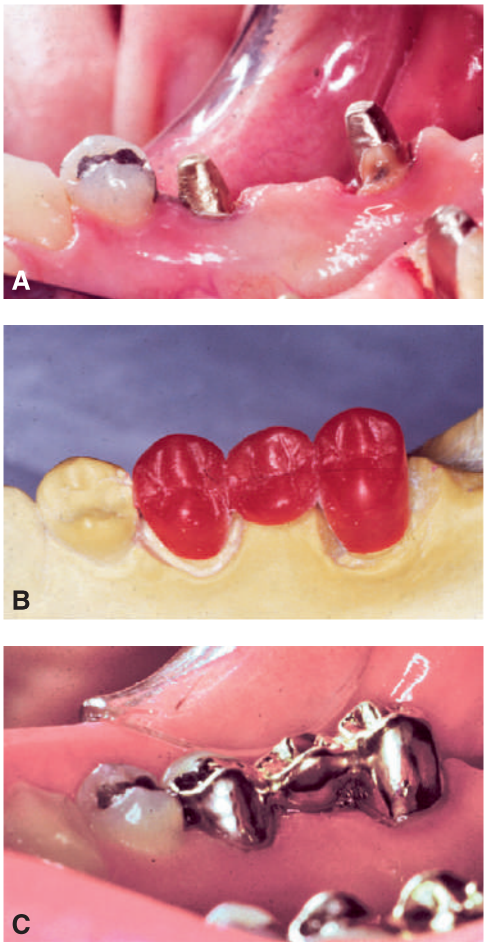


Fig. 12.7 (A) Mandibular premolar and hemisected molar with cast post-and-core restorations. (B) Waxed three-unit fixed dental prosthesis (FPD). (C) The FPD cemented in place. (Courtesy Dr. F. Hsu.)

PRINCIPLES OF TOOTH PREPARATION

Many of the principles of tooth preparation discussed in Chapter 7 apply equally to the preparation of endodontically treated teeth, although certain additional concepts must be understood in order to avoid failure.

Conservation of Tooth Structure

Preparation of the Canal

When post space is created, only minimal tooth structure should be removed from the canal (Fig. 12.8). Excessive enlargement can perforate or weaken the root, which then may split during either cementation of the post or subsequent function. Remaining dentin thickness is the prime variable in fracture resistance of the root. Experimental impact testing of teeth with cemented posts of different diameters[12] showed that teeth with a thicker (1.8-mm) post (thinner dentin walls) fractured more easily than those with a thinner (1.3-mm) one (thicker dentin walls).

Photoelastic stress analysis confirms that internal stresses are reduced with thinner posts. The root can be compared with a ring: The strength of a ring is proportional to the difference between the fourth powers of its internal and external radii. This implies that the strength of a prepared root is derived from its periphery, not from its interior, and so a post of reasonable size should not weaken the root significantly.[25] Nevertheless, it is difficult to enlarge a root canal uniformly and to judge with accuracy how much tooth structure has been removed and how thick the remaining dentin is. Most roots are narrower mesiodistally than faciolingually and often have proximal concavities that cannot be seen on a periapical radiograph. In laboratory testing, most root fractures originate from these concavities where the remaining dentin thickness is minimal.[26] Therefore the root canal should be enlarged only enough to enable the post to fit accurately while strength and retention are ensured. Along the length of a tapered post space, enlargement seldom needs to exceed what would have been accomplished with one or two additional file sizes beyond the largest size used for endodontic treatment. Because of the length of the maintained apical seal, and the consequently more coronal position of the post space, a file size much larger than that used during the endodontic treatment must be used to accomplish this (Fig. 12.9).

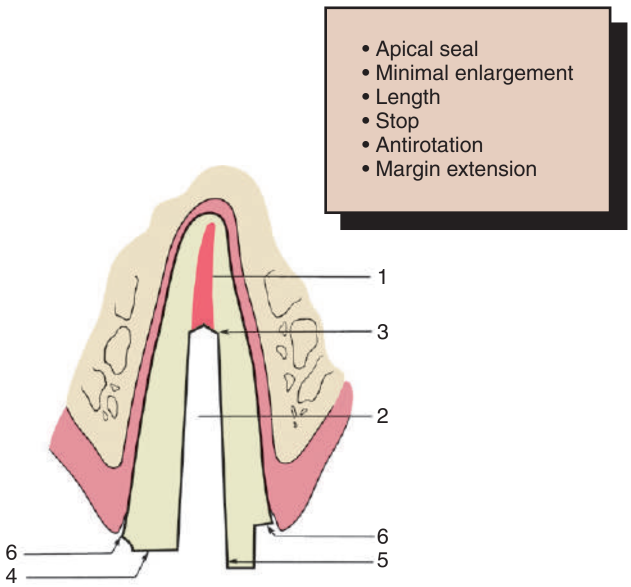


Fig. 12.8 Faciolingual cross section through a maxillary central incisor prepared for a post-and-core restoration. Six features of successful design are identified: *1*, adequate apical seal; *2*, minimum canal enlargement (no undercuts remaining); *3*, adequate post length; *4*, positive horizontal stop (to minimize wedging); *5*, vertical wall to prevent rotation (similar to a box); and *6*, extension of the final restoration margin onto sound tooth structure.

Preparation of Coronal Tissue

Endodontically treated teeth often have lost much coronal tooth structure for several reasons: as a result of caries, because of the size of previously placed restorations, or in the preparation of the endodontic access cavity. However, if a cast core is to be used, further reduction is needed internally to remove undercuts from the chamber and internal walls to accommodate the post-and-core restoration and externally to accommodate a complete crown. This may leave tall thin walls and very little coronal dentin. Every effort should be made to save as much of the coronal tooth structure as possible because this helps reduce stress concentrations at the gingival margin.[27] The amount of remaining tooth structure is probably the most important predictor of clinical success. However, when a cast post-and-core restoration is planned, such walls must have adequate structural integrity to prevent their fracture during the try-in and evaluation of the cast post-and-core restoration. Often, this means that the walls must be shortened to ensure strength. If more than 2 mm of coronal tooth structure remains, the post design probably has a limited role in the fracture resistance of the restored tooth.[28,29] Coronal reduction to

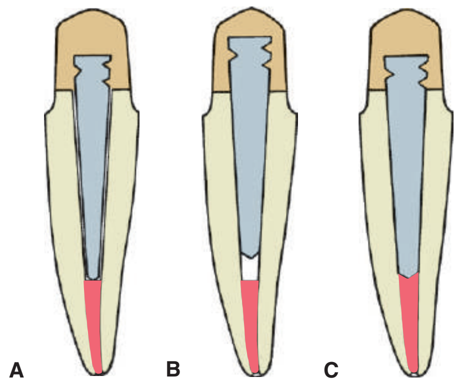


Fig. 12.9 Use of a prefabricated post entails enlarging the canal one or two file sizes to obtain a good fit at a predetermined depth. (A) Incorrect; the prefabricated post is too narrow. (B) Incorrect; the prefabricated post does not extend to the apical seal. (C) Correct; the prefabricated post is fitted by enlarging the canal slightly.

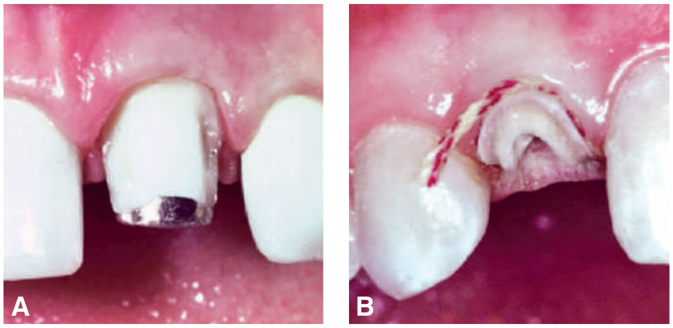


Fig. 12.10 (A) It is preferable to maintain as much coronal tooth structure as possible, if it is sound and of reasonable strength. (B) Extensive caries has resulted in the loss of all coronal tooth structure. This is less desirable than the situation in (A) because greater forces are transmitted to the root.

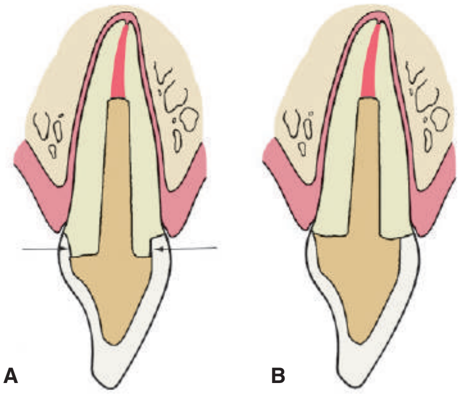


Fig. 12.11 Extending a preparation apically creates a ferrule and helps prevent fracture of an endodontically treated tooth during function. (A) Preparation with a ferrule *(arrows)*. (B) Preparation without a ferrule.

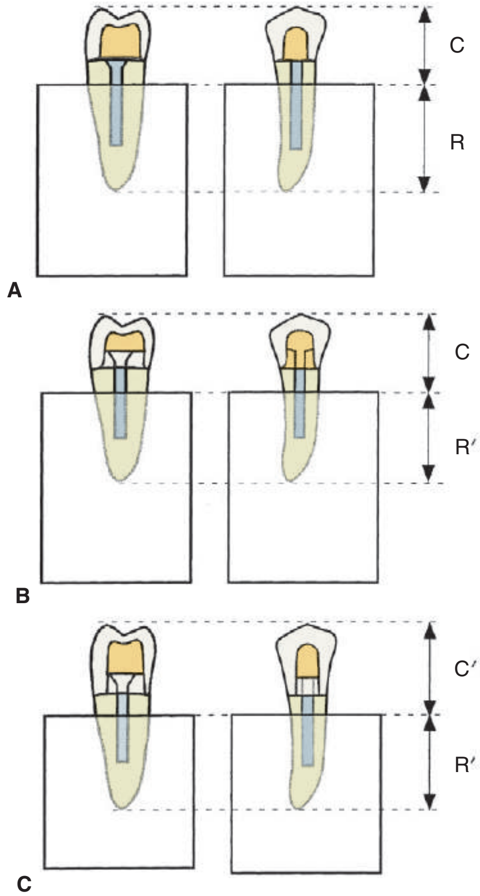


Fig. 12.12 Effect of apical preparation on crown-to-root ratio. (A) Schematic of extensively damaged premolar tooth. Apical extension of the gingival margin would encroach on the biologic width (see Chapter 5). This preparation has no ferrule. *C*, Crown length; *R*, root length. (B) Creating a ferrule with orthodontic extrusion reduces root length *(R′)*, whereas crown length remains unchanged. (C) Surgical crown lengthening (see Fig. 6.21) also reduces root length *(R′)* but increases crown length *(C′)*. This results in a much less favorable crown-to-root ratio, which may, in fact, weaken the restoration. (Courtesy Dr. A.G. Gegauff. From Gegauff AG. Effect of crown lengthening and ferrule placement on static load failure of cemented cast post-cores and crowns. *J Prosthet Dent.* 2000;84:169.)

the gingival level before fabrication of a post-and-core restoration, once common and routine, is poor practice and should be avoided (Fig. 12.10). Extension of the axial wall of the crown apical to the missing tooth structure provides what is known as a restoration with a *ferrule*, which is defined as a metal band or ring used to fit the root or crown of a tooth (Fig. 12.11), as opposed to a crown that merely encircles core material. This is thought to help bind the remaining tooth structure together, while simultaneously preventing root fracture during function,[30–32] although the scientific evidence is far from definitive.[33,34] It is also unclear whether the prognosis is improved by creation of a ferrule in an extensively damaged tooth through a surgical crown-lengthening procedure. In this latter circumstance, although the crown lengthening allows fabrication of a crown with a ferrule, it also leads to a much less favorable crown-to-root ratio and therefore to increased leverage on the root during function (Fig. 12.12).

One laboratory study showed that creating a ferrule through surgical crown lengthening resulted in a weaker, rather than a stronger, restored tooth.[35] In comparison, creating a ferrule with orthodontic extrusion may be preferred because, even though the root is effectively shortened, the crown is not lengthened (see Fig. 12.12B), which results in a more favorable crown-to-root ratio.

Retention Form

Anterior Teeth

An anterior crown and the post-and-core restoration that retains it are frequently dislodged simultaneously as a result of inadequate retention form of the prepared tooth.[18,36] The normal labiolingual convergence of anterior teeth, coupled with smaller tooth size, complicates achieving such retention form. Post retention is affected by the preparation geometry, post length, post diameter, post surface texture, and the luting agent.

Preparation geometry. Some canals, particularly in maxillary central incisors, have a nearly circular cross section (see Table 12.4). These can be prepared with a twist drill or reamer to provide a cavity with parallel walls or minimal taper, which allows the use of a preformed post of corresponding size and configuration. Conversely, canals with elliptical cross sections must be prepared with a restricted amount of taper (usually 6 to 8 degrees) to ensure adequate retention while undesired undercuts are eliminated. This is analogous to an extracoronal preparation (see Chapter 7). With extracoronal preparations, retention increases rapidly as vertical wall taper is reduced (see Chapter 7).

In accordance with this explanation, laboratory testing[3,37–39] has confirmed that parallel-sided posts are more retentive than tapered posts, whereas threaded posts that actively engage radicular dentin are the most retentive (Fig. 12.13). However, these comparisons are relevant only if the post fits the root canal properly, because retention is proportional to the total surface area.

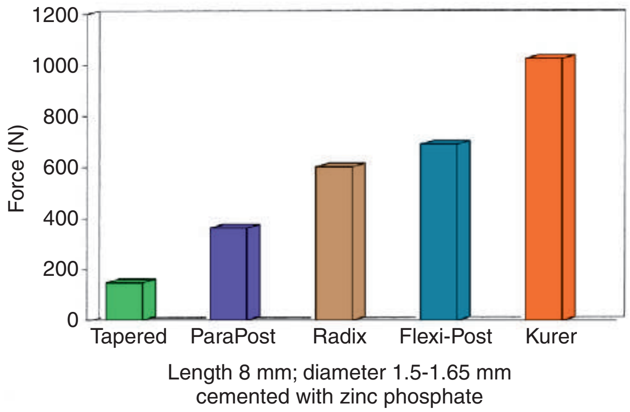


Fig. 12.13 Comparison of forces needed to remove different prefabricated post systems. (Redrawn from Standlee JP, Caputo AA. The retentive and stress distributing properties of split threaded endodontic dowels. *J Prosthet Dent.* 1992;68:436.)

Circular parallel-sided post systems are effective only in the most apical portion of the post space because the majority of prepared post spaces demonstrate considerable flare in the occlusal half. Similarly, when the root canal is elliptical, a parallel-sided post is not effective unless the canal is considerably enlarged, which would significantly weaken the root unnecessarily (Fig. 12.14).

Although retention can be further increased by use of a threaded post, which screws into dentin, this procedure is not recommended because of residual stress in the dentin. If this procedure is used, however, threaded posts must be “backed off” to ensure passivity; otherwise, the root will fracture.

Post length. Studies[37,39,40] have shown that as post length increases, so does retention. However, the relationship is not necessarily linear (Fig. 12.15). A post that is too short will fail (Fig. 12.16), whereas one that is too long may damage the seal of the root canal fill or increase the risk of root perforation if the

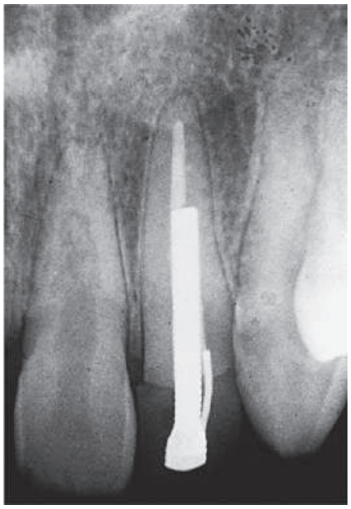


Fig. 12.14 The use of a parallel-sided post in a tapered canal requires considerable enlargement of the post space, which can weaken the root significantly. (Courtesy Dr. R. Webber.)

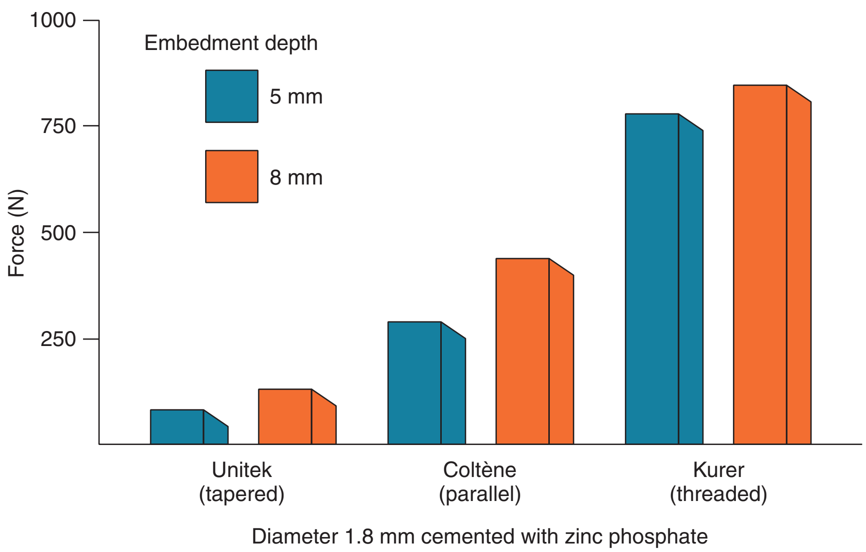


Fig. 12.15 Effect of the depth of embedding a post on its retentive capacity. (Data from Standlee JP, Caputo AA, Hanson EC. Retention of endodontic dowels: effects of cement, dowel length, diameter, and design. *J Prosthet Dent.* 1978;39:401.)

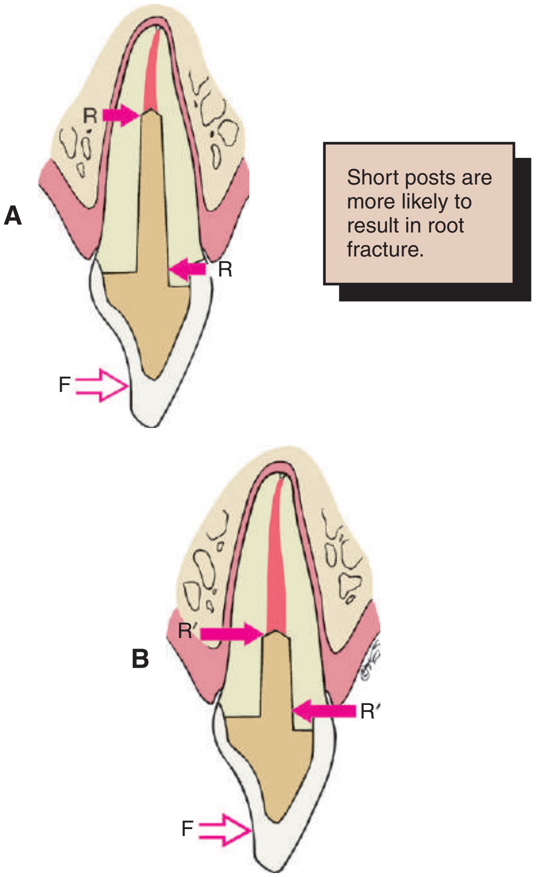


Fig. 12.16 Labiolingual longitudinal sections through a maxillary central incisor. (A) With a post of the correct length, a force *(F)* applied near the incisal edge of the crown generates a resultant couple *(R)*. (B) When the post is too short, this couple is greater *(R′)*, which increases the possibility of root fracture.

