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Author: MSgt Emily E. Jones
381st Training Squadron
Joint Service Dental Laboratory School (AETC)
381 TRS/TXTRR
3038 Hardee Rd. Bldg. 895
JBSA-Fort Sam Houston, Texas 78234-7648
DSN: 420-1950
E-mail address: emily.e.jones.mil@mail.mil

Instructional Systems Specialist: Sherie A. Davis

Editor: Sherie A. Davis

Air Force Career Development Academy (AFCDA)
Air University (AETC)
Maxwell Air Force Base-Gunter Annex, Alabama 36114–3107

THIS VOLUME is comprised of five units. Unit 1, *Introduction to Fixed Prostheses*, presents information about all-metal, metal-ceramic, and all-ceramic restorations. This unit also provides information about the clinical perspective for fabricating fixed restorations. The unit concludes with information about fixed dental prosthesis design. Unit 2, *Metal and Metal-Ceramic Restorations*, discusses how wax patterns are fabricated for all-metal and metal-ceramic structures. Unit 3, *Casting Fixed Prosthodontic Restorations*, presents the "how to" for processing and completing metal restorations, such as how to sprue, invest, and cast wax patterns. This unit concludes with how to finish, polish, and solder all-metal and metal-ceramic restorations. Unit 4, *Dental Ceramics*, shows you the procedures for fabricating and completing porcelain application for metal-ceramic restorations. This includes how to incorporate special effects into a ceramic restoration and the do's and don'ts for glazing, polishing, and repairing metal-ceramic restorations. Unit 5, *Fixed Restoration Applications*, discusses fixed dental prostheses: post and cores, surveyed crowns, porcelain laminate veneers, all-ceramic restorations, and concludes with computer-aided design/computer-aided manufacturing and 3D medical modeling.

A glossary is included for your use.

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NOTE:

In this volume, the subject matter is divided into self-contained units. A unit menu begins each unit, identifying the lesson headings and numbers. After reading the unit menu page and unit introduction, study the section, answer the self-test questions, and compare your answers with those given at the end of the unit. Then complete the unit review exercises.

Unit 1. Introduction to Fixed Prostheses

FABRICATING FIXED PROSTHESIS requires a great deal of knowledge and skill from both you and the dentist. To successfully complete a restoration that is functionally and esthetically acceptable, you must understand some important points of clinical treatment. In this unit, we will discuss various concepts of fixed prostheses.

1–1. Fixed Clinical Procedures

The laboratory fabrication of either all-metal or metal-ceramic restorations usually begins after weeks or months of previous dental treatment. This significant investment of time and effort by the dentist and patient should inspire you, the dental laboratory technician, to produce the best possible restoration—after all, this prosthesis will be seen and used by the patient for years to come. In this section, we will present information about the clinical perspective of fixed prostheses and interim restorations.

801. Principles of design

The dentist is responsible for diagnosing a patient's condition, planning his or her treatment, and providing you, the dental laboratory technician, a clearly defined prescription. Your responsibility is to produce the best restoration possible. Achieving this goal requires you to establish and maintain communication with the prescribing dentist. This is a critical step in meeting both your expectations and the dentist's. In this lesson, we discuss two subjects that are important in understanding how to fabricate a successful restoration:

- The concepts of tooth preparation.
- Impressions.

Preparations

The abutment (preparation) for a cast restoration is guided by the following four principles:

- Maintain existing tooth structure.
- Maintain retention and resistance.
- Maintain structural durability.
- Maintain marginal integrity.

Maintain existing tooth structure

A dentist has many concerns when preparing a tooth for restoration. The first is to maintain as much of the existing tooth as possible. The second is to appropriately reduce the abutment for the final restoration. Sometimes, the preservation of the existing tooth structure requires removal of undamaged portions of a tooth. Reduction of undamaged or healthy tooth tissue is a preventive measure, designed to prevent subsequent or uncontrolled tooth loss at a later date (e.g., only 0.5 millimeter [mm] of occlusal surface is damaged or decayed, but the dentist must remove 1.0–1.5 mm of tooth structure). This is necessary because the metal on the restoration can protect against traumatic occlusal shock if it is of adequate thickness. Failure to properly reduce an abutment could result in failure of the restoration and loss of the supporting tooth. A third concern is over-reduction of the abutment tooth. Over-reduction weakens the tooth and could damage the pulp. Achieving an ideal reduction on a vital tooth is a challenging task for the dentist. This task is even more complicated when preparing endodontically treated teeth because these teeth are brittle and prone to fracture.

Retention and resistance

Retention prevents removal of a restoration along the path of insertion or long axis of a tooth, while resistance prevents crown movement from occlusal forces. You accomplish this combination of retention and resistance by creating an abutment with an axial taper of 10 degrees (°) for anterior teeth, 14° for premolars, and 17° for molars.

Abutment preparations for fixed dental prostheses (FDP) retainers should have the same path of insertion. You should be able to look down on the occlusal surface of the cast with one eye closed and see the margins of both preparations from the same angle. From an occlusal view, prepared teeth are box-like rather than round. This is because a box-like preparation better resists crown rotation than a round preparation. Some dentists will improve crown retention by cutting vertical grooves in the preparation. This is shown in figure 1–1, item A.

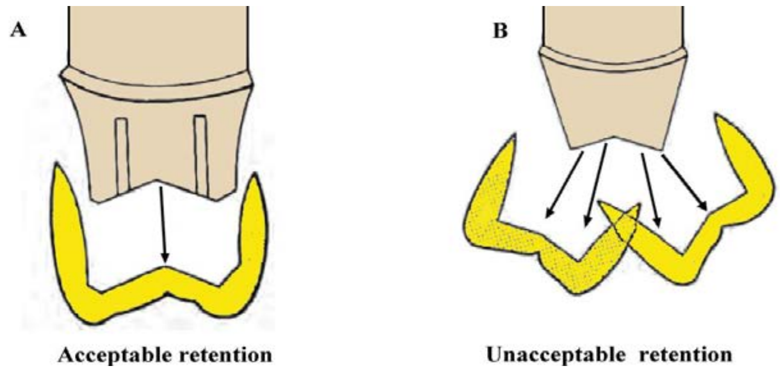


Figure 1–1. Acceptable and unacceptable retention and resistance.

Structural durability

The preparation must have ample reduction to allow adequate metal thickness to meet durability requirements. One of the most important concerns is occlusal clearance—functional cusps should have about 1.5 mm clearance while nonfunctional cusps should have 1 mm. Additionally, the functional cusp area of the abutment should be beveled to improve the fit and stability of the restoration. This is shown in figure 1–2.

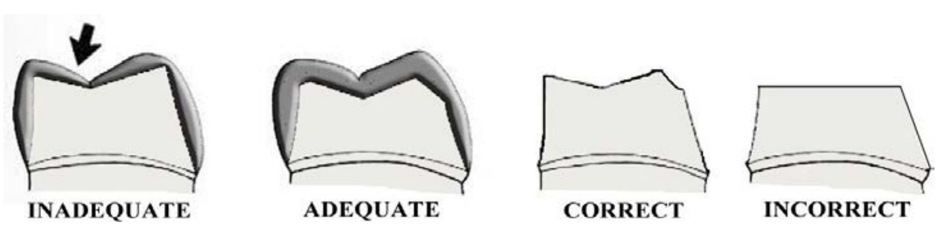


Figure 1–2. Functional cusp bevel.

Marginal integrity

Margins should have definite borders. The margin should also be smooth to ease wax pattern fabrication. There are four basic types of margin designs that are typically used for restorations. They are illustrated in figure 1–3.

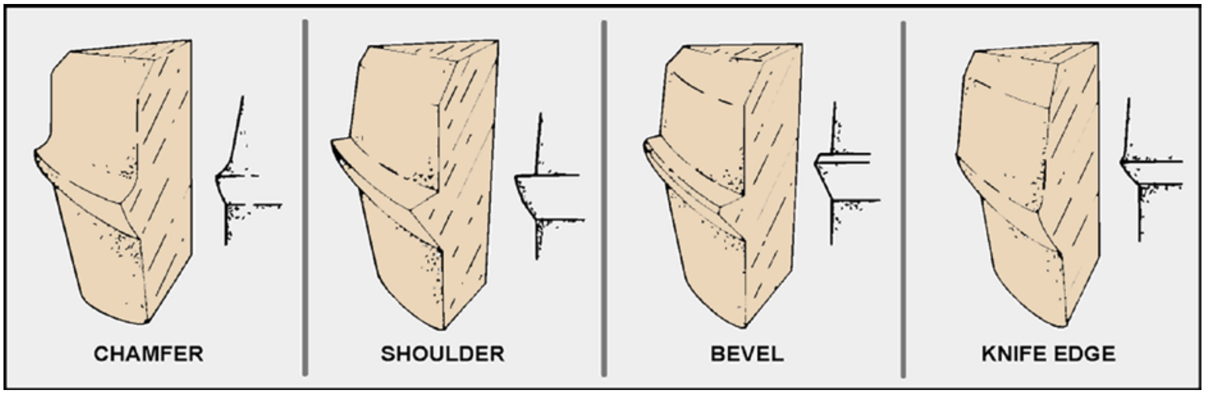


Figure 1–3. Four basic margin designs.

The chamfer, beveled, shoulder, and knife-edge margins are typically used for all-metal restorations. In addition, the beveled and shoulder margins are commonly used for ceramic restorations. These margin designs allow space for porcelain support and color. The knife-edge margins are used when the enamel is too thin to prepare a chamfer or other type margin.

All preparations should meet the following four basic requirements:

- Maintain existing tooth structure.
- Maintain retention and resistance.
- Maintain structural durability.
- Maintain marginal integrity.

If you see an abutment that you, as a dental laboratory technician, believe does not meet these requirements, discuss it with your prescribing dentist, trainer, supervisor, or laboratory flight chief, but remember the dentist ultimately accepts all legal responsibility for the prosthesis. If the dentist is satisfied with the preparation, it is your responsibility to fabricate the restoration.

Impressions

An accurate impression should reveal every detail of the preparation and surrounding dentition. There should be no bubbles, voids, or tears in the impression. The margin in particular should be completely reproduced.

Before an impression is taken, the margin is exposed using a retraction cord placed below the margin. The retraction cord holds the gingiva away from the abutment, allowing a light body impression material to be syringed around the margin. Next, a heavier body impression material in a custom tray is placed against the teeth. This is done quickly to allow the two materials to bond while setting.

802. Fabricating interim fixed restorations

Interim restorations or "temporaries" play a key role in the treatment process. They stabilize the preparation for the crown or FDP and increase the odds that the definitive restoration will fit. In this lesson, we will discuss two important factors in making successful interim restorations: (1) interim restoration requirements and (2) interim restoration methods.