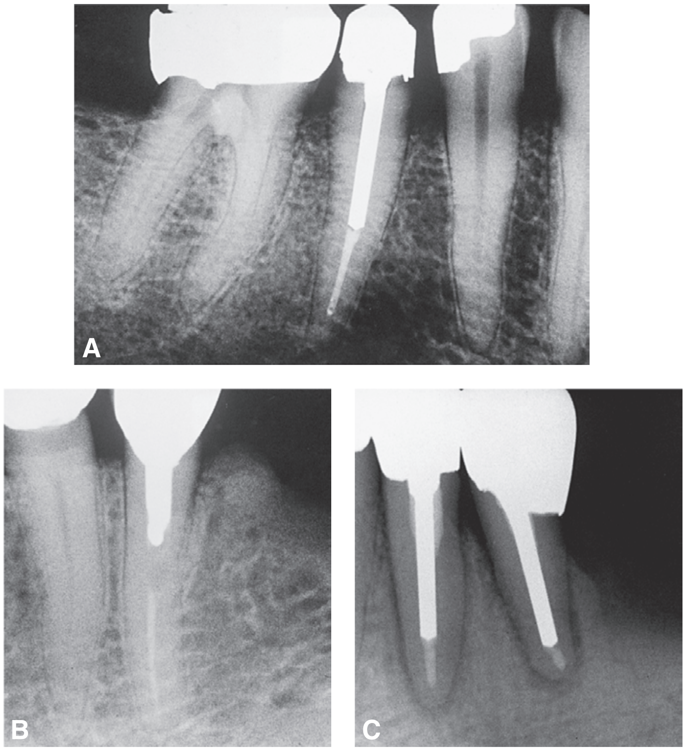


Fig. 12.17 (A) Correct post length. (B) The post is too short; the consequences are inadequate retention and increased risk of root fracture. (C) These posts are too long, jeopardizing the apical seal.

apical third is curved or tapered (Fig. 12.17). Absolute guidelines for optimal post length are difficult to define (Table 12.1). Ideally, the post should be as long as possible without jeopardizing the apical seal or the strength or integrity of the remaining root structure. Most endodontic texts advocate maintaining a 5-mm apical seal. However, if a post is shorter than the coronal height of the clinical crown of the tooth, the prognosis is considered unfavorable because stress is distributed over a smaller surface area, which increases the probability of root fracture. A short root and a tall clinical crown present the clinician with the dilemma of having to compromise the mechanics, the apical seal, or both. Under such circumstances, a shortened apical seal of a minimum of 3 mm is considered acceptable.

Post diameter. Increasing the post diameter in an attempt to increase retention is not recommended because retentive gain is minimal and the remaining root is weakened unnecessarily. Although one group of investigators[41] reported that increasing the post diameter increased retention, other reports have not confirmed this.[37,38] Empirical evidence suggests that the overall prognosis is good when post diameter does not exceed one third of the cross-sectional root diameter.

Post surface texture. A serrated or roughened post is more retentive than a smooth one,[38] and controlled grooving of the post and root canal[42] (Fig. 12.18) considerably increases the retention of a tapered post.

Luting agent. With regard to traditional water-based cements, the choice of luting agent seems to have little effect on post retention[43,44] or the fracture resistance of dentin.[45] However, adhesive resin luting agents (see Chapter 30) have the potential to improve the performance of post-and-core restorations; laboratory studies have shown improved retention.[46,47] Resin cements may be indicated if a post becomes dislodged. Resin cements are affected by eugenol-containing root canal sealers, which should be removed by irrigation with ethanol or by etching with 37% phosphoric acid if the adhesive is to be effective.[48] Root canal contamination with obturation material has been shown to be affected by anatomic shape of the canal.[49] Resin bonding within the root canal has been shown to be effective but can be expected to decrease over time.[50] Zinc phosphate and glass ionomer have comparable retentive properties, whereas polycarboxylate and composite resin cements have slightly less.[51] Some resin and glass ionomer cements have demonstrated significantly higher retention than resin-ionomer cements,[52] although the choice of luting agent may become more important if the post has a poor fit within the canal.[53] A post-and-core restoration should be remade if any rocking, rotation, or wobbling is present.

Posterior Teeth

Relatively long posts with a circular cross section provide good retention and support in anterior teeth, but long posts should be avoided in posterior teeth, which often have curved roots and

TABLE 12.1 **Historical Prospective of Post Length**

Post Length	Year	Reference
Should equal the occlusocervical dimension of the crown	1839	Harris C. *The Dental Art, a Practical Treatise on Dental Surgery*. Baltimore: Armstrong & Berry; 1839.
	1871	Austen PH. *The Principles and Practice of Dentistry, Including Anatomy, Physiology, Pathology, Therapeutics, Dental Surgery and Mechanism*. 10th ed. Philadelphia: Lindsay & Blakiston; 1871.
	1940	Tylman SD. *Theory and Practice of Crown and Bridge Prosthesis*. St. Louis: Mosby; 1940.
	1977	Kantor ME, Pines MS. A comparative study of restorative techniques for pulpless teeth. *J Prosthet Dent*. 1977;38:405.
	1979	Guzy GE, Nicholls JI. In vitro comparison of intact endodontically treated teeth with and without Endo-Post reinforcement. *J Prosthet Dent*. 1979;42:39.
	1985	Trope M, Maltz DO, Tronstad L. Resistance to fracture of restored endodontically treated teeth. *Endod Dent Traumatol*. 1985;1:108.
	1987	Eissmann HF, Radke RA Jr. Postendodontic restoration. In: Cohen S, Burns RC, eds. *Pathways of the Pulp*. 4th ed. St. Louis: Mosby; 1987:640–643.
	1989	Ziebert GJ. Restoration of endodontically treated teeth. In: Malone WF, et al., eds. *Tylman's Theory and Practice of Fixed Prosthodontics*. 8th ed. St. Louis: Ishiyaku EuroAmerica; 1989:407–417.
	1989	Barkhordar RA, Radke R, Abbasi J. Effect of metal collars on resistance of endodontically treated teeth to root fracture. *J Prosthet Dent*. 1989;61(6):676.
Two thirds of the root length	1959	Hamilton AI. Porcelain dowel crowns. *J Prosthet Dent*. 1959;9:639.
	1966	Larato DC. Single unit cast post crown for pulpless anterior tooth roots. *J Prosthet Dent*. 1966;16:145.
	1967	Christy JM, Pipko DJ. Fabrication of a dual-post veneer crown. *J Am Dent Assoc*. 1967;75:1419.
	1968	Bartlett SO. Construction of detached core crowns for pulpless teeth in only two sittings. *J Am Dent Assoc*. 1968;77:843.
	1969	Dewhirst RB, Fisher DW, Schillingburg HT Jr. Dowel-core fabrication. *J South Calif Dent Assoc*. 1969;37:444.
Four fifths of the root length	1984	Sorensen JA, Martinoff JT. Intracoronal reinforcement and coronal coverage: a study of endodontically treated teeth. *J Prosthet Dent*. 1984;51(6):780.
Ending halfway between crestal bone and apex	1984	Sorensen JA, Martinoff JT. Intracoronal reinforcement and coronal coverage: a study of endodontically treated teeth. *J Prosthet Dent*. 1984;51(6):780.
	1986	Randow K, Glantz PO. On cantilever loading of vital and non-vital teeth. An experimental clinical study. *Acta Odontol Scand*. 1986;44(5):271.
	1992	Gutmann JL. The dentin-root complex: anatomic and biologic considerations in restoring endodontically treated teeth. *J Prosthet Dent*. 1992;67:458.

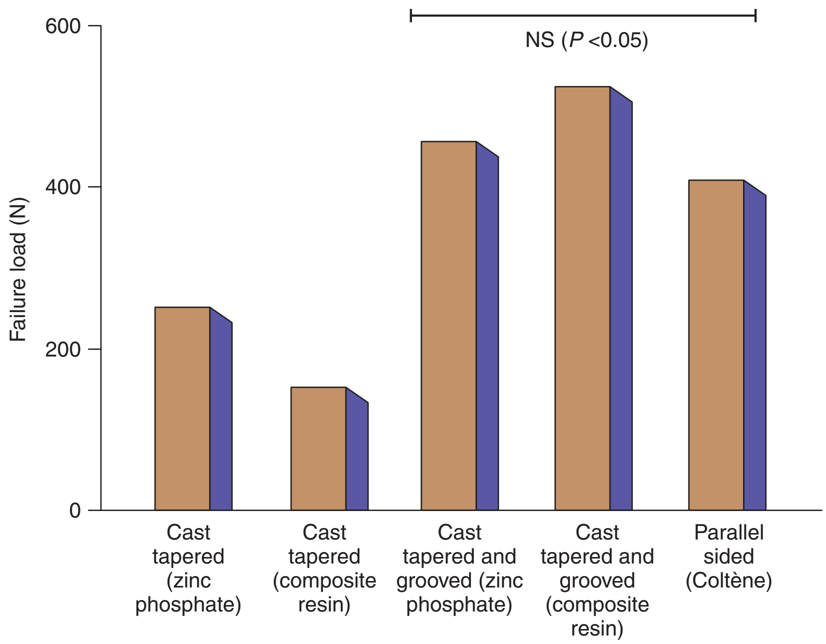


Fig. 12.18 Effect of horizontal grooving on the retention of tapered posts. *NS*, Not significant. (Redrawn from Wood WW. Retention of posts in teeth with nonvital pulps. *J Prosthet Dent*. 1983;49:504.)

elliptical or ribbon-shaped canals (Fig. 12.19). For these teeth, retention is better provided by two or more relatively short posts in divergent canals.

When amalgam is used as the core material, it can be condensed either around cemented metal posts or directly into short, prepared post spaces. If a reasonable amount of coronal tissue remains, use of a single metal post that is cemented in the largest canal can provide adequate retention for the core material. When more than 3 to 4 mm of coronal tooth structure with reasonable wall thickness remains, use of a post in the root canals for retention is not necessary, and not having to prepare post space reduces the risk of perforation.[54] When a post is not used, the chamber must provide adequate retention for the core material. It may then be advantageous to prepare several short divergent post spaces into which the core material extends. Use of the canals for retention can provide good results,[55] although once a complete crown has been provided, the strength of the tooth is not dramatically influenced by differences in technique.[56]

In mandibular premolars and molars with a reasonable amount of remaining coronal tooth structure, foundation restorations, coupled with a circumferential cervical band of tooth structure with restricted taper of about 2 mm, can typically be placed in composite resin or with amalgam directly condensed into the chamber.

Resistance Form

Stress Distribution

One of the functions of a post-and-core restoration is to improve resistance to laterally directed forces by distributing them over as large an area as possible. However, roots are weakened by excessive internal preparation, and the risk of failure increases. Post design should enable stresses to be distributed as evenly as possible. Glass fiber posts have an elastic modulus (flexibility) similar to that of dentin and therefore result in lower stress concentrations than do metal or ceramic posts; this concept is termed *monoblock*.[57]

The influence of post design on stress distribution has been tested with photoelastic materials,[26,40,58–60] strain gauges,[61,62] and finite element analysis.[63,64] Although it is always challenging to base clinical decisions on the results of in vitro studies, the following conclusions have been drawn:

- The greatest stress concentrations are found at the shoulder margin, particularly interproximally, and at the apex. Dentin should be conserved in these areas if possible.
- Stresses are reduced as post length increases.
- Parallel-sided posts may distribute stress more evenly than do tapered posts, which may have a wedging effect. However, parallel-sided posts heighten stresses at the apex.
- Sharp angles should be avoided because they heighten stresses during loading.
- High stress can be generated during insertion, particularly with smooth, parallel-sided posts that have no vent for cement escape.
- Threaded posts can heighten stress concentrations during insertion and loading, but they have been shown to distribute stress evenly if the posts are backed off a half-turn.[46]
- The cement layer results in a more even stress distribution to the root, with lower stress concentrations.
- Glass fiber posts lead to lower stresses during in vitro testing, with less catastrophic failures: Fractures may occur in posts rather than in the remaining tooth structure.[65]

Rotational Resistance

To minimize the risk of dislodgment, it is important that preparation geometry prevents a post with a circular cross section from rotating during function (Fig. 12.20). This usually does not present a problem when the remaining coronal tooth structure is sufficient because a vertical coronal wall prevents rotation. Where coronal dentin has been completely lost, a small groove placed in the canal wall can serve as an antirotational element. The groove is normally located where the root is bulkiest, usually on its lingual surface. Alternatively, rotation can be prevented by an auxiliary pin

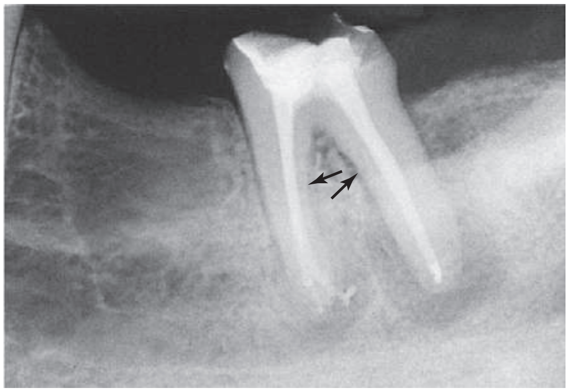


Fig. 12.19 When preparing posterior teeth for intracoronal retention, the practitioner must be careful to avoid perforation, especially on the distal surface of mesial roots and the mesial surface of distal roots, where residual tooth structure is normally thinnest and where concavities are often present *(arrows)*.

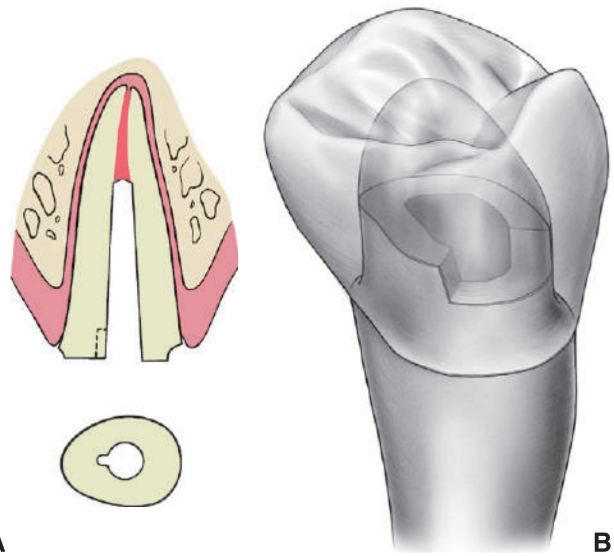


Fig. 12.20 (A) Rotational resistance in an extensively damaged tooth can be obtained from preparation of a small groove in the root canal. This must be in the path of placement of the post-and-core restoration. (B) Alternatively, it may be possible to incorporate a number of vertical walls in the completed preparation that offer rotational resistance.

in the root surface. Rotation of a threaded post can also be prevented[39] by preparation of a small cavity (half in the post, half in the root) and condensing amalgam into it after the post is cemented.

PROCEDURES

Tooth Preparation

Tooth preparation for endodontically treated teeth is a three-stage operation:

1. Removal of the root canal filling material to the appropriate depth
2. Enlargement of the canal
3. Preparation of the coronal tooth structure

Removal of the Endodontic Filling Material

The root canal system is first completely filled to ensure that lateral canals are sealed; space is then made for a post. If the canal is filled with a full-length silver point, a post cannot be placed, and so the point must be removed and the tooth re-treated with gutta-percha. It is not advisable to shorten previously cemented silver points because leakage will result even if only a small portion is removed.[66,67]

Two methods are commonly used to remove gutta-percha (Fig. 12.21): (1) using a warmed endodontic plugger and (2) using a rotary instrument, sometimes in conjunction with chemical agents. Although more time consuming, the warmed endodontic plugger method is preferred because it eliminates the possibility that the rotary instrument will inadvertently damage the dentin. If it is convenient, the gutta-percha can be removed with a warmed condenser immediately after obturation. This does not disturb the apical seal.[68,69] This method offers the additional advantage of allowing the operator to work in an area where the root canal anatomy is still familiar.

The procedure is as follows:

Before removing gutta-percha, calculate the appropriate post length. It should be adequate for retention and resistance but not long enough to weaken the apical seal. As a guide, make the post length equal to the height of the anatomic crown (or two-thirds the length of the root), but leave 5 mm of apical gutta-percha. On short teeth, it is not possible to meet both these conditions, and a compromise must be made. An absolute minimum of 3 mm of apical fill is needed. If this cannot be achieved while the post remains very short, the tooth's prognosis is poor, and extraction may be the best treatment choice.

If possible, avoid the apical 5 mm, where curvatures and lateral canals are prevalent. Average values for crown and root lengths are given in Table 12.2. If the working length of the canal is known, desired post space length can be determined easily. Therefore the incisal or occlusal reference point used during obturation must not be lost as a result of premature removal of coronal tooth structure.

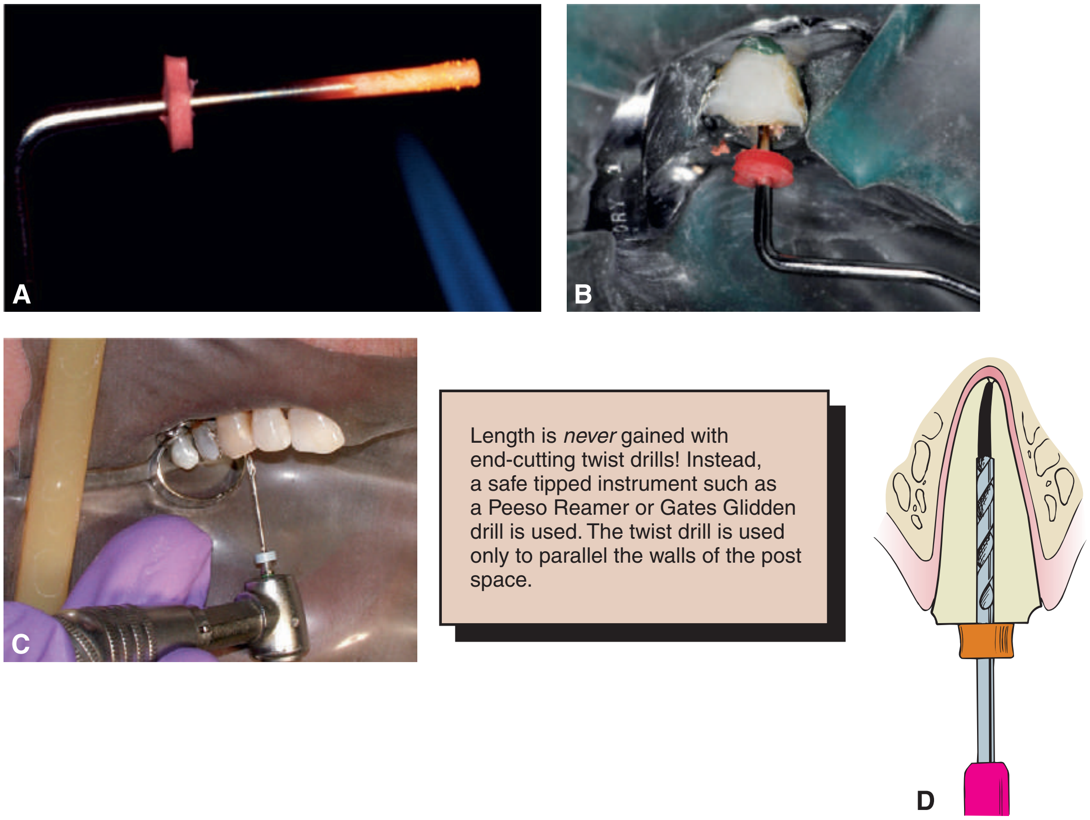


Fig. 12.21 Gutta-percha can be removed from the canal with a heated endodontic plugger (A) and (B) or a non–end-cutting bur, such as a Gates Glidden twist drill (C). A ParaPost twist drill (D) can be used to parallel the post space wall (with a rubber stop to ensure accuracy of the preparation depth). (A and B, Courtesy Dr. D.A. Miller.)