Interim restoration requirements

Interim restorations have three interrelated requirements: (1) biological, (2) mechanical, and (3) esthetic.

Biological

Biological requirements include protecting the pulp from extreme temperatures (it's very sensitive after preparation), protecting the periodontal health of the patient, and stabilizing the abutment and adjacent teeth. If the prepared tooth is not stabilized by an interim restoration, the opposing tooth may erupt. This eruption can cause difficulty for the dentist when seating the crown. An interim restoration also prevents the adjacent teeth from drifting and reducing the existing mesial-distal space.

Mechanical

The mechanical requirement for interim restorations is primarily related to function. The long-term function of an interim restoration is dependent upon the abutment's contours. A tooth that is improperly reduced won't support an interim restoration. This requirement for a properly reduced abutment becomes acutely obvious when an interim restoration is seated, particularly since polymerized acrylic resin has about one-twentieth the strength of metal-ceramic alloys. If the abutment's reduction is less than the prescribed limits, the interim restoration will fracture. If this occurs and the patient doesn't return to have a new one made, the abutment and adjacent teeth may shift. Since this can change the orientation of abutment, you and the dentist may need to re-accomplish a significant amount of work.

Esthetic

An interim restoration's shape and shade should blend in, as well as the material allows, to the patient's surrounding dentition. Often, the interim restoration is used as a guide to achieving optimum esthetics in the final crown.

Interim restoration methods

The two primary methods for producing an interim restoration are direct and indirect. The dentist performs the direct method. Primarily, the dental lab technician performs the indirect method. In many cases, the indirect method is preferred because the interim restoration is usually stronger. In addition, the curing techniques are less disruptive to the patient's mucosa (they are not exposed to methyl methacrylate). The indirect method also reduces the dentist's chairside fabrication time.

Indirect method

We discuss the indirect method here because it's the most laboratory intensive method. Follow the steps below for the indirect method.

Indirect Restoration Method	
Step	**Action**
1	If the tooth to be restored is still present but has an abnormality (fractured cusp), build it up to normal contours with wax or acrylic resin.
2	Adjust an acrylic tooth to fit the edentulous area of the cast and match the opposing occlusion.
3	If required, duplicate the master cast for vacuum forming the stent material.
4	Fabricate the matrix on the cast using stent material and a vacuum former unit.
5	Cut stent material to include the tooth to be restored an adjacent tooth on each side.
6	Remove matrix from diagnostic cast.
7	Disinfect the impression of the prepared teeth received from dentist.
8	Fabricate working cast.
9	Apply separating medium to working cast.
10	Mix appropriate tooth-shaded acrylic in dappen dish.
11	Pour a thin stream of tooth-shaded acrylic with no bubbles into matrix.
12	Invert the matrix onto the working cast.
13	Secure the matrix to the cast using a rubber band.
14	Cure the restoration in a pressure pot filled with 115 degrees Fahrenheit (°F) water for 30 minutes at 20 pounds per square inch (psi).
15	Remove the matrix and separate the restoration from the cast.
16	Remove excess acrylic from adjacent teeth using a Bard Parker, if required.

Indirect Restoration Method	
Step	**Action**
17	Finish and polish axial contours, avoid over-finishing interproximal contact areas.
18	Disinfect the restoration and return it to the dentist for completion.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

801. Principles of design

1. What four principles should you follow when preparing a tooth abutment?

2. Why are crown preparations more box-like than round from the occlusal aspect?

3. What four basic types of margin designs are typically used for restorations?

4. What structure should an accurate impression reveal?

802. Fabricating fixed interim restorations

1. What are the three biologic requirements of interim restorations?

2. What will happen when an interim restoration abutment is reduced *less than* the prescribed limits?

3. What problem may occur when an interim restoration fractures and it is not replaced?

4. What are the two methods of fabricating an interim restoration?

5. What is the most often used method for fabricating an interim restoration? Why?

1–2. Fixed Restorations

The most frequently fabricated fixed restorations are single-unit crowns and FDPs. They are typically used to replace damaged or discolored tooth structures. Fixed restorations are usually fabricated using metal alloys and/or porcelains. They can be constructed of all metal, a combination of metal and porcelain (metal-ceramic), or all ceramic (porcelain).

803. Types of fixed restorations

In this lesson, we will present general information about all-metal, metal-ceramic, and all-ceramic restorations. As we go through the lesson, we will discuss some design requirements for single-units and FDPs using either all-metal or metal-ceramic structures.

All-metal and metal-ceramic

Figure 1–4 illustrates four common types of crowns: (1) complete metal crown, (2) veneered crown, (3) 3/4 partial crown, and (4) 7/8 partial crown.

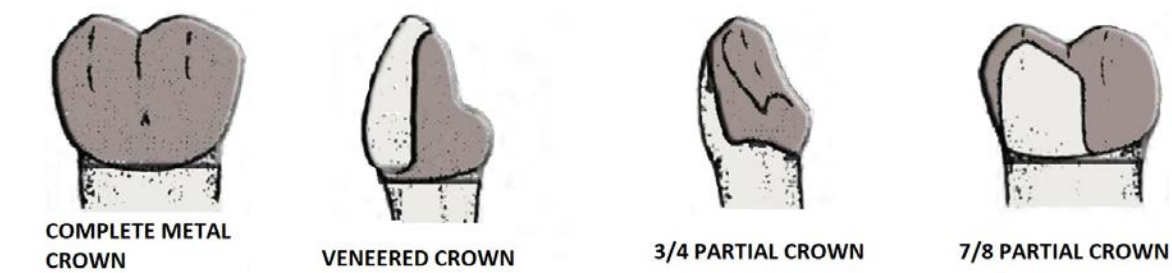


Figure 1–4. Four types of fixed restorations.

Figure 1–5 illustrates the major parts of an FDP: (1) retainers, (2) connectors, and (3) pontics. Figure 1–5 also shows how the FDP is secured to the abutments by the retainers (which are held in place by friction and cement). The retainers are linked to the pontics via the connectors, and the pontics fill the edentulous space.

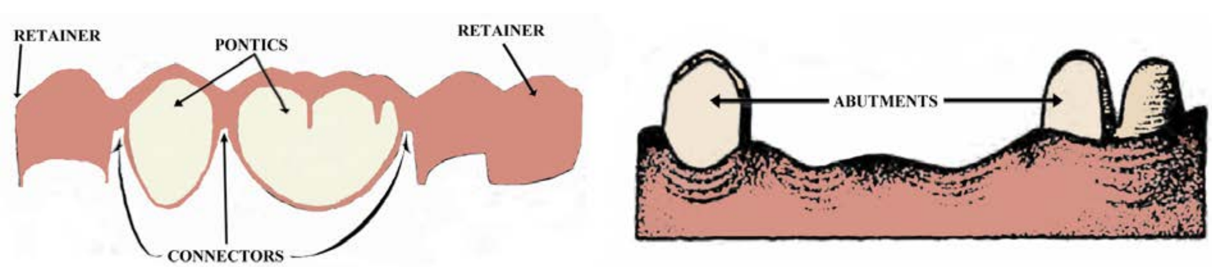


Figure 1–5. Fixed dental prosthesis.

Double abutment FDP

Another type of FDP is the double abutment FDP, illustrated in figure 1–6. This FDP is used when the abutments lack adequate periodontal support or when a large edentulous area is being restored.

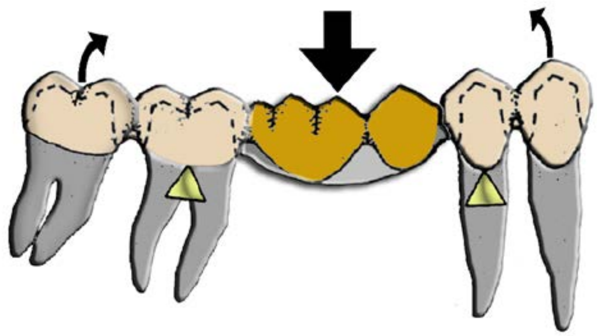


Figure 1–6. Double abutment FDP.

Intermediate abutment FDP

Special consideration must also be given to the patient with an intermediate abutment between the terminal abutments. As you see in figure 1–7, there is an edentulous area on each side of the intermediate abutment. The intermediate abutment may act as a fulcrum during mastication and create extra stress on the terminal abutments. As a result, the terminal retainers may loosen, allowing food to enter under the retainer and cause decay.

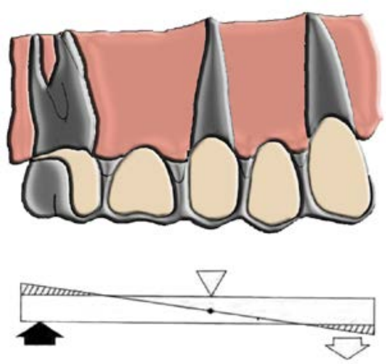


Figure 1–7. Fulcrum effect caused by an intermediate abutment.

To counteract this problem, the FDP can be made with a stress-breaker (nonrigid) connector. Figure 1–8 illustrates how the fulcrum effect of the intermediate abutment is canceled with this nonrigid connector.

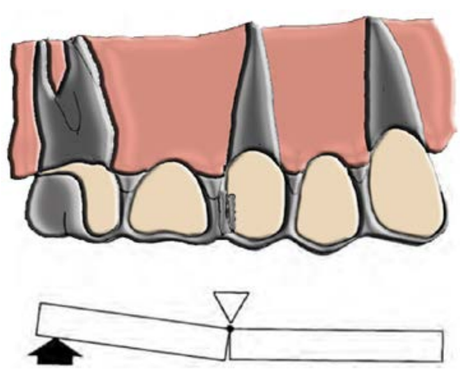


Figure 1–8. Stress-breaker connector used to cancel the fulcrum effect.

Figure 1–9 shows the key and keyway connector of a stress-breaker connector. Stress-breaker connectors are also used when the abutment's path of insertion diverges, that is, when the distal abutment path of insertion differs from the mesial abutment.

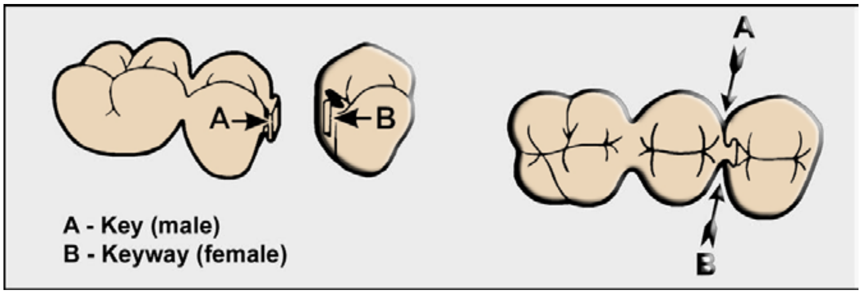


Figure 1–9. Stress-breaker connector components.