TABLE 12.2 Average Crown and Root Lengths (in Millimeters)

Tooth	Mean Crown Length[a]	Mean Root Length[a]	Two Thirds of Root Length	Root Length (to 4 mm From Apex)
Maxillary Teeth				
Central incisor	10.8 ± 0.7	12.5 ± 1.6	8.3	8.5
Lateral incisor	9.7 ± 0.9	13.1 ± 1.4	8.7	9.1
Canine	10.2 ± 0.8	15.8 ± 2.1	10.5	11.8
First premolar	8.6 ± 0.8	12.7 ± 1.7	8.5	8.7
Second premolar	7.5 ± 0.6	13.5 ± 1.4	9.0	9.5
First molar	7.4 ± 0.5			
• Mesiofacial		12.5 ± 1.2	8.3	8.5
• Distofacial		12.0 ± 1.3	8.0	8.0
• Lingual		13.2 ± 1.4	8.8	9.2
Second molar	7.4 ± 0.5			
• Mesiofacial		12.8 ± 1.5	8.5	8.8
• Distofacial		12.0 ± 1.4	8.0	8.0
• Lingual		13.4 ± 1.3	8.9	9.4
Mandibular Teeth				
Central incisor	9.1 ± 0.5	12.4 ± 1.4	8.3	8.4
Lateral incisor	9.4 ± 0.7	13.0 ± 1.5	8.7	9.0
Canine	10.9 ± 0.9	14.3 ± 1.4	9.5	10.3
First premolar	8.7 ± 0.7	13.4 ± 1.3	8.9	9.4
Second premolar	7.8 ± 0.6	13.6 ± 1.7	9.1	9.6
First molar	7.4 ± 0.5			
• Mesial		13.5 ± 1.3	9.0	9.5
• Distal		13.4 ± 1.3	8.9	9.4
Second molar	7.5 ± 0.5			
• Mesial		13.4 ± 1.2	8.9	9.4
• Distal		13.3 ± 1.3	8.9	9.3

[a]Standard deviation listed after mean length.
Data from Shillingburg HT, Kessler JC, Wilson EL Jr. Root dimensions and dowel size. *Calif Dent Assoc J.* 1982;10(10):43.
For each tooth, $n = 50$.

To prevent aspiration of an endodontic instrument, apply a dental dam before preparing the post space.

Select an endodontic condenser large enough to hold heat well but not so large that it binds against the canal walls.

Mark it at the appropriate length (normally endodontic working length, −5 mm), heat it, and place it in the canal to soften the gutta-percha.

If the gutta-percha is old and has lost much of its thermoplasticity, use a rotary instrument; ensure that it follows the gutta-percha and does not engage dentin, which causes a root perforation (for this reason, high-speed instruments and conventional burs are contraindicated). Special post preparation instruments are available (Fig. 12.22). Peeso Reamer drills and Gates Glidden drills are often used for this purpose. The convex football shape of the cutting head of the Gates Glidden drill often results in small divots in the wall of the post space. These are avoided with the more cylindrically shaped Peeso Reamer drill. Both are considered safe-tip instruments because neither is end-cutting. The friction generated between the fill and the tip of these burs softens the gutta-percha, allowing the rotary instrument to track the canal with reasonable predictability. In one comparison of rotary instruments,[70] investigators concluded that the Gates Glidden drill conformed to the original canal more consistently than did the ParaPost drill, which is an end-cutting instrument. The latter is a twist drill and should be used only to parallel the walls of the post space. Considerable heat can be generated by these rotary instruments, especially during the ParaPost preparation stage.[71] Of importance: Never use end-cutting instruments to gain length because root perforation will result.

If you are using a rotary instrument, choose one that is slightly narrower than the canal.

Ensure that the instrument follows the center of the gutta-percha and does not cut dentin. In many cases, only a part of the root canal fill needs to be removed with a rotary instrument, and the remainder can be removed with the heated condenser.

When the gutta-percha has been removed to the appropriate depth, shape the canal as needed. This can be accomplished with an endodontic file or a low-speed drill. In this procedure, undercuts are removed, and the canal is prepared to receive an appropriately sized post without excessive enlargement of the canal. Files are a conservative approach to shaping the canal walls and enable simultaneous removal of any small residual undercuts in the chamber. If a parallel-sided post is desired, a matching-size low-speed twist drill that is set to the same length as the most recently used Peeso Reamer drill can be used.

The post should be no more than one-third the root diameter,[1,72] with the root and walls at least 1 mm thick circumferentially. Obviously, for deciding on appropriate post diameters, knowledge of average root dimensions is important. These have been calculated[73] and are presented in Table 12.3. Knowledge of root canal cross section also is significant in post selection. Prefabricated posts are circular in cross section, but many root canals are elliptical, which makes uniform reduction with a drill impossible. Canal shapes are summarized in Table 12.4.

Canal Enlargement

Before the canal is enlarged, the type of post system that will be used for fabrication of the post-and-core restoration must be chosen.

The advantages and disadvantages of different post types are summarized in Table 12.5. Because no system is universally applicable, familiarity with more than one technique is a significant advantage. Prefabricated posts range widely in shape and size with varying radiopacity that may assist in their identification on radiographs (Table 12.6; Figs. 12.23 and 12.24).

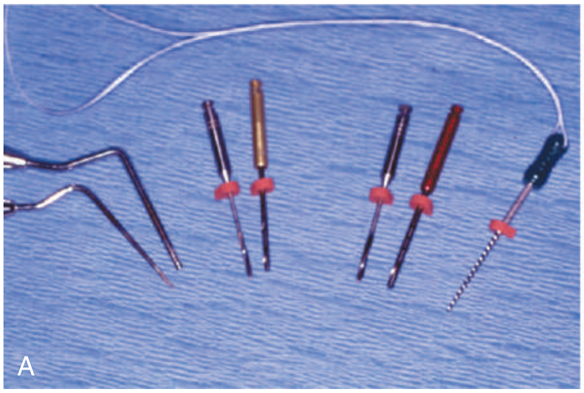


Fig. 12.22 Commonly used instruments for gutta-percha removal and canal enlargement. (A) Endodontic pluggers, two sizes of Peeso Reamer drills with corresponding twist drills, and endodontic file. Note floss attached to the file as a safety precaution. (B) The ParaPost twist drill corresponds in size to an aluminum post used to fabricate interim restorations, a plastic post for patterns, and a stainless steel or titanium post. (Courtesy Dr. J.A. Nelson.)

TABLE 12.3 Average Root Diameters and Recommended Post Sizes (in Millimeters)[a]

Tooth	CEJ	Furcation[b]	Midpoint	Diameter 4 mm From Apex[c]	Recommended Post Diameter
Maxillary Teeth					
Central incisor					1.5
• Mesiodistal	6.3 ± 0.5	—	5.2 ± 0.5	3.8 ± 0.4	
• Faciolingual	6.4 ± 0.4	—	5.8 ± 0.4	4.3 ± 0.4	
Lateral incisor					1.3
• Mesiodistal	4.9 ± 0.5	—	4.0 ± 0.5	3.2 ± 0.5	
• Faciolingual	5.7 ± 0.5	—	5.4 ± 0.5	4.2 ± 0.4	
Canine					1.5
• Mesiodistal	5.4 ± 0.5	—	4.4 ± 0.5	3.3 ± 0.5	
• Faciolingual	7.7 ± 0.6	—	7.2 ± 0.6	4.8 ± 0.6	
First premolar					
• Mesiodistal	4.1 ± 0.3	Facial MD	3.6 ± 0.4	2.6 ± 0.4	0.9
• Faciolingual	8.1 ± 0.7	— FL —	3.4 ± 0.4	2.4 ± 0.4	
		Lingual MD	3.3 ± 0.3	2.5 ± 0.4	0.9
		— FL —	3.3 ± 0.4	2.4 ± 0.5	
Second premolar					
• Mesiodistal	4.9 ± 0.3	—	3.8 ± 0.4	3.2 ± 0.6	1.1
• Faciolingual	7.9 ± 0.5	—	7.0 ± 0.7	5.0 ± 0.7	
First molar					
• Mesiodistal	7.7 ± 0.4	Mesial- MD 3.4 ± 0.3	3.1 ± 0.3	2.9 ± 0.4	1.1
• Faciolingual	10.5 ± 0.5	Facial FL 6.8 ± 0.5	5.8 ± 0.7	4.8 ± 0.7	
		Distal- MD 3.1 ± 0.2	2.8 ± 0.3	2.6 ± 0.4	1.1
		Facial FL 5.0 ± 0.4	4.4 ± 0.5	3.8 ± 0.5	
		Lingual MD 5.7 ± 0.5	5.0 ± 0.5	4.4 ± 0.5	1.3
		FL 4.3 ± 0.4	3.7 ± 0.4	3.3 ± 0.4	
Second molar					
• Mesiodistal	7.3 ± 0.4	Mesial- MD 3.4 ± 0.3	3.1 ± 0.3	2.7 ± 0.4	1.1

Continued

TABLE 12.3 Average Root Diameters and Recommended Post Sizes (in Millimeters)[a]—cont'd

Tooth	CEJ	Furcation[b]	Midpoint	Diameter 4 mm From Apex[c]	Recommended Post Diameter
• Faciolingual	10.4 ± 0.6	Facial FL 6.6 ± 0.5	5.6 ± 0.7	4.5 ± 0.7	
		Distal- MD 3.1 ± 0.4	2.8 ± 0.3	24 ± 0.4	0.9
		Facial FL 4.3 ± 0.4	3.8 ± 0.4	3.2 ± 0.4	
		Lingual MD 4.9 ± 0.5	4.2 ± 0.5	3.6 ± 0.5	1.3
		FL 4.5 ± 0.4	3.9 ± 0.4	3.1 ± 0.4	
Mandibular Teeth					
Central incisor					
• Mesiodistal	3.3 ± 0.3	—	2.7 ± 0.3	2.1 ± 0.2	0.7
• Faciolingual	5.5 ± 0.5		5.6 ± 0.4	4.3 ± 0.6	
Lateral incisor					
• Mesiodistal	3.6 ± 0.3	—	2.7 ± 0.4	2.0 ± 0.2	0.7
• Faciolingual	5.9 ± 0.4		5.7 ± 0.5	4.3 ± 0.5	
Canine					
• Mesiodistal	5.2 ± 0.6	—	4.0 ± 0.5	3.2 ± 0.7	1.5
• Faciolingual	7.8 ± 0.8		7.3 ± 0.6	5.0 ± 0.5	
First premolar					
• Mesiodistal	5.1 ± 0.4	—	4.0 ± 0.4	3.2 ± 0.4	1.3
• Faciolingual	6.6 ± 0.4		6.0 ± 0.5	4.3 ± 0.5	
Second premolar					
• Mesiodistal	5.3 ± 0.3	—	4.3 ± 0.3	3.5 ± 0.5	1.3
• Faciolingual	7.0 ± 0.5		6.0 ± 0.6	4.4 ± 0.5	
First molar					
• Mesiodistal	8.9 ± 0.6	Mesial- MD 3.7 ± 0.2	3.2 ± 0.3	2.8 ± 0.3	1.1
• Faciolingual	8.3 ± 0.6	Facial FL 3.4 ± 0.3	3.1 ± 0.3	2.8 ± 0.4	
		Mesial- MD 3.4 ± 0.3	2.9 ± 0.3	2.5 ± 0.3	0.9
		Lingual FL 3.5 ± 0.4	3.2 ± 0.3	2.7 ± 0.4	
		Distal MD 3.6 ± 0.3	2.8 ± 0.3	2.6 ± 0.3	0.9
		Facial FL 3.2 ± 0.3	2.8 ± 0.3	2.4 ± 0.4	
		Mesial- MD 3.6 ± 0.4	3.0 ± 0.4	2.5 ± 0.4	0.9
		Lingual FL 3.2 ± 0.5	2.8 ± 0.4	2.3 ± 0.4	
		Distal MD 4.1 ± 0.4	3.5 ± 0.4	3.0 ± 0.4	1.1
		FL 6.8 ± 0.8	5.9 ± 0.9	4.7 ± 0.7	
Second molar	MD 9.3 ± 0.7	Mesial- MD 3.6 ± 0.3	3.1 ± 0.3	2.6 ± 0.3	0.9
	FL 8.3 ± 0.7	Facial FL 3.2 ± 0.3	2.8 ± 0.3	2.4 ± 0.4	
		Mesial- MD 3.6 ± 0.4	3.0 ± 0.4	2.5 ± 0.4	0.9
		Lingual FL 3.2 ± 0.5	2.8 ± 0.4	2.3 ± 0.4	
		Distal MD 4.1 ± 0.4	3.5 ± 0.4	3.0 ± 0.4	1.1
		FL 6.8 ± 0.8	5.9 ± 0.9	4.7 ± 0.7	

[a]For each tooth, $n = 50$.
[b]Furcation distance from the CEJ: maxillary first molar, 4.1 mm; maxillary second molar, 3.2 mm; mandibular first molar, 3.1 mm; mandibular second molar, 3.3 mm.
[c]Because of greater root length, the mean distance from the apex on maxillary canine measurements is 5.1 mm.
CEJ, Cementoenamel junction; *FL*, faciolingual; *MD*, mesiodistal.
Data from Shillingburg HT, Kessler JC, Wilson EL Jr. Root dimensions and dowel size. *Calif Dent Assoc J*. 1982;10(10):43.

TABLE 12.4 Root Canal Configurations

	ELLIPTICAL	
Circula	**Buccolingual**	**Mesiodistal**
Maxillary central incisor	Maxillary lateral incisor Maxillary canine Mandibular incisors Mandibular canine	
Maxillary first premolar (two roots)	Maxillary first premolar (single root) Mandibular first premolar	
Mandibular second premolar	Maxillary second premolar	
Maxillary molars (distobuccal roots)	Maxillary molars (mesiobuccal roots) Mandibular molars (mesial and distal roots)	Maxillary molars (palatal roots)

From Weine FS. *Endodontic Therapy*. 4th ed. St. Louis: Mosby; 1989:225–269.

TABLE 12.5 Available Post-and-Core Restoration Systems

Material	Advantages	Disadvantages	Recommended Use	Precautions
Amalgam	Conservative of tooth structure Straightforward technique	Low tensile strength Corrosion with base metal	Molar with adequate coronal tooth structure	Not recommended for teeth under lateral load (anterior teeth)
Glass ionomer	Conservative of tooth structure Straightforward technique	Difficult condensation Low strength	Minimal missing tooth structure	Not recommended for teeth under lateral load
Composite resin	Conservative of tooth structure Straightforward technique	Low strength Continued polymerization Microleakage	Minimal missing tooth structure	Not recommended for teeth under lateral load
Custom cast post-and-core restoration	High strength Better fit than prefabricated restoration	Less stiff than wrought materials Time-consuming, complex procedure	Elliptical or flared canals	Care to remove nodules before try-in
Wire post and cast core	High strength High stiffness	Corrosion of base metal Pt-Au-Pd wire expensive	—	Care to avoid perforation during preparation
Tapered prefabricated post	Conservative of tooth structure High strength and stiffness	Less retentive than parallel-sided or threaded system	Small circular canals	Not recommended for excessively flared canals
Parallel-sided prefabricated post	High strength Good retention Comprehensive system	Precious metal post expensive Corrosion of stainless steel Less conservative of tooth structure	Small circular canals	Care during preparation
Threaded post	High retention	Stresses generated in canal may lead to fracture Not conservative of coronal and radicular tooth structure	Only when maximum retention is essential	Care to avoid fracture during seating
Carbon fiber post	Dentin bonding Easy removal	Low strength Microleakage Black color	Minimal missing tooth structure Uncertain endodontic prognosis	Not recommended for teeth under lateral load
Zirconia ceramic posts	Esthetics High stiffness	Uncertain clinical performance	High esthetic demand	—
Woven fiber post	Esthetics Dentin bonding	Low strength Uncertain clinical performance	High esthetic demand	Not recommended for teeth under lateral load
Glass fiber posts	Esthetics Dentin bonding	Low strength Uncertain clinical performance	High esthetic demand	Not recommended for teeth under lateral load

Pt-Au-Pd, Platinum-gold-palladium.

TABLE 12.6 Currently Available Prefabricated Posts and Adaptable Post Systems[a]

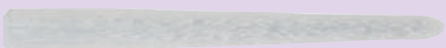
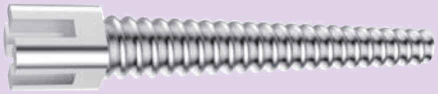
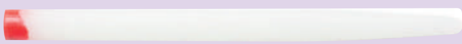
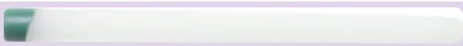
		SHANK		
Example[b]	Product (Vendor)	Composition[c]	Diameter (mm)[d]	Characteristics
Tapered Smooth-Sided Posts				
	EndoSequence Fiber Post (Brasseler USA)	ZGF (unidirectional, LT)	0.8–1.4	Flat tip, 0.04 and 0.06 taper[e]
	FibreKleer 4X Tapered Fiber Post (Pentron)	GF (unidirectional, LT)	1.2–1.5	Flat tip, 0.04 taper[e]
	LuxaPost (DMG America)	GF (unidirectional, LT)	1.2–1.5	Flat tip
	FRC Postec Plus (Ivoclar AG)	GF (unidirectional, LT)	1.5–1.7	Flat tip
	EXACTO (Angelus Dental Products)	GF (unidirectional, LT)	1.1–1.8	Flat tip
	EUROPOST, FIBIO Aesthetic Nonmetal Post (Dental Anchor Systems)	GF (unidirectional)	1.2–1.5	Flat tip
	C-I White Glass Fiber Post (Parkell)	GF (braided)	1.3 and 1.6	Blunt tip
	GLASSIX+plus Fiber Post (JS Dental Manufacturing)	GF (helicoidal, LT)		Blunt tip, twisted grooves
	Filpost (Filhol Dental)	Ti	1.3 and 1.6	Blunt tip
	C-Post (Komet USA)	ZrO_2	1.1–1.7	Blunt tip
	RelyX Fiber Post (3M Oral Care Solutions Division)	ZGF (unidirectional, LT)	0.8–1.3	Blunt tip
	RelyX Fiber Post 3D (3M Oral Care Solutions Division)	ZGF (unidirectional, LT)	0.8–1.3	Blunt tip
	FluoroPost (Dentsply Sirona)	ZGF (unidirectional, LT)	1.3–1.7	Blunt tip
	DentinPost X (Komet USA)	GF (unidirectional, LT)	1.1–1.7	Blunt tip
	DentinPost (Komet USA)	GF (unidirectional, LT)	1.1–1.7	Blunt tip
	Achromat-T-Tapered (Kerr Dental)	GF (unidirectional, LT)	1.0–1.4	Blunt tip
	Achromat-THP-Tapered-Arrow Head (Kerr Dental)	GF (unidirectional, LT)	1.0–1.4	Blunt tip
	Rebilda Post (VOCO America)	GF (unidirectional, LT)	1.0–2.0	Blunt tip, apical 8 mm is tapered
	Twin Luscent Anchors (Dentatus USA)	GF (unidirectional, LT)	1.4–1.8	Pointed tip, hourglass shape
	Luscent Anchors (Dentatus USA)	GF (unidirectional, LT)	1.1–1.8	Pointed tip
	Luscent-R Anchors (Dentatus USA)	GF (unidirectional, LT)	1.1–1.8	Pointed tip

TABLE 12.6 Currently Available Prefabricated Posts and Adaptable Post Systems[a]—cont'd

		SHANK		
Example[b]	**Product (Vendor)**	**Composition[c]**	**Diameter (mm)[d]**	**Characteristics**
	UniCore (Ultradent Products, Inc)	QF (unidirectional, LT)	1.1–1.7	Pointed tip
	DT Light-Post (RTD Dental)	QF (unidirectional, LT)	1.0–1.6	Pointed tip, double taper
	DT Light-Post Illusion X-RO (RTD Dental)	QF (unidirectional, LT)	1.0–1.6	Pointed tip, double taper
Tapered Serrated Posts				
	Mirafit Clear (Hager Worldwide)	GF (unidirectional, LT)	0.5–1.0	Spiraling grooves, pointed tip
	Macro-Lock Illusion X-RO (Clinician's Choice)	GF (unidirectional, LT)	1.3–1.7	Spiraling grooves, blunt tip
	Marco-Lock Oval (Clinician's Choice)	GF (unidirectional, LT)	1.3–1.7	Spiraling grooves, blunt tip
	REFORPOST Metallic (Angelus Dental Products)	SS	1.3 and 1.4	Tight spiraling grooves, flat tip
	C-I Stainless Steel Post (Parkell)	SS	1.3 and 1.6	Shallow narrow grooves, flat tip
Tapered Threaded Posts				
	Surtex (Dentatus USA)[f]	Ti, SS, Brass	1.1–1.8	Tightly threaded
	Ancorex (E. C. Moore)[f]	Ti	1.1–1.8	Tightly threaded
Parallel Smooth-Sided Posts				
	IntegraPost (Premier)	Ti alloy	0.9–1.5	Fine diamond shaped grooves, flat tip
	Pro-Post (Dentsply Sirona)	SS	1.0–1.7	Tapered apical end, flat tip
	GT Post (Dentsply Sirona)	SS	1.0–1.5	Flat tip
	GT Fiber Post (Dentsply Sirona)	GF (unidirectional, LT)	1.0–1.5	Flat tip
	FibreKleer 4X Parallel Fiber Post (Pentron)	GF (unidirectional, LT)	1.0–1.5	Flat tip
	Super Fiber Post (iLumi Sciences, Inc.)	GF (unidirectional, LT)	1.1–1.7	Tapered apical end, flat tip
	GC Fiber Post (GC America)	GF (unidirectional, LT)	1.0–1.6	Tapered apical end, blunt tip
	DentFlex Fiber Post (Brasseler USA)	ZGF (unidirectional, LT)	0.8–1.6	Tapered apical end, blunt tip
	Cure-Thru IntegraPost (Premier USA)	ZGF (unidirectional, LT)	1.0–1.5	Tapered apical end, blunt tip

Continued

TABLE 12.6 Currently Available Prefabricated Posts and Adaptable Post Systems[a]—cont'd

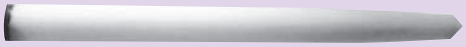
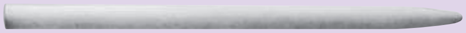
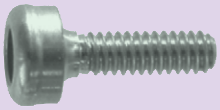
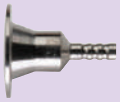
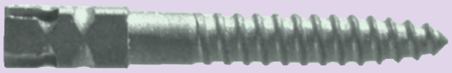
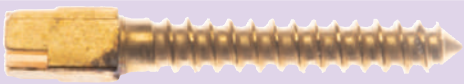
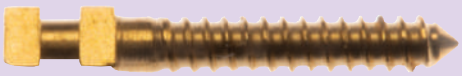
		SHANK		
Example[b]	**Product (Vendor)**	**Composition[c]**	**Diameter (mm)[d]**	**Characteristics**
	ICELIGHT (Zest Dental Solutions)	GF (unidirectional, LT)	1.0–1.6	Tapered apical end, blunt tip
	ICEPOST (Zest Dental Solutions)	GF (unidirectional)	1.0–1.6	Tapered apical end, blunt tip
	Core-Post Glass Fiber (Den-Mat)	GF (unidirectional)	1.0–2.0	Flat tip
	Core-Post Carbon Fiber (Den-Mat)	CF	1.0–2.0	Flat tip
	Mirafit White (Hager Worldwide)	GF (braided)	1.2–1.6	Pointed tip
	Mirafit Carbon (Hager Worldwide)	CF	1.2–1.6	Pointed tip
	GF Glass Fiber Post (J. Morita USA)	GF (braided)	1.1–1.6	Blunt tip
	CF Carbon Fiber Post (J. Morita USA)	CF	1.1–1.6	Blunt tip
Parallel Serrated Posts				
	ParaPost (Coltène)	Ti alloy, SS	0.9–1.8	Numerous shallow grooves, flat tip
	ParaPost XP (Coltène)	Ti alloy, SS, PB	0.9–1.8	X-shape grooves, flat tip
	ParaPost XH (Coltène)	Ti alloy	0.9–1.8	X-shape grooves, flat tip
	ParaPost Plus (Coltène)	Ti alloy, SS	0.9–1.8	Inverse ledges, flat tip
	ParaPost Fiber White (Coltène)	GF (unidirectional)	1.1–1.5	Inverse ledges, flat tip
	FibreKor (Pentron)	GF (unidirectional)	1.0–1.5	Inverse ledges, flat tip
	REFORPOST Glass Fiber (Angelus Dental Products)	GF (unidirectional)	1.1–1.5	Inverse ledges, tapered apical end
	REFORPOST Carbon Fiber (Angelus Dental Products)	CF	1.1–1.5	Inverse ledges, tapered apical end
	ParaPost Taper Lux (Coltène)	GF (unidirectional, LT)	1.1–1.5	Inverse ledges, tapered apical end
	ParaPost Fiber Lux (Coltène)	GF (unidirectional, LT)	1.1–1.5	Inverse ledges, flat tip
	FibreKleer 4X Original Fiber Post (Pentron)	GF (unidirectional, LT)	1.0–1.5	Inverse ledges, flat tip
	EZ-Fit Translucent Post (Essential Dental Systems)	GF (unidirectional, LT)	0.9–1.4	Shallow grooves, flat tip

TABLE 12.6 Currently Available Prefabricated Posts and Adaptable Post Systems[a]—cont'd

Example[b]	Product (Vendor)	SHANK Composition[c]	SHANK Diameter (mm)[d]	SHANK Characteristics
	Super Serrated Post (iLumi Sciences, Inc.)	GF (unidirectional, LT)	1.1–1.7	Wide grooves, tapered apical end
	Achromat-Parallel (Kerr Dental)	GF (unidirectional, LT)	1.3 and 1.6	Wide grooves, flat tip
	Achromat-HP-Parallel-Arrowhead (Kerr Dental)	GF (unidirectional, LT)	1.1–1.6	Wide grooves, flat tip
	Vlock Passive Post (Brasseler USA)	Ti alloy	1.2–1.6	Wide grooves, flat tip
	T-Post XP (Komet USA)	Ti	1.2 and 1.4	Wide grooves, flat tip
	AccessPost (Essential Dental Systems)	SS	0.8–1.6	Deep spiraling groove, flat tip
	AccessPost Overdenture (Essential Dental Systems)	SS	1.1–1.6	Deep spiraling groove, flat tip
	LOCATOR Root Abutment (Zest Dental Solutions)	SS	1.8	Numerous shallow grooves, flat tip
	ERA Direct Overdenture (Sterngold)	SS	1.3 and 1.7	Numerous shallow grooves, flat tip
	Standard Stern Root Anchor (Sterngold)	Ti alloy	0.9/2.9	Shallow grooves, flat tip
Parallel Threaded Posts				
	Surtex (Dentatus USA)[f]	Ti, SS, Brass	1.1–1.8	Tightly threaded, threaded tapered tip
	Ancorex (E. C. Moore)[f]	Ti	1.1–1.8	Tightly threaded, threaded tapered tip
	Titanium Screw Post (E.C. Moore)	Ti	1.1–1.8	Tightly threaded, pointed tip
	Golden Screw Post (E.C. Moore)	Brass	1.1–1.8	Tightly threaded, pointed tip
	Compo-Post (Henry Schein)	Brass	1.1–1.8	Tightly threaded, pointed tip
	EUROPOST Stainless Steel "C" Post (Dental Anchor Systems)	SS	0.9–1.5	Tightly threaded, pointed tip

Continued

TABLE 12.6 Currently Available Prefabricated Posts and Adaptable Post Systems[a]—cont'd

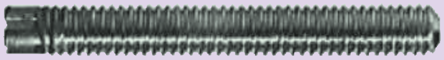
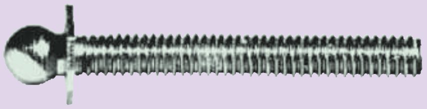
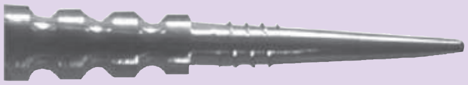
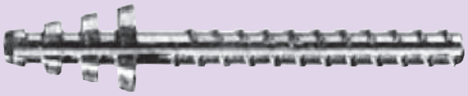
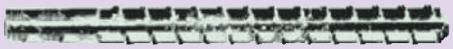
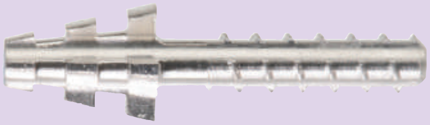
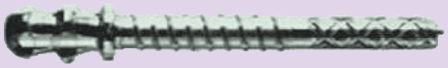
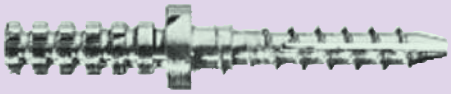
		SHANK		
Example[b]	**Product (Vendor)**	**Composition[c]**	**Diameter (mm)[d]**	**Characteristics**
	Obturation Screws (Pearson Dental)	SS, Ti	1.3	Tightly threaded, pointed tip
	Kurer K4 Anchor System—Ready Core Anchor (Marie Reiko)	SS, Ti alloy	1.6–2.0	Tightly threaded, flat tip
	Kurer K4 Anchor System—Universal Anchor (Marie Reiko)	SS, Ti alloy	1.5–2.0	Tightly threaded, flat tip
	Kurer K4 Anchor System—Custom Core Anchor (Marie Reiko)	SS, Ti alloy	1.7–2.0	Tightly threaded, flat tip
	Kurer K4 Anchor System—Denture Anchor (Marie Reiko)	SS, Ti alloy	1.8–2.0	Tightly threaded, flat tip
	Cytco-K (Dentsply Sirona)	Ti alloy	0.9 and 1.2	4 coronal threads, long tapered tip
	EUROPOST Titanium "B" Post (Dental Anchor Systems)	Ti alloy	0.9–1.5	Sparsely threaded, pointed tip
	EUROPOST Active (TVS) Headless Post (Dental Anchor Systems)	Ti alloy	1.2–1.8	Sparsely threaded, blunt tip
	EUROPOST Active (RVS) Headed Post (Dental Anchor Systems)	Ti alloy	1.2–1.8	Sparsely threaded, blunt tip
	Vlock Active Post (Brasseler USA)	Ti alloy	1.3–1.8	Sparsely threaded, blunt tip
	Vario Active Post (Brasseler USA)	Ti alloy	1.3–1.8	Sparsely threaded, blunt tip
	Radix-Anchor (Dentsply Sirona)	Ti alloy	1.2–1.6	Sparsely threaded, flat tip
	T-Post X—Threaded (Komet USA)	Ti	1.3 and 1.5	Sparsely threaded, flat tip
	T-Post (Komet USA)	Ti	1.3 and 1.5	Sparsely threaded, flat tip
	ParaPost XT (Coltène)	Ti alloy	0.9–1.5	Sparsely threaded, X-shape grooves, flat tip

TABLE 12.6 Currently Available Prefabricated Posts and Adaptable Post Systems[a]—cont'd

		SHANK		
Example[b]	**Product (Vendor)**	**Composition[c]**	**Diameter (mm)[d]**	**Characteristics**
	Flexi-Post (Essential Dental Systems)	Ti alloy, SS	1.0–1.9	Sparsely threaded, split shank
	Flexi-Flange (Essential Dental Systems)	Ti alloy, SS	1.1–1.9	Sparsely threaded, split shank
	Flexi-Overdenture (Essential Dental Systems)	Ti alloy, SS	1.4–1.9	Sparsely threaded, split shank
	Flexi-Post Fiber (Essential Dental Systems)	GF (proprietary S-glass)	1.2–1.7	Sparsely threaded, pointed tip
	Flexi-Flange Fiber (Essential Dental Systems)	GF (proprietary S-glass)	1.2–1.7	Sparsely threaded, pointed tip
Adaptable Posts Systems				
	SpiraPostPFS Taper (DMG America)	Poly Fiber and SS wire		Stainless steel wire twisted around poly fiber strands
	SpiraPostPFS Parallel (DMG America)	Poly Fiber and SS wire		Stainless steel wire twisted around poly fiber strands
	ParaPost XP Casting System Burnout Post (Coltène)	PB	0.9–1.8	Parallel, X-shape grooves, flat tip
	Endowel (DentalEZ/Star Dental)	PB	1.0–1.6	ISO[e] sizes: 80–140, smooth-sided, pointed tip
	C-I Plastic Burnout Post (Parkell)	PB	1.3 and 1.6	Tapered smooth-sided, blunt tip
	Plastic Burnout Post (Sterngold)	PB	1.7 and 1.8	Tapered smooth-sided, blunt tip
	Luminex Grooved Burnout Post (Dentatus USA)	PB	1.1–1.8	Wide grooves, tapered tip
	Luminex Smooth Impression Posts (Dentatus USA)	Plastic, (LT)	1.1–1.8	Creates shape for a corresponding Surtex post or Luminex Grooved Burnout Post
	REFORPIN Glass Fiber Accessory Post (Angelus Dental Products)	GF (LT)	0.9	Small apical diameter, extreme taper

Continued

TABLE 12.6 Currently Available Prefabricated Posts and Adaptable Post Systems[a]—cont'd

		SHANK		
Example[b]	**Product (Vendor)**	**Composition[c]**	**Diameter (mm)[d]**	**Characteristics**
	Rebilda Post GT (VOCO America)	GF rods (LT)	0.8–1.4 (bundle diameter)	Bundle of individual GF rods (each bundle varies in the number of rods)
	SPLENDOR—SAP Single Adjustable Post (Henry Schein)	Post: GF Sleeve: Epoxy resin	Post: 1.0; Sleeve: Apex 1.4. Top 2.4	Post: Parallel, shallow grooves, flat tip Sleeve: Tapered, slides over post

[a]Posts are categorized by their radiographic silhouette from the apical 8 mm of the shank.
[b]Posts are not photographed to scale.
[c]Composition key: *Brass*, alloy of copper and zinc (brass posts are gold plated); *CF*, carbon fibers bound by resin matrix; *GF*, glass fibers bound by resin matrix (glass fibers are either braided or unidirectional in orientation); *LT*, light transmission through the post; *PB*, plastic burnout for cast posts (composition of a cast post will depend on the metal selected in the casting process); *QF*, quartz fibers bound by resin matrix (quartz fibers are unidirectional orientation); *SS*, stainless steel; *Ti*, titanium (Ti indicates approximately 99% pure titanium, Ti alloy indicates a content of approximately 90% titanium); *ZGF*, zirconia glass fibers bound by resin matrix; *ZrO2*, zirconium oxide or zirconia.
[d]Shank diameter includes the threads of relevant posts; diameters of tapered posts are taken 8 mm from the apical tip (exceptions include: REFORPOST Metallic by Angelus Page 8 Dental Products, sizes No. 1 and No. 2 shank length is less than 8 mm and diameters are not listed, where sizes No. 3 and No. 4 have shank lengths longer than 8 mm and have diameters of 1.3 and 1.4 mm respectively; Standard Stern Root Anchor by Sterngold has a preparation depth of 7 mm, the most apical diameter of the parallel shank is 0.9 mm).
[e]Post shape corresponds to the taper of an endodontic file (0.04 and 0.06 taper found under ANSI/ADA Specification No. 101, which is an increase in diameter by 0.04 and 0.06 mm, respectively, for each millimeter from the tip; ISO [International Standards Organization] indicates a conventional standard file taper of 0.02, which is an increase in diameter by 0.02 mm for each millimeter from the tip).
[f]Surtex and Ancorex post categorization is dependent on the length of the post: The medium and longer sizes are parallel-sided threaded posts; the shorter sizes are tapered threaded posts.
Table by Donald A. Miller, Private Practice, Orland Park, Illinois.
Photographic services by: James Cockerill, Oak Park, Illinois; Brodie Sturm Photography, Chicago, Illinois; Keith French Photography, Elgin, Illinois.

Fig. 12.23 Classification of prefabricated posts. (A) Tapered smooth post. (B) Tapered serrated post. (C) Tapered threaded post. (D) Parallel-sided smooth post. (E) Parallel-sided serrated post. (F) Parallel-sided threaded post. (Redrawn from Shillingburg HT, Kessler JC. *Restoration of the Endodontically Treated Tooth*. Chicago, IL: Quintessence Publishing; 1982.)

The popular prefabricated posts are listed by diameter in Table 12.7. Parallel-sided prefabricated posts are recommended for conservatively prepared root canals in teeth with roots of circular cross section. Excessively flared canals (i.e., those found in young persons or in individuals after re-treatment of an endodontic failure) are most effectively managed with a custom post, although multifilament fiber posts are available.[74] However, each situation should be evaluated on its own merits.

Prefabricated posts. Many prefabricated posts are available in kits that include rotary instruments for post space preparation that correspond in size to the posts. Alternatively, some of these posts are manufactured to match standard sizes of endodontic files.

Enlarge the canal one or two sizes with a drill, an endodontic file, or a reamer that matches the configuration of the post (Fig. 12.25). When using rotary instruments, alternate between the Peeso Reamer drills and twist drills that correspond in size. Gain length with the Peeso Reamer drill, and then make the walls parallel with the twist drill.

Use a prefabricated post that matches standard endodontic instruments. A tapered post conforms better to the canal than does a parallel-sided post and requires less removal of dentin to achieve an adequate fit. However, it is slightly less retentive and results in greater stress concentrations, although retention may be improved by controlled grooving.[42]

Be especially careful not to remove more dentin at the apical extent of the post space than is necessary (see Figs. 12.14 and 12.25).

Of importance is that if measurements have been made carefully, radiographs are not normally necessary to verify the post space preparation.