Surveyed crown

Another restoration you may encounter is the surveyed crown. Surveyed crowns are used in conjunction with removable dental prosthesis (RDP). This crown is usually seated on the abutment tooth. The surveyed crown may possess one or all of these:

- Retentive areas.
- Guide planes.
- Rests.

The surveyed crown is usually an all-metal restoration, but it can be made as a metal-ceramic crown if necessary. Surveyed crowns are waxed to match the path of insertion of the rest of the arch. A dental surveyor is used to develop retentive areas and guide planes.

Inlays and onlays

Along with making crowns and FDPs, you may occasionally make inlays and onlays.

Inlays

An inlay fits within a preparation of a tooth's surface and may cover more than one tooth surface. An inlay should be cast with a type II, medium dental alloy because an inlay's margins may need to be burnished. This concept is shown in the table below. The Roman numerals shown on each tooth example are explained in this table:

Class	Location
I	Occlusal surfaces of bicuspids or molars.
II	Occlusal surface combined with one or both proximal surfaces.
III	Mesial and distal surface of anterior teeth.
IV	Mesial and distal surface of anterior teeth plus one or both of its incisal angles.
V	Limited to facial surface of any of the teeth.

Onlays

In contrast, to the inlay, which fits within the preparation of a tooth, an onlay fits over preparation of a tooth and replaces one or more cusps and all or part of the occlusal surface.

Porcelain veneer restoration

The most common ceramic restoration is the metal-ceramic restoration. It is also called a porcelain veneer restoration because the facial surface is replaced by a veneer of dental porcelain. It can be made as a single unit or an FDP. One type of veneered FDP is the cantilever bridge (fig. 1–10). The typical cantilever has only one retainer with a pontic. As you can see in the illustration, any occlusal load results in a tipping force on the abutment tooth. This must be taken into account when the cantilever is used.

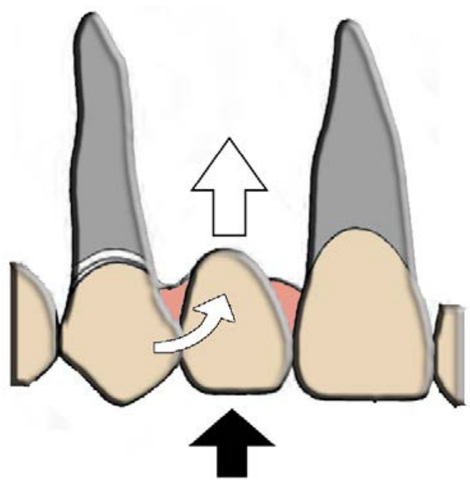


Figure 1–10. Effect of occlusal loading on a cantilever FDP.

All-ceramic restoration

Another type of ceramic restoration is the all-ceramic restoration. The all-ceramic restoration doesn't require metal support for the porcelain. The major difference between metal-ceramic and all-ceramic restorations is that the metal-ceramic restoration has a metal interface with the prepared tooth, while an all-ceramic restoration does not. All-ceramic restorations are usually made with aluminous porcelain or leucite reinforced porcelain rather than feldspathic porcelain. All-ceramic restorations need the extra strength of aluminous- or leucite-reinforced porcelain since they are not supported by a metal framework.

The types of all-ceramic restorations include porcelain laminate veneers, porcelain inlays, and all-ceramic crowns (described in the following table). All-ceramic inlays, onlays, veneers, and crowns can provide esthetically pleasing restorations. All-ceramic restorations can match natural teeth in color, translucency, and surface texture. A well-constructed, all-ceramic restoration can be indistinguishable from unrestored natural teeth.

Types of All-Ceramic Restorations

Type	***Description***
Porcelain laminate veneers	Porcelain laminate veneers are a cosmetic restoration. The laminate covers the facial surface and incisal edge of the tooth. The dentist prepares the tooth by *reducing* the *facial* surface 0.5 mm. The preparation should have definite margins. The two common methods for fabricating porcelain laminate veneers are the *refractory* method and the *pressable* method. In the *refractory method*, a working cast is made of a refractory material and the laminate is fired directly on the refractory cast. The laminates are then seated on the master cast. With the *pressable method*, the laminate is built in wax, invested, and pressed using a pressable ceramic system.
Porcelain inlays	Inlays can also be constructed in an all-ceramic material using pressable ceramic systems or refractory dies and casts.
Pressable	All-ceramic crowns can be fabricated with pressable ceramic systems. Depending on the system, the core or the entire crown may be built in wax, invested, and pressed.
CAD/CAM restoration	There is a wide variety of ceramic computer-aided design (CAD)/computer-aided manufacturing (CAM) material. Each differs in terms of their microstructure, strength, translucency, and clinical indications.

804. Fixed restoration contour and design

In this lesson, we discuss the contour requirements of single-unit restorations for both healthy and periodontally involved teeth. More specifically, we will look at the following subjects:

- Crown contours.
- Proximal contacts.
- Embrasures.
- Restorations for periodontally involved teeth.

Crown contours

Proper crown contours are essential to tissue health and the long-term success of the restoration. Building crown contours that adapt to the surrounding tissues is more important than the esthetics of the crown because poor contours can lead to destruction of the supporting tissues of the tooth.