Most of the time, a preformed parallel-sided post fits only in the most apical portion of the canal. Modified posts are available with tapered ends, and these conform better to the shape of the canal, although they have slightly less retention than parallel-sided posts do, particularly in restoration of shorter roots.[40]

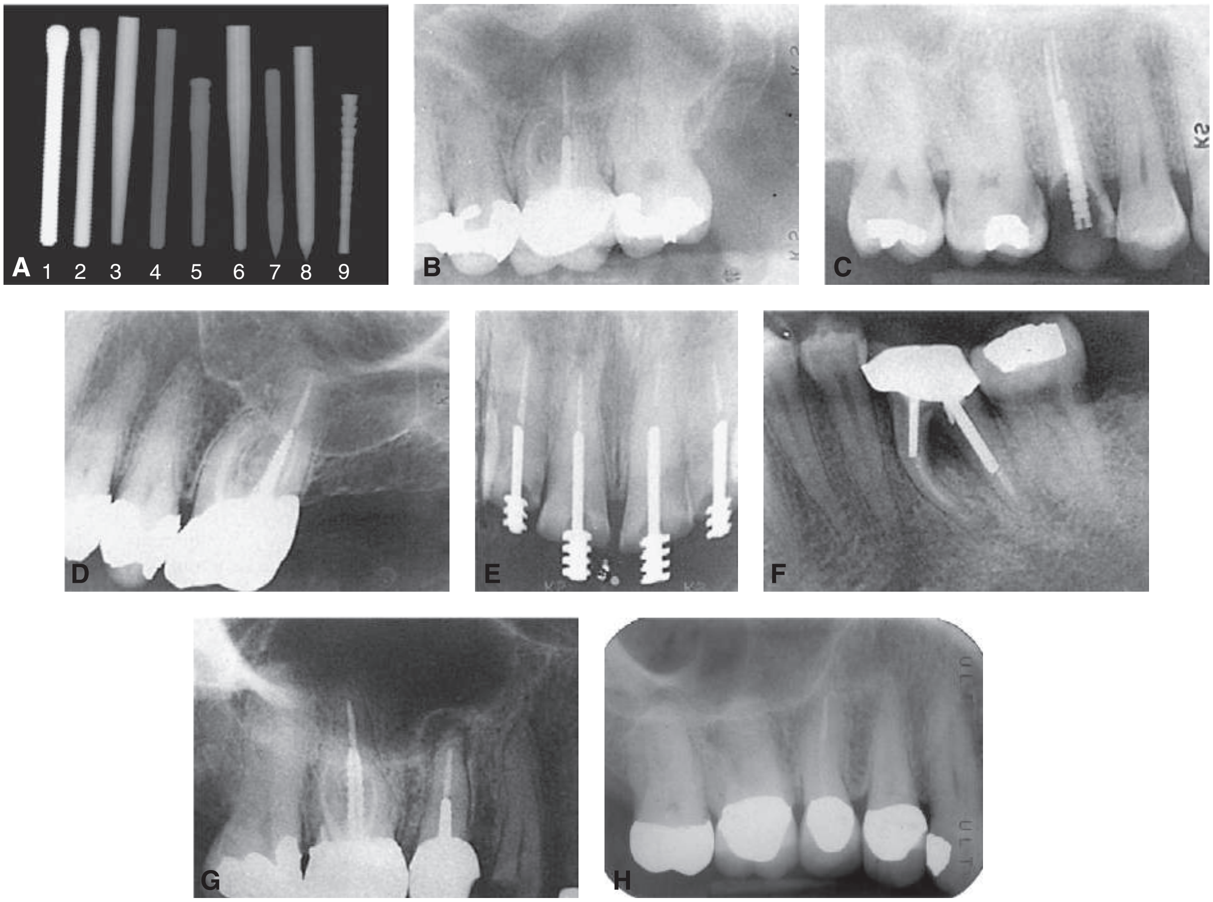


Fig. 12.24 The various endodontic posts encountered in clinical practice have varying degrees of radiopacity. Dentists accustomed to seeing traditional stainless steel and titanium posts may be deceived by more recently introduced systems. (A) The radiopacity of a post is in part due to its composition. Ten representative posts demonstrate how the material can change the radiopacity relative to a gutta-percha cone (from left to right): (1) C-Post, zirconium oxide (Komet USA); (2) Surtex, brass plated (Dentatus USA); (3) ParaPost, stainless steel (Coltène); (4) ParaPost Plus, titanium alloy (Coltène); (5) Filpost, pure titanium (Filhol Dental); (6) DT Light-Post Illusion X-RO, quartz fibers bound by resin matrix (RTD Dental); (7) FibreKleer 4X Tapered Fiber Post, glass fibers bound by resin matrix (Pentron); (8) EndoSequence Fiber Post, zirconia glass fibers bound by resin matrix (Brasseler USA); (9) CF Carbon Fiber Post, carbon fibers bound by resin matrix (J. Morita USA); and (10) size 40 Dia-Pro ISO.04 Plus gutta-perch cone (DiaDent). The type of cement that is used has a role in the radiopacity of the post (see Fig 30.6). The pure carbon fiber posts (not included in part A) are completely radiolucent. The type of cement that is used has a role in the radiopacity of the post (see Fig. 30.6). (B–I) Radiographs of the six categories: (B) Endowel (Star Dental), tapered and smooth sided. (C) Unimetric (Dentsply Sirona), tapered and serrated. (D) Surtex (Dentatus USA), tapered and threaded. (E) CTH Beta Post (CTH), parallel-sided and smooth. (F) ParaPost (Coltène) (two sizes), parallel-sided and serrated. (G) Flexi-Post (Essential Dental Systems) (in the right maxillary first molar), parallel-sided and threaded (note the split shank). (H) ParaPost Fiber Lux (Coltène) cemented with RelyX Luting Plus (3 M ESPE Dental). Note the radiolucency of the post in comparison with the radiopacity of the gutta-percha endodontic fill. (B, Courtesy Dr. D.A. Miller and Dr. H.W. Zuckerman. C, Courtesy Dr. I.A. Roseman. D, Courtesy Dr. F.S. Weine and Dr. S. Strauss. E, Courtesy Dr. J.F. Tardera. F, Courtesy Dr. J.L. Wingo. G, Courtesy Dr. L.R. Farsakian. H, Courtesy Dr. D.A. Miller and Dr. G. Freebeck.)

In the absence of a vertical stop on sound tooth structure, such posts can also create an undesirable wedging effect.

Custom-made posts

Use custom-made posts (Fig. 12.26) in canals that have a noncircular cross section or extreme taper. Enlarging canals to conform to a preformed post may lead to perforation. Often very little preparation is needed for a custom-made post. However, undercuts within the canal must be removed, and some additional shaping is usually necessary.

Be most careful on molars to avoid root perforation. In mandibular molars, interradicular root concavities make the distal wall of the mesial root and the mesial wall of the distal root particularly susceptible. In maxillary molars, the curvature of the mesiobuccal root increases the chance of mesial or distal perforation (Fig. 12.27).[75] Therefore neither post size nor length should be excessive.

Preparation of the Coronal Tooth Structure

After the post space has been prepared, the remaining coronal tooth structure is reduced for the extracoronal restoration. Specific reduction depends on the type of crown that is planned. When esthetic requirements apply, as for anterior teeth,

TABLE 12.7 Diameters of Eight Commonly Used Prefabricated Posts

	DIAMETER (in mm)									
Post	**0.80**	**0.90**	**0.95**	**1.00**	**1.05**	**1.15**	**1.20**	**1.25**	**1.35**	**1.40**
Surtex[a]					X		X		X	
Flexi-Post[a]			X		X					X
Endowel, size 80		[b]		[c]						
FibreKleer 4X Parallel Post				X				X		
Kurer K4 Anchor System—Universal (Crown Saver) Anchor										
ParaPost		X		X				X		
Radix[a]						X			X	
Vlock Passive Post						X			X	
	1.45	**1.50**	**1.60**	**1.65**	**1.75**	**1.80**	**1.85**	**1.90**	**2.00**	
Surtex[a]	X		X		X					
Flexi-Post[a]				X				X		
Stress-free post size 70										
FibreKleer 4X Parallel Post		X								
Kurer K4 Anchor System—Universal (Crown Saver) Anchor	X		X	X			X		X	
ParaPost		X			X					
Radix[a]			X	X						
Vlock Passive Post			X							

[a]Diameter includes threads.
[b]Five millimeters from tip.
[c]Ten millimeters from tip.
X, Available size.

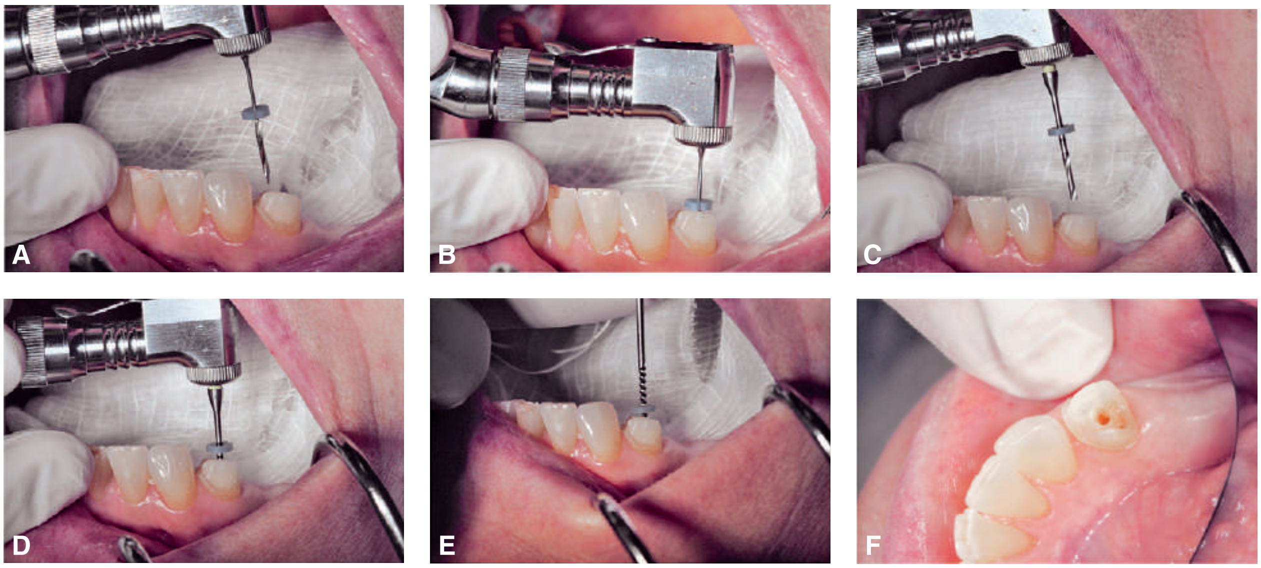


Fig. 12.25 Enlargement of the root canal for a prefabricated post. (A and B) Peeso Reamer drill used to remove gutta-percha to desired depth. (C and D) Twist drill is used to parallel the apical portion of the post space. No depth should be gained with the twist drill because perforation may result. (E) File is used to flare the coronal portion of the post space and to remove any undercuts. A file is used to verify both length of post space and placement of prefabricated post. (F) Completed post space preparation.

Fig. 12.26 Custom-made posts are indicated for teeth with root canals whose cross section is not circular or is extremely tapered. Further enlargement of the root canal is often not necessary on these teeth. (Courtesy C. Poeschl.)

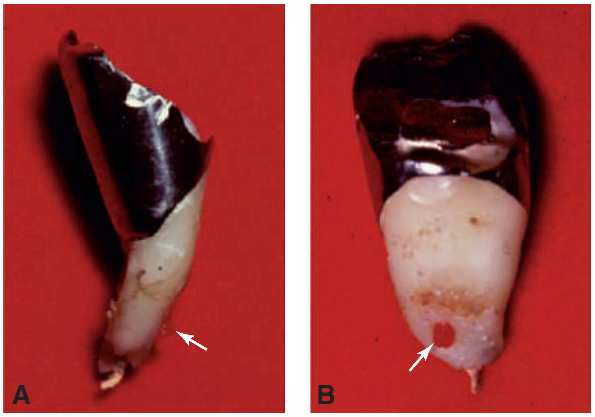


Fig. 12.27 (A and B) Distal root curvature contributed to this mesial perforation *(arrows)* of a mandibular molar and necessitated removal of the distal root segment. (Courtesy Dr. J. Davila.)

metal-ceramic crowns or all-ceramic crowns are indicated (see Chapters 9, 11, 24, and 25).

Ignore missing coronal tissue (from previous restorative procedures, caries, fracture, or endodontic access), and prepare the remaining tooth structure as if the coronal portion of the tooth is intact. The same specifications should be met (i.e., if a metal-ceramic crown with a porcelain labial margin is planned, a facial shoulder margin and a lingual chamfer margin are placed). The prepared walls are the starting point for the core materials, and ensuring that the interface is correct facilitates achieving correct preparation form in the core.

Be sure that the facial structure of the tooth is adequately reduced for good esthetics.

Remove all internal and external undercuts that will prevent withdrawal of the pattern.

Remove any unsupported tooth structure but preserve as much of the crown as possible. Because tooth structure has been removed internally and externally, the remaining walls often are thin and weakened. Defining absolute measurements for the dimensions of the residual coronal walls is difficult, but ideally, they should probably be at least 1 mm wide. Wall height is reduced in proportion to the remaining wall thickness because tall, thin walls tend to fracture when the interim restoration is removed and during evaluation and seating of the casting.

In addition, be sure that at least part of the remaining coronal tissue is prepared perpendicular to the path of placement of the post (see step 4 in Fig. 12.8) because this creates a horizontal flat surface that will serve as a positive stop to minimize wedging and potential splitting of the tooth. Similarly, prevent rotation of the post by preparing a flat surface parallel to the post (see step 5 in Fig. 12.8). If remaining tooth structure is insufficient for this feature, an antirotation groove should be placed in the canal (see Fig. 12.22).

Complete the preparation by eliminating sharp angles and establishing a smooth finish line.

Post Fabrication

Prefabricated Posts

Technique simplicity and treatment expediency are advantages of prefabricated posts. A post is selected to match the dimensions of the canal, and only minimum adjustment is needed to seat it to the full depth of the post space. The coronal part of the post may have an inadequate fit because the root canal has been flared. The dentist can correct this by adding material when the core is made.

Available materials. Prefabricated metal parallel-sided posts are made of platinum-gold-palladium (Pt-Au-Pd), nickel-chromium (Ni-Cr), cobalt-chromium, or stainless-steel wire (see Table 12.6). Serrated posts come in stainless steel, titanium, or nonoxidizing noble alloy. Tapered metal posts are available in Pt-Au-Pd, Ni-Cr, and titanium alloys. All these posts have a high modulus of elasticity and an elongated grain structure; thus they are more rigid than cast posts and therefore more suitable.

Bending has been attributed to failure of posts cast in type III gold when loaded at a 45-degree angle.[76] Although posts cast in stiffer (type IV) gold, Ni-Cr, or Co-Cr alloys can be expected to resist bending better, prefabricated posts should possess even more desirable physical properties, although their properties can deteriorate when a core is cast to a wrought post.[77]

The popularity of fiber composite posts has increased.[78] These posts consist of bundles of stretched aligned glass or carbon fibers (C-Posts, Bisco) embedded in a resin matrix. The resulting post is strong but has significantly less stiffness and strength than ceramic and metal posts do (Fig. 12.28).[79] However, in a laboratory study in which teeth restored with carbon fiber posts and composite-resin foundations were compared with teeth restored with custom post-and-core restorations cast in type III alloy, there were significantly higher fracture thresholds for the cast post-and-core restorations.[80] One advantage of fiber composite posts is their ease of removal if endodontic re-treatment is necessary. The preferred technique involves drilling in an apical direction with a Gates Glidden drill after a small pilot hole has been prepared with a round bur. Because significant heat is generated during removal, irrigation should be used. The very strong carbon fibers prevent the drill from tracking laterally, precludes penetration of the dentin, and prevents the post

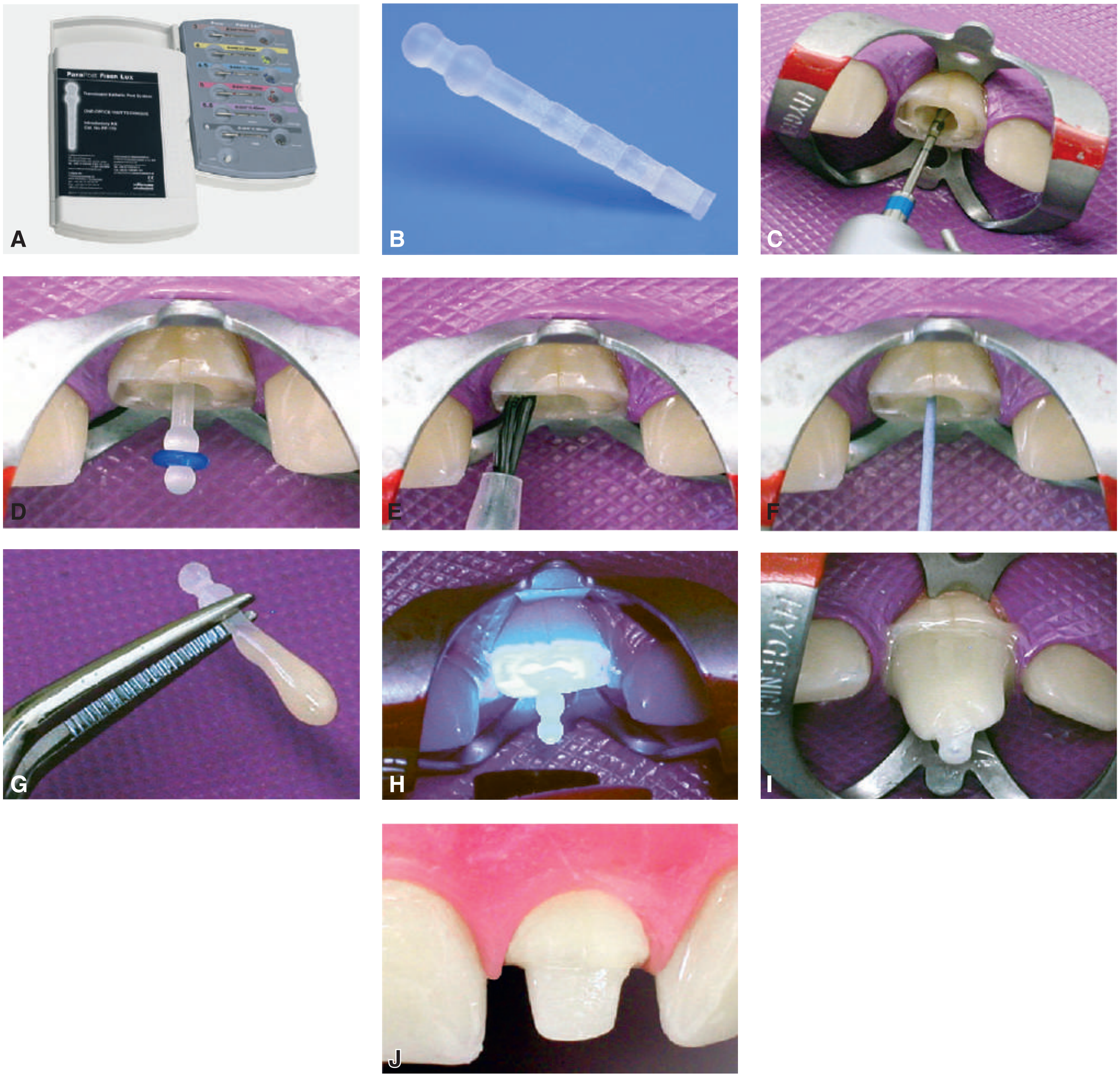


Fig. 12.28 Fiber composite posts. (A and B) The ParaPost Fiber Lux system is available in various sizes. (C) Gutta-percha is removed with hot instruments or a Gates Glidden drill. The canal is prepared sequentially with the drills provided by the manufacturer. (D) The post is seated in the canal. (E) The canal is prepared by etching and priming according to the manufacturer's recommendations. (F) The luting resin is introduced into the canal with a paper point. (G) The post is coated with resin luting agent and seated. (H) The resin is polymerized. The translucent post allows light transmission to the luting agent. (I) The core is built up with the recommended core resin. (J) Final appearance of the preparation. (Courtesy Coltène, Altstatten, Switzerland.)

from shattering easily into small fragments (Fig. 12.29). Glass fiber posts embedded in an epoxy matrix have properties that are somewhat comparable with those of carbon fiber posts, and translucent posts are available that can aid in light polymerization of resin luting agents.