Facial and lingual surfaces should have flat or slightly convex contours with no obvious convexities in the gingival third. The gingival third of a restoration should have a straight-line continuance between the height of contour and the gingival sulcus. This imaginary line emerges occlusally from the base of the gingival sulcus past the gingiva to the junction of the gingival and middle third of the tooth. This line of contour is known as the emergence angle and is shown in figure 1–11.

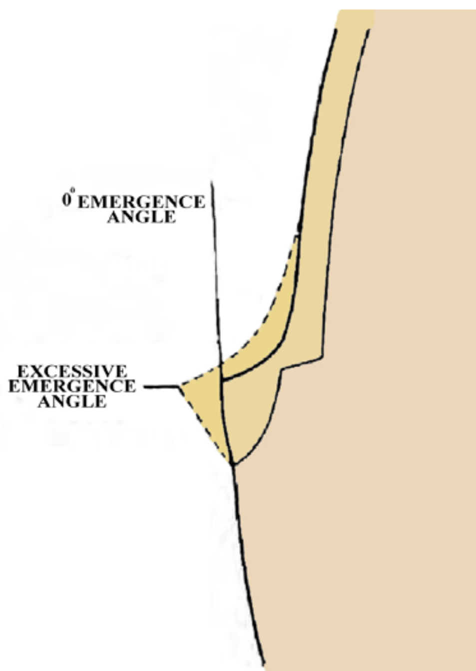


Figure 1–11. Emergence angle.

A restoration with a poorly contoured emergence angle can constrict the surrounding tissue, which can lead to soft tissue damage and failure of the restoration. Achieving a proper emergence angle requires the dentist to reduce the preparation to the proper depth and contour.

Interproximal surfaces must be properly contoured to avoid affecting the interdental papilla. The interproximal surfaces are arched or rounded at the contact area; however, they become flat or concave below the contact to allow room for the interdental papilla.

The height of contour is defined as the most prominent convexity of a tooth. Examples are shown in figure 1–12. A common mistake when beginning to wax crowns is to overemphasize the height of contour. The contour may be too bulky, insufficient, or in the wrong location. An overcontoured crown can crowd the gingiva and cause tissue resorption.

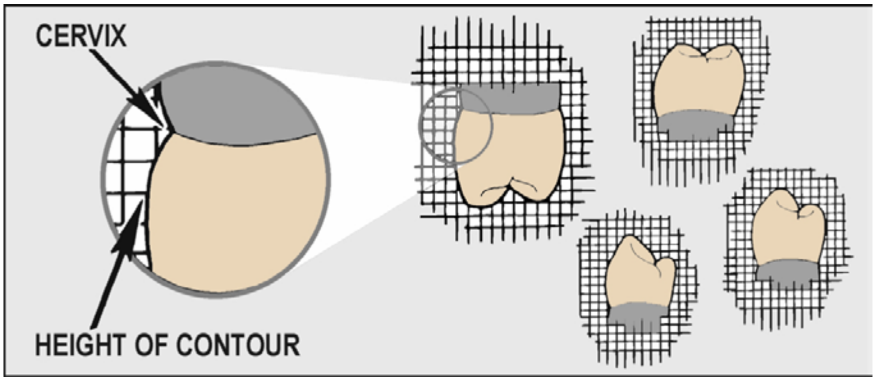


Figure 1–12. Tooth contours.

The height of contour and emergence angle must be correct in order to maintain the patient's oral health. The height of contour on the facial surface of all posterior teeth is at the cervical third. The height of contour is also at the cervical third on the lingual surface of maxillary posteriors, but it's found at the middle third of mandibular posteriors. A healthy natural tooth's emergence angle supports the gingiva while allowing the gingiva freedom of movement. Though the gingiva should be free to move, a tooth's anterior and posterior movement should be restricted by adjacent contact areas.

Proximal contacts

Proximal tooth contacts stabilize the teeth and keep food from being trapped between the teeth. The correct contact area for anterior teeth should occur at the proximal junction of the middle and incisal thirds (fig. 1–13, right side). The correct contact area for posterior teeth should be at the junction of the occlusal and middle thirds (fig. 1–13, left side). Placing the proximal contact below this point restricts the interdental papilla, which can inflame the papilla, causing tissue resorption. This results in a reduction of tissue support for the tooth.

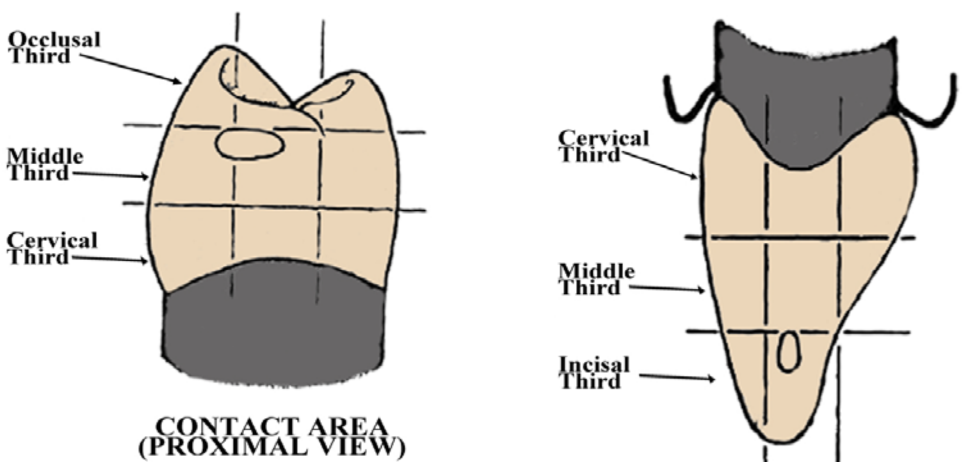


Figure 1–13. Proximal posterior and anterior tooth contacts.