Manufacturers have also developed high-strength ceramic[5,81] (zirconia) posts (CosmoPost, Ivoclar AG; Fig. 12.30) and ceramic composite (AEstheti-Post, Bisco, Inc.; Fig. 12.31) and woven fiber (e.g., polyethylene) posts (FibreKor, Pentron Clinical), all of which have excellent esthetic properties (see also Chapter 25). Ceramic is very strong and rigid; woven fiber is weaker and more flexible.[82]

Corrosion resistance. In several reports,[83–85] root fracture has been linked to corrosion of base metal prefabricated post-and-core systems. In a report on 468 teeth with vertical or oblique root fracture,[81] investigators attributed 72% of these failures to electrolytic action of dissimilar metals used for the post and the core (reaction occurring between tin in the amalgam core and stainless steel, German silver, or brass in the post). The authors suggested that volume changes produced by corrosion products

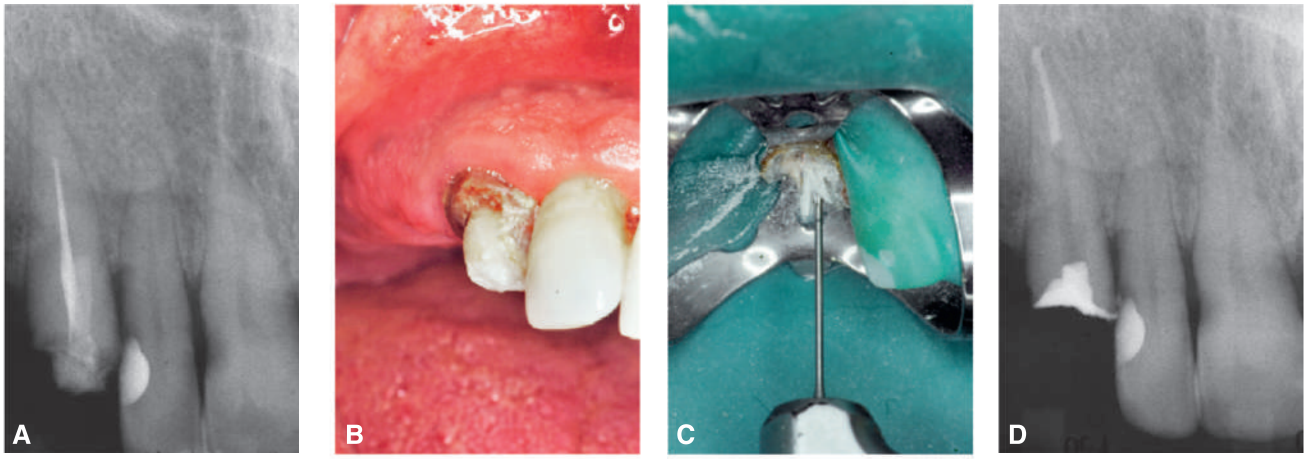


Fig. 12.29 (A) Maxillary canine requires fiber post removal for endodontic re-treatment. (B) Composite resin core is removed first. (C) Gates Glidden drill used to remove the fiber post. (D) Endodontically re-treated tooth before fabrication of a new post-and-core restoration and a new extracoronal restoration. If concern exists about the long-term prognosis of an endodontically treated tooth, a carbon fiber post should be considered. The chief disadvantage of a carbon fiber post is its black appearance, which presents an esthetic problem (as can metal posts). (Courtesy Dr. D.A. Miller.)

Fig. 12.30 Zirconia posts, such as the CosmoPost, shown with the corresponding rotary instruments, are esthetic and strong. Special pressable ceramics are available to form the core (composite resin can also be used). (Courtesy Ivoclar AG, Amherst, NY.)

split the root. Although possible fracture mechanisms have been suggested,[81,83] these studies appear to confuse cause with effect: The corrosion may have occurred after root fracture rather than causing it.[86]

Further study is needed to answer the question conclusively. However, in the meantime, avoiding the use of potentially corrodible dissimilar metals for post, core, and crown is recommended.

Custom-Made Posts

A custom-made post-and-core restoration can be made of cast metal or from zirconia or PICN fabricated with CAD-CAM technology. A cast metal post-and-core restoration can be made from a direct pattern fabricated in the patient's mouth or from an indirect pattern fabricated in the dental laboratory. A direct technique with autopolymerizing (Fig. 12.32) or light-polymerized resin is recommended for single canals with good clinical access, whereas an indirect procedure is more appropriate when access is more problematic or for multiple canals. An alternative to autopolymerizing resin is thermoplastic resin (Fig. 12.33).

Direct pattern procedure

Fit a prefabricated plastic dowel to the root canal. For a flared canal, the fit will be adequate only in the apical half of the prepared post space (Fig. 12.32A). It must extend to the full depth of the prepared canal. Lightly lubricate the canal (Fig. 12.32B). Dry the canal by directing air across the root surface (Fig. 12.32C). Never blow air directly into a root canal for fear of introducing air into the tissues.

Use the "brush-bead" technique to add resin to the occlusal half dowel (Fig. 12.32D) and seat it in the prepared canal (Fig. 12.32E). Push the resin into the canal with a small condenser (Fig. 12.32F).

Do not allow the resin to harden fully within the canal. Loosen and reseat it several times while it is still rubbery.

Once the resin has polymerized, remove the pattern (Fig. 12.32G).

Form the core part of the post by adding additional autopolymerizing resin (Fig. 12.32H) or light-polymerized resin (Palavit G LC, Heraeus).

Pattern fabrication with thermoplastic resin

Fit the plastic rod to the prepared post space. Trim the rod until the bevel area is approximately 1.5 to 2 mm occlusal to the finish line for the core.

Lubricate the canal with a periodontal probe and petroleum jelly (Fig. 12.33A).

Heat the thermoplastic resin over a flame until the material turns clear (Fig. 12.33B), or heat the resin in a low-temperature glue gun (Thermogrip, Black, & Decker).

Apply a small amount of the heated resin to the apical end of the rod to cover two thirds of the anticipated length of the post pattern (Fig. 12.33C).

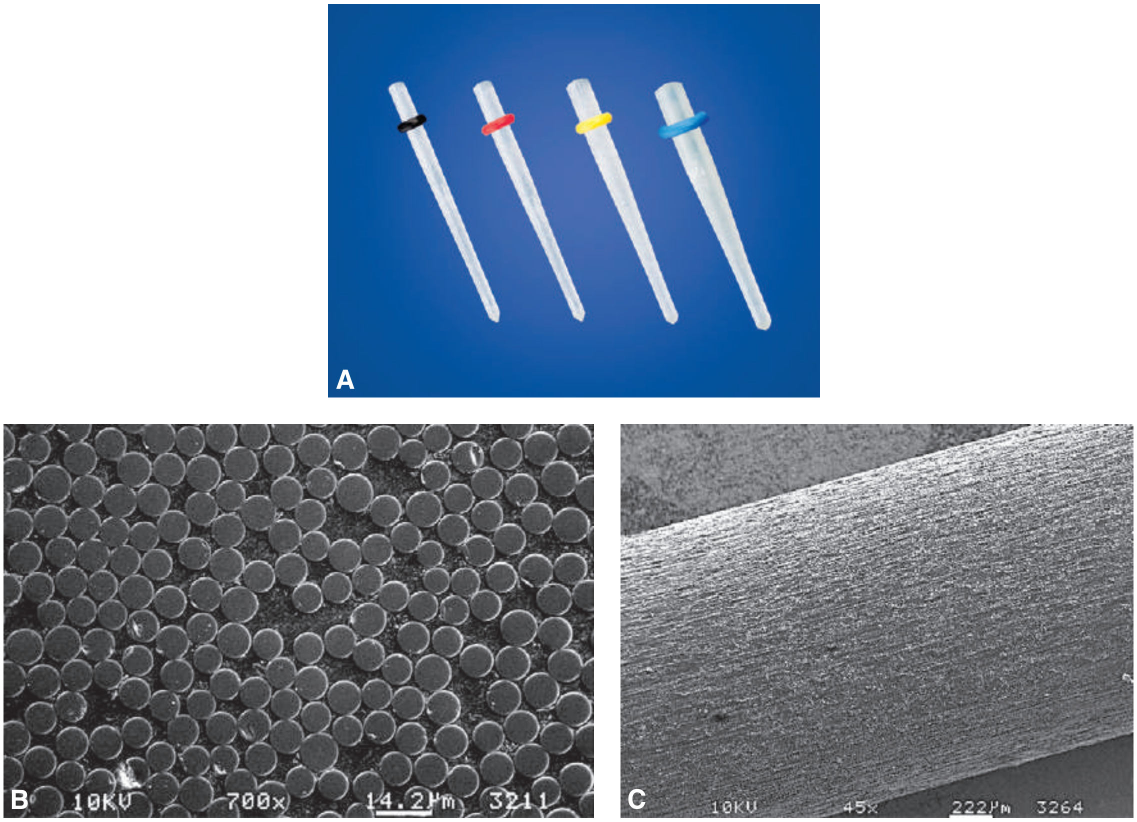


Fig. 12.31 Ceramic composite post. (A) In the D.T. Light-Post system, quartz fibers are used in an epoxy resin matrix. Cross-sectional (B) and longitudinal (C) views of the fiber composite. (Courtesy Bisco, Inc., Schaumburg, IL.)

Fully insert the rod into the prepared post space (Fig. 12.33D). Lift after 5 to 10 seconds and reseat. Inspect the post pattern for completeness, and, with a scalpel blade, remove any projections that result from undercuts in the canal.

For the direct technique, fabricate the core with conventional autopolymerizing resin (Fig. 12.33E), using the "brush-bead" technique, or use a syringe to apply a light-polymerized pattern resin (an easier technique).

If the indirect technique is preferred, pick up the pattern with an elastomeric impression material, which can be poured in the conventional manner. Soak the cast in warm water to help release the pattern. Reseat the post pattern, and wax the core.

Invest and cast (Fig. 12.33F) the post-and-core restoration. Phosphate-bonded investment is recommended because of its higher strength.

Indirect procedure. Any elastomeric material will make an accurate impression of the root canal (Fig. 12.34A) if wire reinforcement is placed to prevent distortion.

Cut pieces of orthodontic wire to length, and shape them like the letter J (see Fig. 12.34B).

Verify the fit of the wire in each canal. It should fit loosely and extend to the full depth of the post space. If the fit is too tight, the impression material will be stripped away from the wire when the impression is removed.

Coat the wire with tray adhesive. If subgingival margins are present, tissue displacement may be helpful. Lubricate the canals to facilitate removal of the impression without distortion (die lubricant is suitable).

Using a Lentulo spiral (Dentsply Sirona), fill the canals with elastomeric impression material. Before loading the impression syringe, verify that the Lentulo spiral will cause the material to spiral in an apical direction (clockwise). Pick up a small amount of material with the largest Lentulo spiral that fits into the post space. Insert the Lentulo spiral with the handpiece set at low rotational speed to slowly carry material into the apical portion of the post space. Then increase handpiece speed, and slowly withdraw the Lentulo spiral from the post space. This technique prevents the impression material from being dragged out. Repeat until the post space is filled.

Seat the wire reinforcement to the full depth of each post space, use a syringe to fill in more impression material around the prepared teeth, and insert the impression tray (see Fig. 12.34C).

Remove the impression (see Fig. 12.34D), evaluate it, and pour the definitive cast (see Fig. 12.34E) as usual (see Chapter 17). Access for waxing is generally adequate without placement of dowel pins or sectioning of the cast.

Roughen a loose-fitting plastic post (a plastic toothpick is suitable) and, using the impression as a guide, make sure that it extends into the entire depth of the canal.

Apply a thin coat of sticky wax to the plastic post, and, after lubricating the stone cast, add soft inlay wax in increments (Fig. 12.35). Start from the most apical point, and make sure that the post is correctly oriented as it is seated to adapt the wax. When this post pattern has been fabricated, the wax core can be added and shaped.

Use the impression to evaluate whether the wax pattern is completely adapted to the post space.

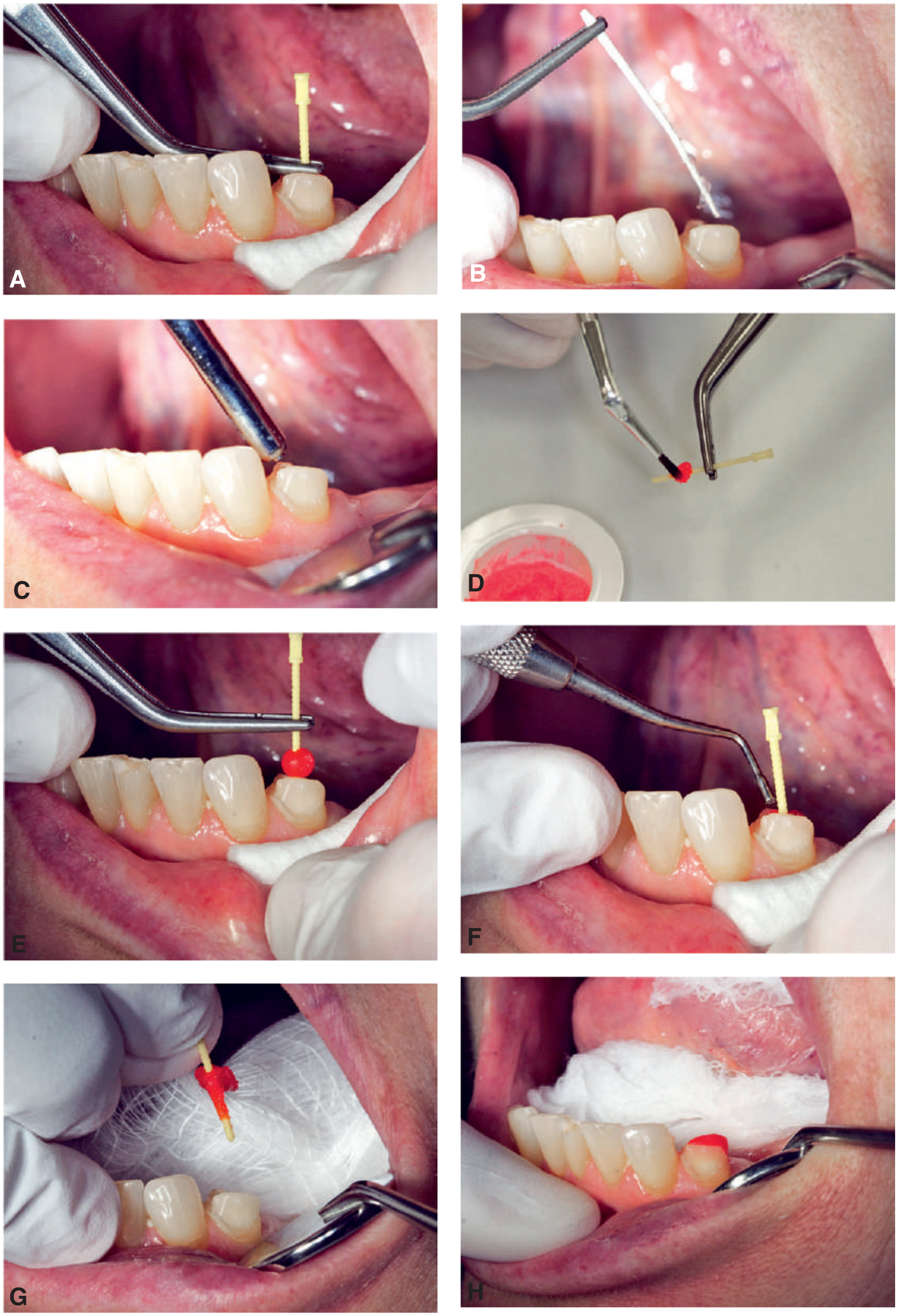


Fig. 12.32 Fabrication of a custom-made pattern for a custom-made post. (A) Prefabricated plastic post is tried in. The post should seat the full length of the prepared post space. Lubricant is carried into the post space on a paper point (B), and compressed air is used to remove any excess (C). (D) A small brush is used to pick up some pattern resin and added at the level of the chamber. The plastic post is seated (E), and a small condenser can be used to ensure adequate adaptation of the resin (F). (G) Completed post pattern after additional resin has been added. Note that the apical portion of this prefabricated plastic post corresponds in size to the twist drill used. Therefore the tip of the pattern is not covered with resin. (H) The core portion of the pattern can now be developed through addition of more resin.

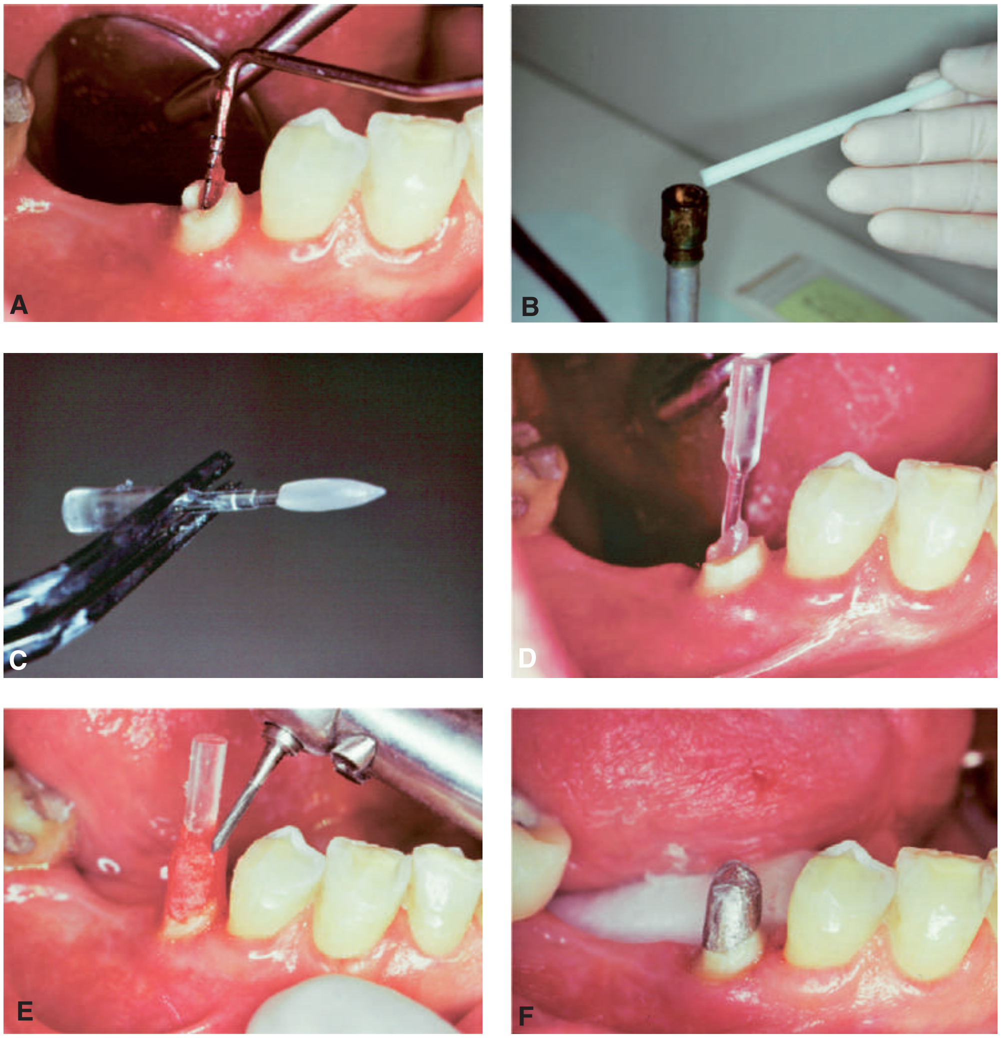


Fig. 12.33 The Merritt EZ Cast Post system. (A) The canal is lubricated, and excess lubricant removed with paper points. The post was previously trimmed until its beveled portion protruded approximately 1.5 to 2 mm above the tooth preparation. (B) A stick of the thermoplastic material is heated. (C) The plastic rod is covered for approximately two thirds of the anticipated post length. (D) The coated post is inserted and can be removed in 5 to 10 seconds. (E) After any protrusions have been removed, the core is built from autopolymerizing resin and trimmed to ideal tooth preparation form. (F) The completed custom post-and-core restoration. (From Rosenstiel SF, Land MF, Holloway JA. Custom-cast post fabrication with a thermoplastic material. *J Prosthet Dent*. 1997;77:209.)

CAD-CAM POST-AND-CORE RESTORATIONS

Strong, esthetic post-and-core restorations can be fabricated from high strength zirconia or PICN with CAD-CAM technology.[87] Typically, the dentist makes an impression of the prepared tooth, which is scanned and digitized by the dental laboratory technician before the zirconia is milled and sintered (Fig. 12.36).[82] One disadvantage of a custom-milled zirconia system is the difficulty of removal if an endodontic re-treatment is indicated.

Core Fabrication

The core of a post-and-core restoration replaces missing coronal tooth structure and, in combination with the remaining coronal tissue, forms the shape of the optimal tooth preparation. It can be shaped in resin or wax and added to the post pattern before the assembly is cast in one piece. It is cast directly onto a prefabricated post. There is some concern that the casting process may unfavorably affect the physical properties of wrought metal posts. A third alternative is to make the core from a plastic restorative material, such as amalgam, or from composite resin or glass ionomer.