Both anterior and posterior proximal contacts shift as they move from the anterior (midline) to the posterior regions of the mouth. The incisal-gingival position of anterior proximal contacts migrates gingivally as the contacts move away from the midline (fig. 1–14, left side). As the contacts move away from the midline, the buccal-lingual position of maxillary posterior proximal contacts move progressively towards the central sulcus of each tooth. Conversely, the buccal-lingual position of mandibular posterior proximal contacts shifts progressively outward away from the central sulcus (fig. 1–14, right side).

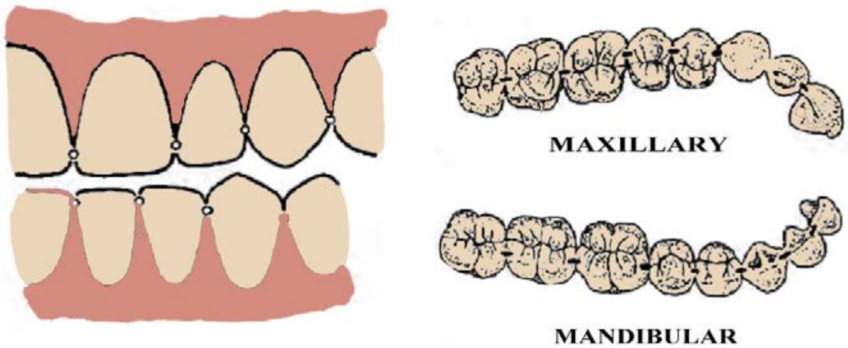


Figure 1–14. Labial view of anterior teeth and occlusal view of posterior tooth contacts.

Embrasures

The embrasure must have enough room for the interdental papilla. The following four embrasures are created when teeth contact proximally:

- Occlusal (incisal).
- Buccal.
- Lingual.
- Gingival (apical).

The occlusal, buccal, and lingual embrasures not only mark the separation of teeth, more importantly, they allow food to escape during mastication. This concept is shown in figure 1–15. Proper axial contours and contacts are necessary prerequisites to sustain a tooth's functional purpose.

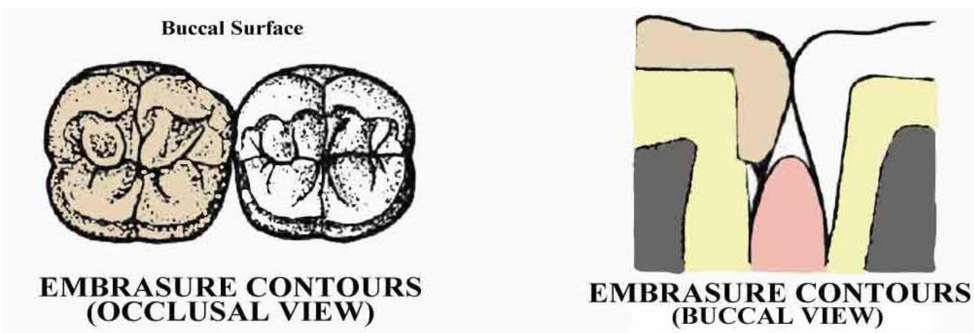


Figure 1–15. Embrasure contours.

Restorations for periodontally involved teeth

The phrase "periodontally involved teeth" indicates a lack of periodontal support in the alveolus. This means the roots of the patient's teeth are not stable. This causes particular concern for the dentist when considering a fixed restoration. The restored tooth, or teeth, should have a reasonable chance of remaining in the alveolar after cementing the restoration. Periodontal therapy before and after prosthodontic treatment increases the tooth's retainability. The restoration itself can help retain the involved teeth. In the following paragraphs, we will look at two restoration scenarios: (1) fixed splints and (2) exposed roots.

Fixed splints

These restorations support and stabilize periodontally involved teeth. The double abutment FDP is an example of one type of fixed splint. When there are no edentulous areas, the mobile teeth can be restored with crowns connected to each other. This type of splint is made like an FDP, but without pontics. Once the dentist is satisfied with a patient's oral condition, a fixed splint could be prescribed for an extremely mobile tooth.

Exposed roots

Periodontally involved teeth often have exposed roots. This poses special problems when restoring molars. Molars have furcations formed by the meeting of roots. The furcations are V-shaped depressions that trap food and cause plaque formation. This plaque formation further deteriorates the periodontium, which can lead to the loss of teeth. A fluted crown (fig. 1–16, bottom) may be used to restore a mild furcation exposure. A fluted crown is contoured with distinct embrasures, which coincide and are harmonious with the furcated root. Figure 1–16, top, illustrates the effect a normal crown contour has on a furcation. The height of contour of a normal crown further increases the V-shaped depression and the accompanying detrimental effects to periodontal health. In contrast, fluting the crown allows self-cleansing while increasing the effectiveness of tooth brushing.