Plastic Filling Materials

The advantages of composite resin, resin-modified glass ionomer, or amalgam[76,88,89] include the following:

- Maximum tooth structure can be conserved because undercuts do not need to be removed.
- Treatment requires one fewer patient visit.
- There are fewer laboratory procedures.
- Testing has generally revealed good resistance to fatigue testing[90] and good strength characteristics,[91] possibly because of the good adaptation to tooth structure. However, these plastic restorative materials, especially the glass ionomers, have lower tensile strength than do cast metals.

All of the elastomeric impression materials require some form of reinforcement when making a postspace impression.

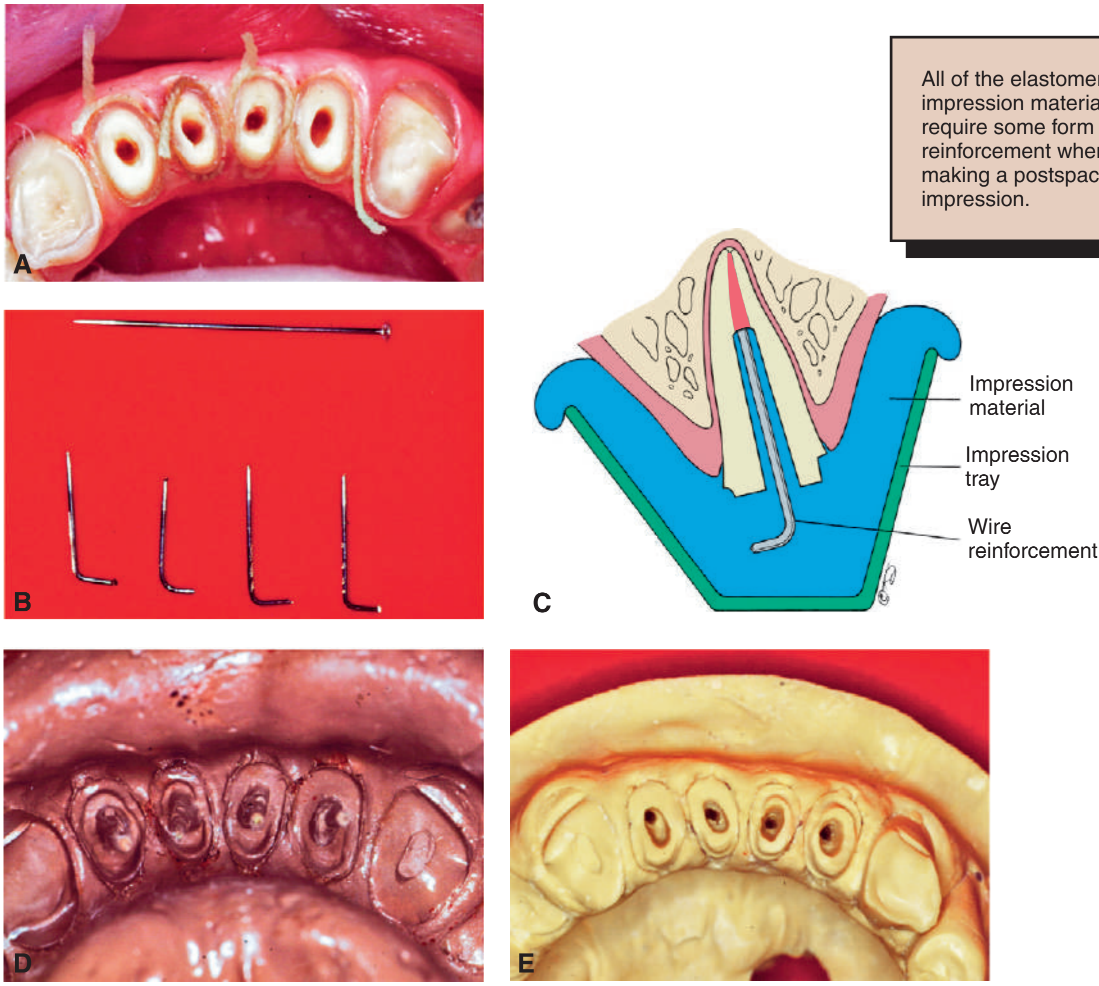


Fig. 12.34 Indirect procedure for post-and-core restorations. (A) Mandibular incisors prepared for post and cores. (B) Wire reinforcement coated with tray adhesive. (C) Cross section through indirect post space impression. (D) Completed impression. (E) Definitive cast.

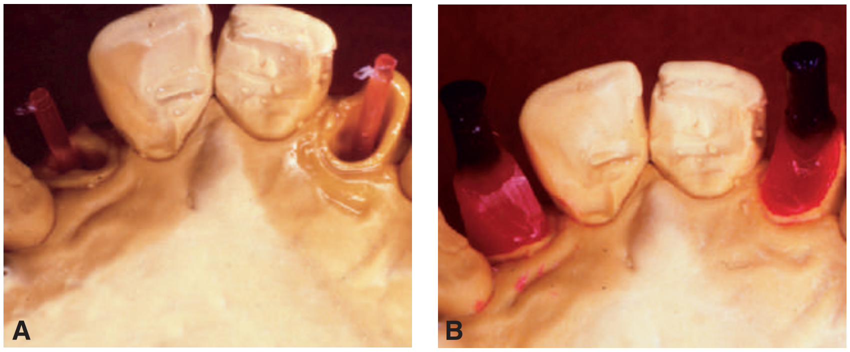


Fig. 12.35 (A and B) Post-and-core restoration patterns made by adding wax to prefabricated plastic posts.

- Disadvantages include the following:
- Long-term success may be affected by corrosion of amalgam cores, the low strength of glass ionomer,[92] or the continued polymerization[93] and high thermal expansion coefficients of composite resin cores.
- Microleakage with temperature fluctuations (thermocycling) is greater under composite resin and amalgam cores than under conventional crown preparations[94] (however, the extent of leakage under cast cores has yet to be determined).
- Difficulty may be encountered with certain operative procedures such as dental dam or matrix application (particularly on badly damaged teeth).

Amalgam cores are suitable for restoring posterior teeth, particularly when some coronal structure remains. The procedure

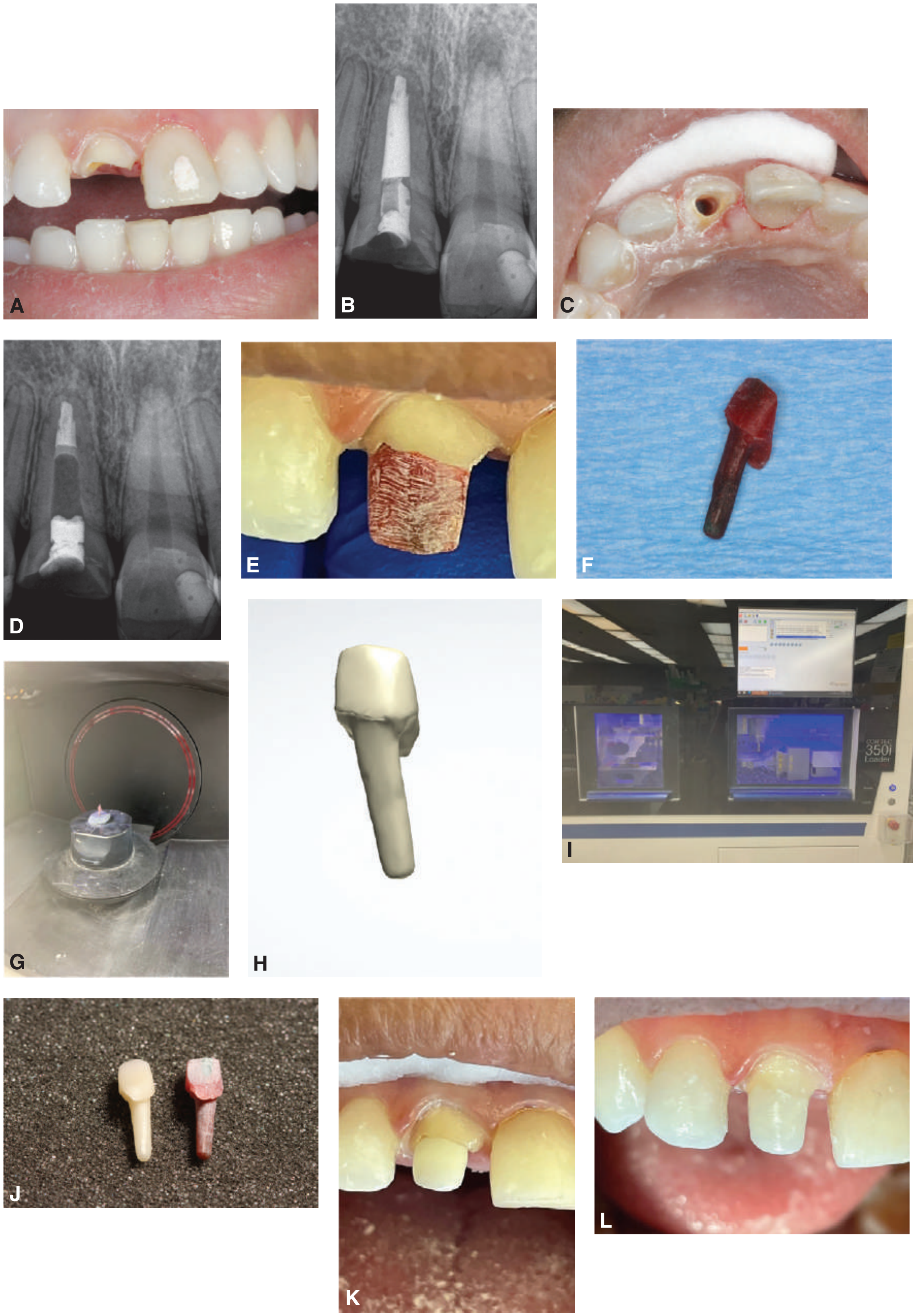


Fig. 12.36 Milled zirconia post-and-core. (A) Fractured central incisor in young patient with minimal ferrule after endodontic treatment. (B) Periapical radiograph. (C) Note large post-space diameter. (D) Radiograph of prepared post space. (E and F) Completed resin pattern. (G) Pattern positioned in laboratory scanner. (H) Design of intended mill. (I) Milling green state pattern before sintering. (J) Completed post-and-core after sintering next to original resin pattern. (K) Zirconia post-and-core at initial clinical evaluation. Note compromised adaptation in area where junction between core and tooth structure was notched rather than smooth because the milling process cannot reproduce such areas well (see also E). (L) Completed post-and-core after cementation. (Clinical treatment images courtesy Drs Xavier Lepe and Shirley Soeun Park. Laboratory images courtesy Nakanishi Dental Lab, Bellevue, WA.)

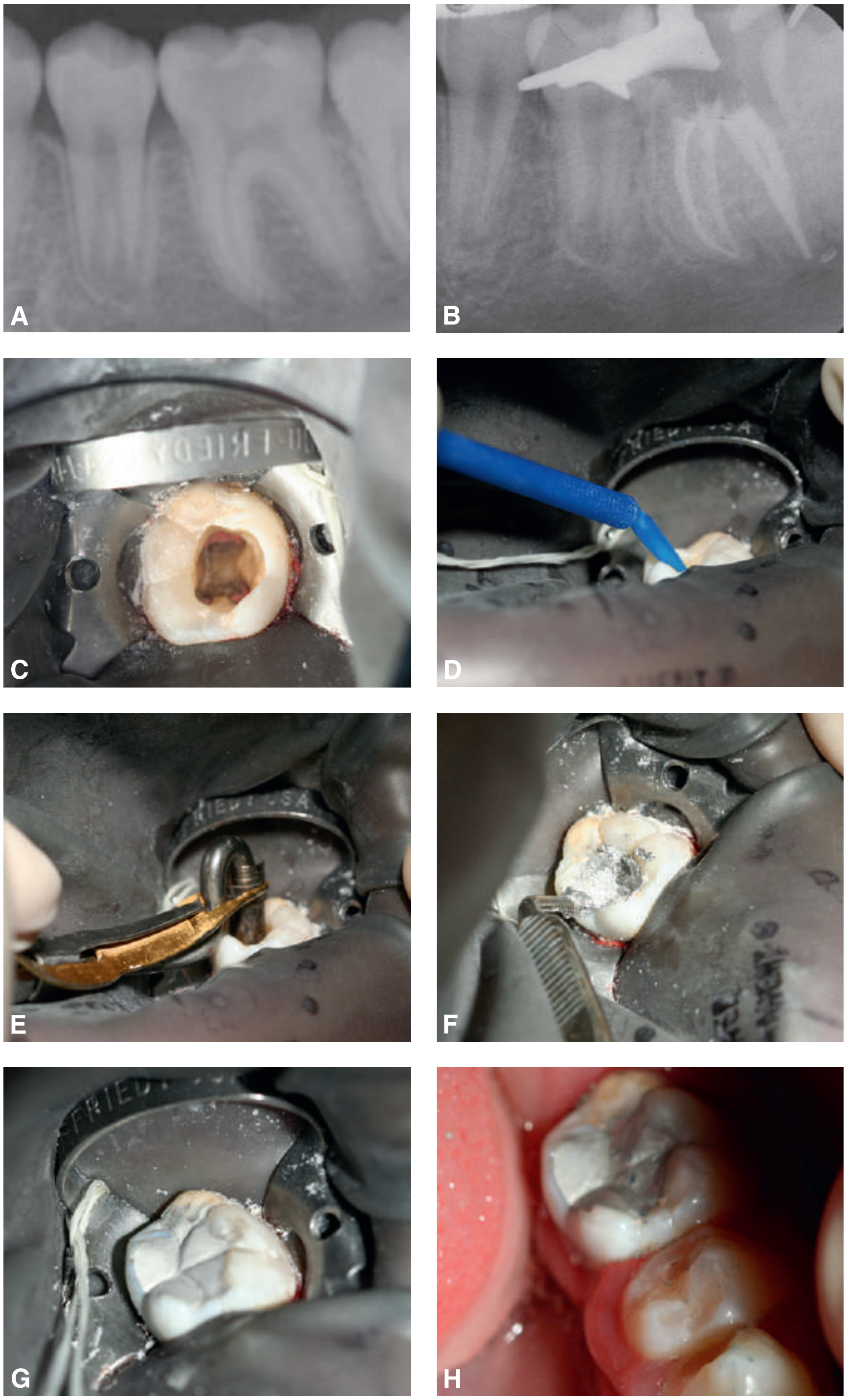


Fig. 12.37 Amalgam core technique. (A and B) Extensive caries resulted in need for endodontic treatment. (C) Chamber preparation may include slight extension into canals. (D) After etching, bonding agent is applied under dental dam isolation. (E) Amalgam is carried into the chamber. (F) Alloy being condensed. (G and H) Completed amalgam foundation restoration. (Courtesy Dr. R.D. Douglas.)

described by Nayyar et al.,[55] in which amalgam is also used for the posts, is conservative of tooth structure (Fig. 12.37). The cores are placed during the same appointment as the root canal obturation because then the teeth are still isolated by the dental dam, the practitioner is still familiar with the root canal structure, and the cores can serve as a support for the interim restoration (Fig. 12.38).

Step-by-step procedure for amalgam. See also Chapter 6.

Apply the dental dam, and, using a warmed endodontic instrument, remove gutta-percha from the pulp chamber, as well as 2 to 4 mm into each root canal if less than 4 mm of coronal height remains.

Remove any existing restoration, undermined enamel, or carious or weakened dentin. Establish the cavity form by using

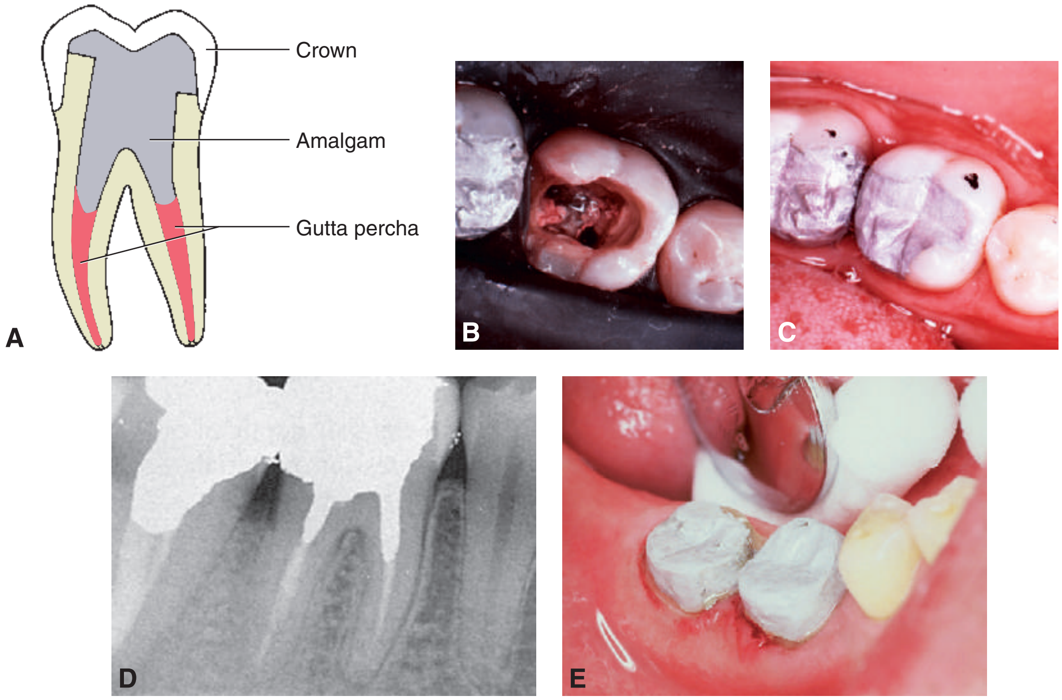


Fig. 12.38 Retention for an amalgam foundation can be obtained from the root canal system, preserving as much tooth structure as possible. (A) Cross section of chamber-retained amalgam foundation. (B) Gutta-percha removed from pulp chamber and root canals for amalgam foundation restoration. (C) Amalgam condensed and contoured. (D) Radiograph showing extent of amalgam. (E) Teeth prepared for complete crowns. (B to D, Courtesy Dr. M. Padilla.)

conventional principles of resistance and retention form. Even if cusps are missing, pins are not normally required because adequate retention can be obtained by extension of the amalgam into the root canals.

If the floor of the pulp chamber could be thin, protect it from condensing pressures with a cement base.

Fit a matrix band. Where lack of tooth structure makes the application of a conventional matrix system difficult, an orthodontic or annealed copper band may be used.

Condense the first increments of amalgam (select a material with high early strength) into the root canals with an endodontic plugger.

Fill the pulp chamber and coronal cavity in the conventional manner.

Carve the alloy to shape. The impression can be made immediately. Alternatively, the amalgam can be built up to anatomic contour and later prepared for a complete crown. Under these circumstances, the patient must be cautioned to avoid forces that would fracture the tooth or the newly placed restoration.

Cast Metal

Cast metal cores have the following advantages:

- They can be cast directly onto a prefabricated post, which will provide the restoration with good strength characteristics.
- Conventional high noble-metal content alloys can be used.
- An indirect procedure can be used, which will facilitate restoration of posterior teeth.

Direct procedure for single-root teeth. Direct patterns can be formed by combining a prefabricated post with autopolymerizing resin. Alternatively, a thermoplastic material can be used to create a post pattern,[95] and the core portion can be developed in autopolymerizing resin, light polymerized resin, or wax.

Pattern fabrication with autopolymerizing resin.

Use a prefabricated metal or custom acrylic resin post.

Add resin by the "brush-bead" technique, dipping a small brush in monomer and then into polymer and applying it to the post. Alternatively, light-cured resin can be used to facilitate this step.[96]

Slightly overbuild the core, and let it polymerize fully (Fig. 12.39A).

Shape the core with carbide finishing burs or diamonds (see Fig. 12.39B). Use water spray to prevent overheating of the acrylic resin. Correct any small defects with wax.

Remove the pattern (see Fig. 12.39C); sprue and invest it immediately.

Interim Restorations

To reduce the need for endodontic re-treatment, endodontically treated teeth should be restored as soon as practical after completion of the endodontic procedure. Zinc oxide–eugenol (ZOE) luting materials have been used for many years to achieve a seal of the endodontic access cavity before initiation of prosthetic treatment. However, such ZOE materials have been shown to leak at the dentin-material interface.[97] Thus, if definitive restoration of the tooth is delayed, it is appropriate to etch and seal the access cavity with an adhesive resin to reduce the risk of microleakage. Nonetheless, teeth in the esthetic zone often require a well-adapted interim restoration (see Chapter 15).

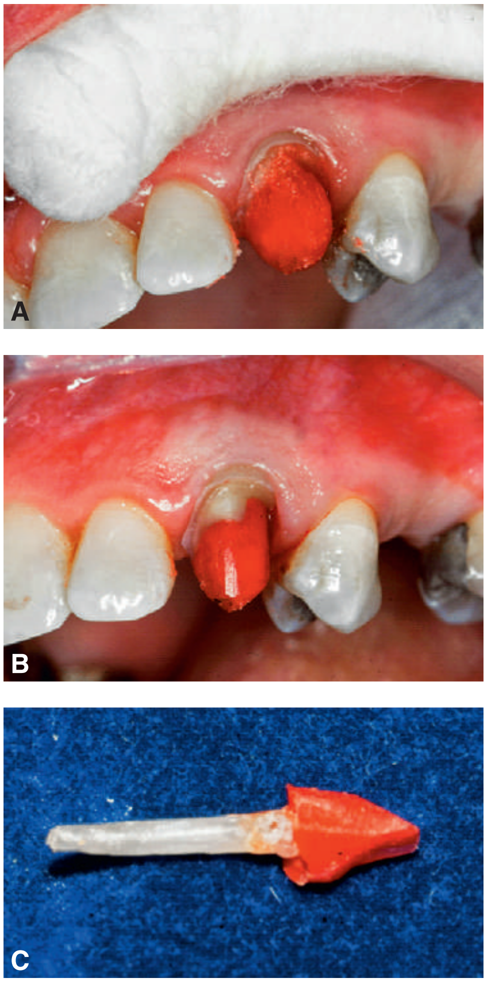


Fig. 12.39 Direct pattern for a single-root tooth. (A) Pattern slightly overbuilt with brush-bead technique. (B) Pattern prepared with tungsten carbide finishing bur. (C) Direct post-and-core pattern.

> It is not essential that the reline material extend all the way down the post space. By engaging the apical portion of the post space, the wire will enhance resistance of the interim restoration.

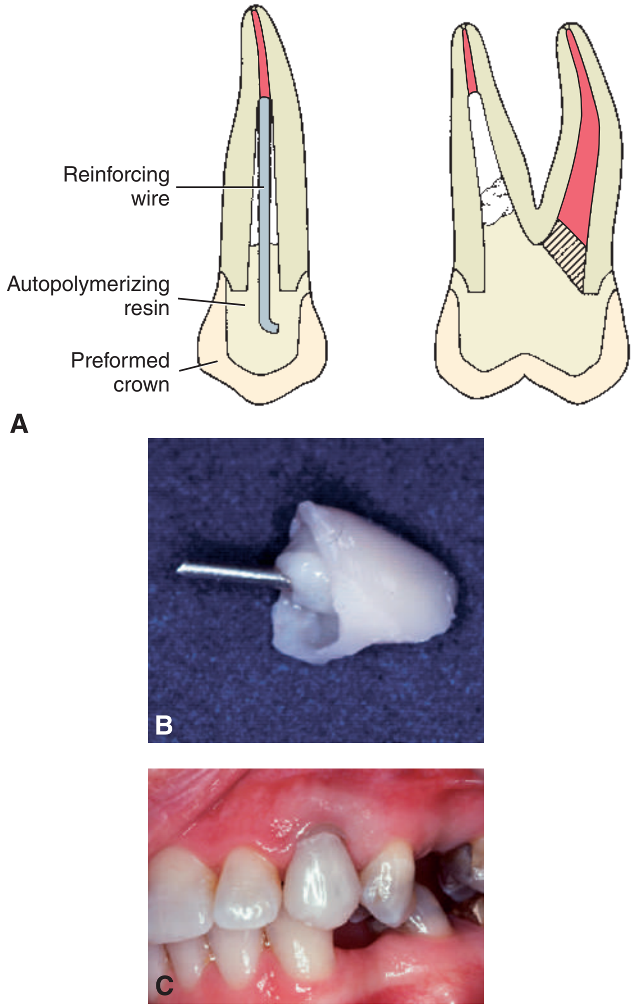


Fig. 12.40 (A and B) Interim restorations made for endodontically treated teeth by lining a polycarbonate crown with autopolymerizing resin. The post is made of metal wire (orthodontic wire or a paper clip; see Chapter 15). (C) Restoration seated. (A, Redrawn from Taylor GN, Land MF. Restoring the endodontically treated tooth and the cast dowel. In: Clark JW, ed. *Clinical Dentistry*. Vol 4. New York: Harper & Row; 1985.)

Such interim restorations prevent drifting of the tooth itself and of opposing or adjacent teeth after completion of endodontic treatment (Fig. 12.40). Of particular importance are good proximal contacts to prevent tooth migration that leads to unwanted root proximity. If a cast post-and-core restoration is made, the tooth will require an interim restoration while the post-and-core restoration is being fabricated. To retain tooth position, a wire of suitable diameter, or an interim post that matches the size of the selected post-and-core restoration system, can be fitted into the prepared canal. The restoration is then fabricated with autopolymerizing resin by the direct technique.

Investing and Casting

A cast post-and-core restoration should be slightly undersized in relation to the prepared post space to ensure full seating. However, the fit should not be so loose that light finger pressure causes rocking, rotation, or wobbling. On the other hand, a tight fit may cause root fracture. The casting should be slightly undersized, which the dentist can accomplish by appropriately restricting expansion of the investment (e.g., by omitting the usual ring liner or by casting at a lower mold temperature; see Chapter 22).

An accelerated casting technique may facilitate the laboratory phase.[98] CAD-CAM technology can also be used for the rapid fabrication of a post-and-core restoration (Fig. 12.41).[99] The casting alloy should have suitable physical properties. Extra-hard partial dental prosthetic gold (American Dental Association type IV) or Ni-Cr alloys have high moduli of elasticity and are recommended for cast posts (see Chapter 19). A sound casting technique is essential because any undetected porosity can lead to weakening and then failure of the casting (Fig. 12.42).

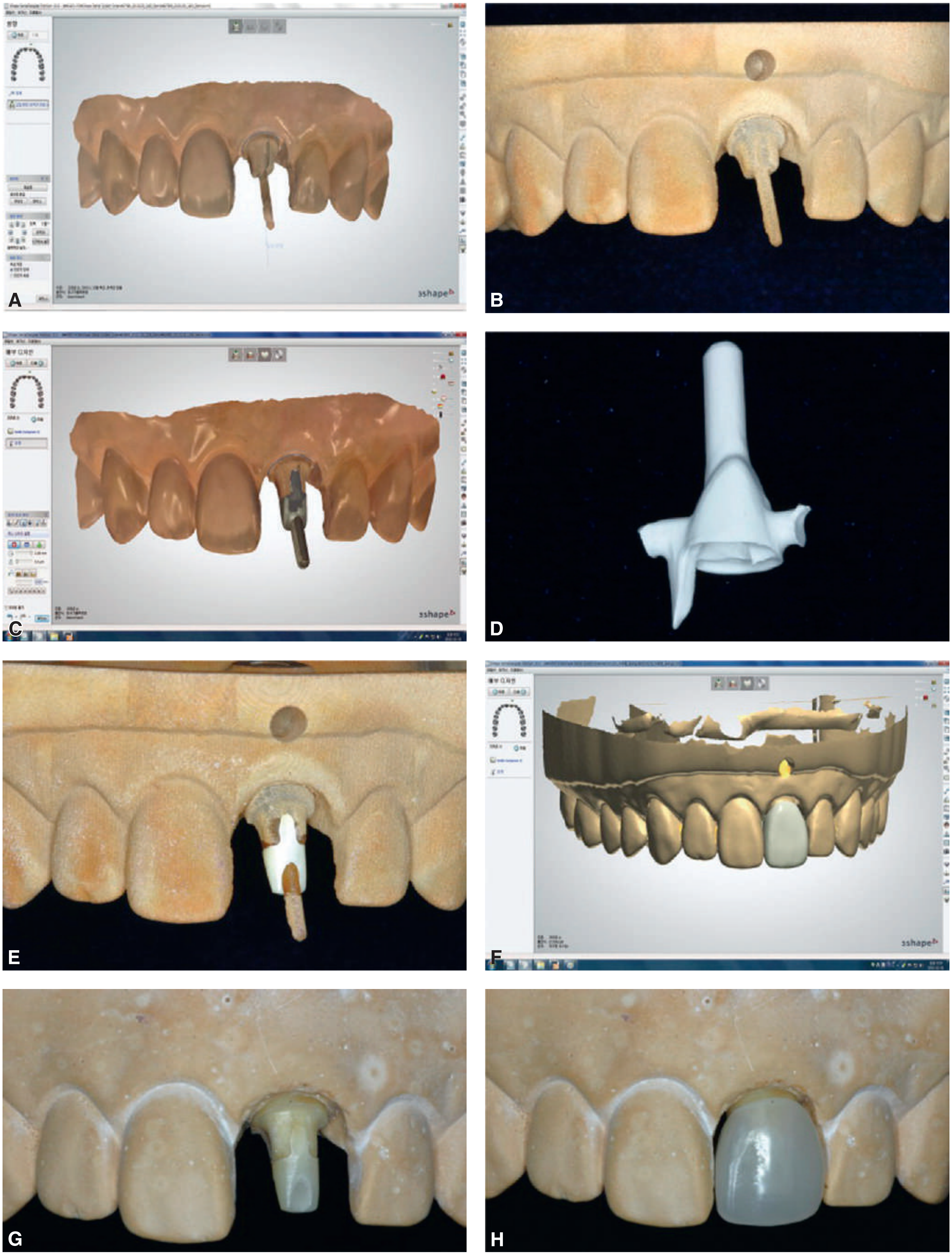


Fig. 12.41 (A) Software view of digital scan by intraoral digital scanner. (B) Polyurethane cast. (C) Software view of computer-aided design of anatomically correct core that is based on contralateral tooth. (D) Milled zirconia core before sintering. (E) Zirconia core fitted in polyurethane cast. (F) Software view of computer-aided design of anatomically correct crown that is based on contralateral tooth. (G) Fiber-reinforced composite resin post and zirconia core in place. (H) Interim restoration milled from high-density polymer.

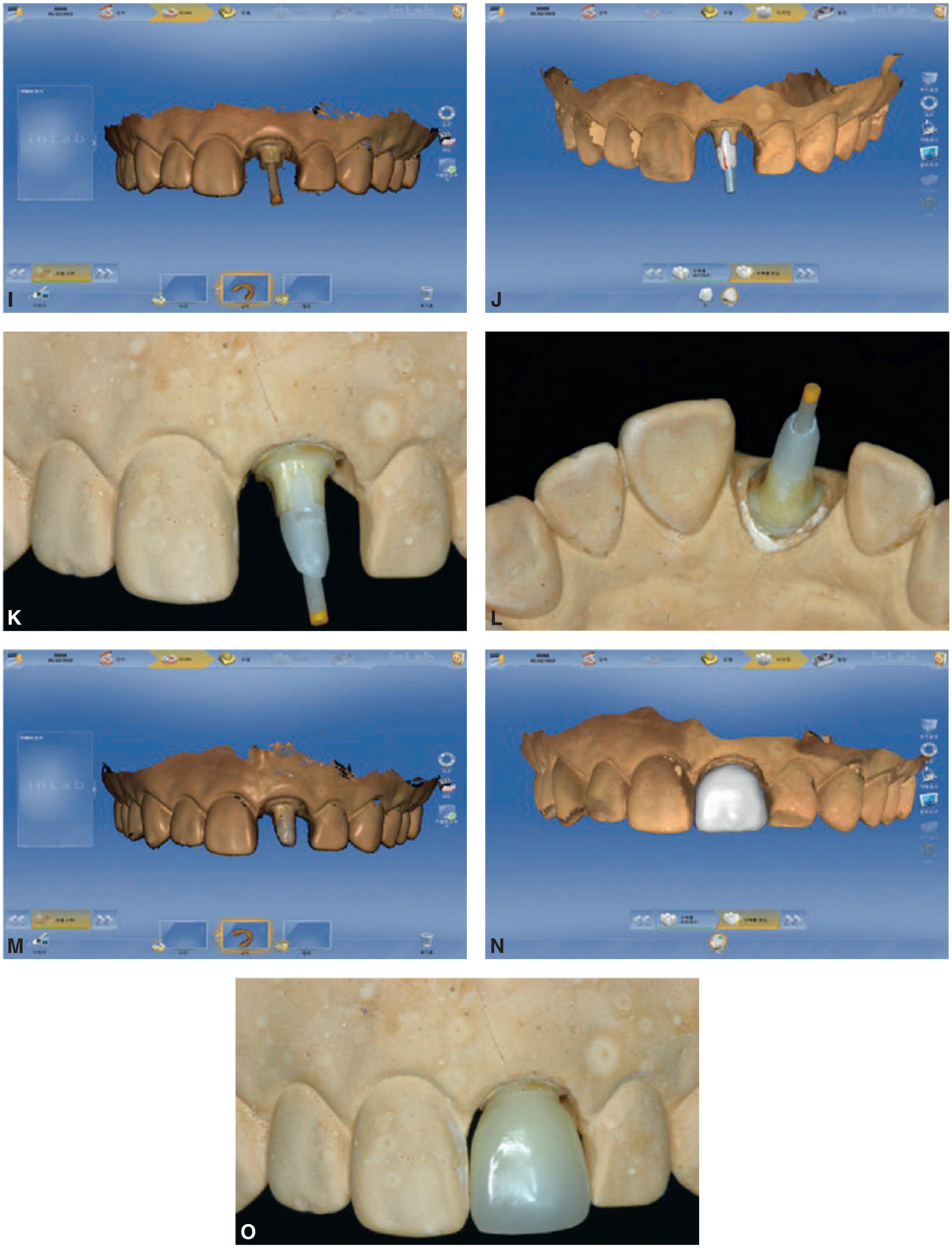


Fig. 12.41 cont'd (I) Software view of digital scan by intraoral digital scanner. (J) Software view of computer-aided design of anatomically correct core that is based on tooth anatomy library. (K) Frontal view of fiber-reinforced composite resin (FRC) post and ceramic core fitted in abutment tooth. (L) Occlusal view of FRC post and ceramic core fitted in abutment tooth. (M) Software view of digital scan by intraoral digital scanner. (N) Software view of computer-aided design of anatomically correct crown form that is based on the tooth anatomy library incorporated in the software program. (O) Definitive restoration milled from ceramic block. (From Lee JH. Accelerated techniques for a post-and-core restoration and a crown restoration with intraoral digital scanners and CAD/CAM and rapid prototyping. *J Prosthet Dent*. 2014;112[5]:1024.)

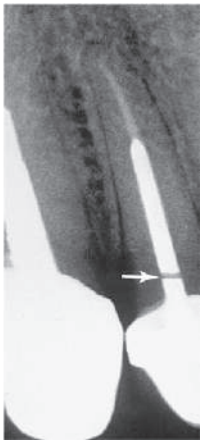


Fig. 12.42 Fractured post (*arrow*). (Courtesy Dr. D. Francisco.)

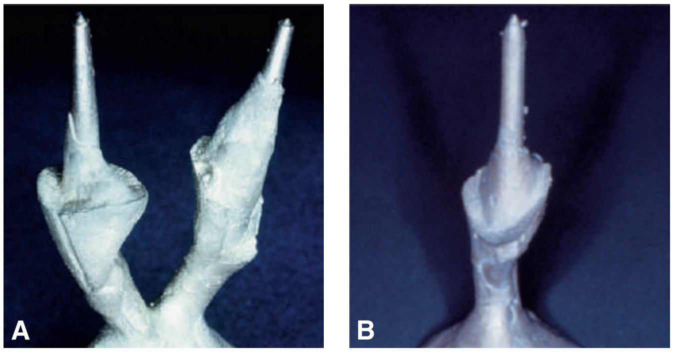


Fig. 12.43 (A) The fitting surface of the casting must be carefully evaluated. (B) Nodules, as seen here, could easily lead to root fracture and tooth loss.

Evaluation

The practitioner must be particularly careful that casting defects such as small nodules do not interfere with seating of the post; otherwise, root fracture can result. Post-and-core restorations should be inserted with gentle pressure. Should any resistance be encountered, the practitioner must remove the casting and determine what prevents full seating before proceeding. Once the casting is seated, however, the marginal fit of a cast foundation is not as crucial as that of extracoronal restorations because the margins will be covered by the final crown. Air-abrading the surface to a matte finish may help detect interferences at try-in (Fig. 12.43).

The shape of the foundation is evaluated and adjusted as necessary until tooth preparation geometry is optimal.

Cementation

The luting agent must fill all space within the root canal system (Fig. 12.44). Voids may be a cause of periodontal inflammation via lateral canals.

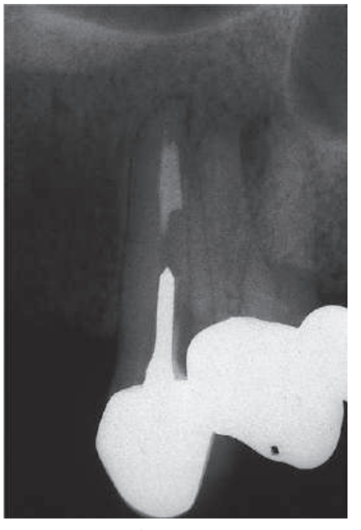


Fig. 12.44 Residual voids after cementation can cause inflammation. (Courtesy Dr. D. Francisco.)

A rotary (Lentulo) spiral filler or cement tube (Fig. 12.45) is used to fill the canal with cement. The post-and-core restoration is inserted gently to reduce hydrostatic pressure, which could cause root fracture. Many prefabricated parallel-sided posts have longitudinal grooves incorporated into their design to allow for improved escape of excess cement. If needed, such a groove may be added with a small bur. Use of such venting procedures has also been shown to reduce the necessary seating force, although the latter is probably cement specific.[100]

Removal of Existing Posts

On occasion, an existing post-and-core restoration must be removed (e.g., for re-treatment of a failed root canal filling). Patients must understand in advance that post removal is a risky process and occasionally results in radicular fracture and tooth loss. If sufficient length of post is exposed coronally, the post can be retrieved with thin-beaked forceps. Causing the post to vibrate first with an ultrasonic scaler weakens brittle water-based cements and facilitates removal. A thin scaler tip or special post removal tip is recommended (Fig. 12.46). Although histologic examination with animal models reveals no harmful effect in the periodontal tissues,[101] ultrasonic removal is slower than other methods and may result in an increased number of canal and intradentin cracks.[102] An alternative method is to use a post puller.[103] One of these devices consists of a vise to grip the post and legs that bear on the root surface. A screw activates the vise and extracts the post.

A post that has fractured within the root canal cannot be removed with a post puller or forceps. The post may possibly be drilled out, but great care is needed to avoid perforation. The technique is best limited to relatively short, fractured posts (Fig. 12.47).

Another means of handling an embedded fractured post (described by Masserann[104] in 1966) is to use special hollow end-cutting tubes (or trephines) to prepare a thin trench around the post (Fig. 12.48). This technique has been successful.[105] Retrieval can be facilitated by using an adhesive to attach a hollow tube extractor[106] or by using a threaded extractor (Fig. 12.49).[107]