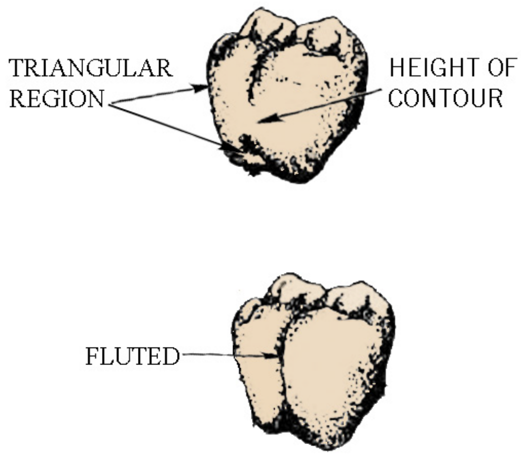


Figure 1–16. Fluted crown compared to a crown with normal facial contour.

For extreme root exposure and accompanying deep furcation, a more drastic treatment is available. The dentist could cut the molar into mesial and distal halves and then prepare them to receive crowns. This procedure is called a hemisection; however, it is better known as bicuspidization, since the crowns you make to restore these preparations resemble bicuspids.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

803. Types of fixed restorations

1. When is a double abutment FDP used in the mouth?

2. What three features can a surveyed crown possess?

3. What is the difference between an inlay and an onlay?

4. What undesirable force may result when a cantilever fixed dental prosthesis is used?

5. What is the major difference between metal-ceramic and all-ceramic restorations?

804. Fixed restoration contour and design

1. Which portion of a restoration should have a straight line of continuance between the height of contour and the gingival sulcus?

2. What is the “height of contour” of a tooth?

3. Where is the correct proximal contact area for anterior teeth?

4. What does the phrase “periodontally involved teeth” mean?

5. When is the use of a fixed splint indicated?

6. What are two forms of treatment for a molar with exposed root furcation?

Answers to Self-Test Questions

801

1. (1) Maintain existing tooth structure.
   (2) Maintain retention and resistance.
   (3) Maintain structural durability.
   (4) Maintain marginal integrity.
2. A box-like preparation better resists crown rotation on the prepared tooth than a round preparation.
3. Chamfer, beveled, shoulder, and knife-edge.
4. Every detail of the preparation and surrounding dentition.

802

1. (1) Protect the pulp from extreme temperatures.
   (2) Protect the patient’s periodontal health.
   (3) Stabilize the abutment and adjacent teeth.
2. The restoration will fracture.
3. The abutment and adjacent teeth may shift.
4. Direct and indirect.
5. In many cases, the indirect method is preferred because the interim restoration is usually stronger.

803

1. When the abutments lack adequate periodontal support or when a large edentulous area is being restored.
2. (1) Retentive areas.
   (2) Guide planes.
   (3) Rests.
3. An inlay fits within a preparation of a tooth's surface and may cover more than one tooth surface. An onlay replaces one or more cusps of a tooth and all or part of the occlusal surface.
4. Any occlusal loading that puts a tipping force on the abutment tooth.
5. All-ceramic restorations lack metal support for porcelain.

804

1. Gingival third.
2. The most prominent convexity of a tooth.
3. Proximal junction of the middle and incisal thirds.
4. Indicates a lack periodontal support in the alveolus, which means the roots of the patient's teeth aren't stable.
5. Fixed splints are used to stabilize and support periodontally involved teeth.
6. For mild exposure, a fluted crown may be used. Extreme exposure can be treated by dividing the clinical crown and constructing crowns for the mesial and distal portions (hemisection).

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter.

1. (801) Which of the following is *not* a guiding principle for preparing an abutment for a cast restoration?
   a. Maintaining tooth structure.
   b. Optimizing surface texture.
   c. Maintaining structural durability.
   d. Maintaining resistance.

2. (801) Which abutment preparation principle *prevents* crown movement from *occlusal* forces?
   a. Maintaining tooth structure.
   b. Structural durability.
   c. Marginal integrity.
   d. Resistance.

3. (801) How much occlusal clearance is required for an abutment tooth functional cusp?
   a. 0.5 millimeters (mm).
   b. 1.0 mm.
   c. 1.5 mm.
   d. 2.0 mm.

4. (802) If the prepared tooth *is not* stabilized with an interim restoration, the *opposing tooth* may
   a. erupt.
   b. recede.
   c. drift distally.
   d. drift mesially.

5. (802) What is the *primary* mechanical requirement for interim restorations?
   a. Function.
   b. Esthetics.
   c. Contours.
   d. Comfort.

6. (803) A typical cantilever fixed dental prosthesis (FDP) has how many retainers?
   a. 0.
   b. 1.
   c. 2.
   d. 3.

7. (803) How much facial reduction does the dentist need for a porcelain laminate veneer?
   a. 0.2 millimeters (mm).
   b. 0.3 mm.
   c. 0.4 mm.
   d. 0.5 mm.

8. (803) Porcelain laminate veneers are constructed and fired on
   a. study casts.
   b. master casts.
   c. refractory casts.
   d. diagnostic casts.

9. (804) Which portion of a fixed restoration’s contour should have a straight-line continuance between the height of contour and the gingival sulcus?
   a. Middle.
   b. Incisal.
   c. Gingival.
   d. Occlusal.

10. (804) The correct interproximal contact area for *anterior* teeth of a fixed restoration is located at the
    a. incisal third.
    b. middle third.
    c. junction of the incisal thirds.
    d. junction of the incisal and middle thirds.

11. (804) Which embrasure does *not* help food escape during mastication?
    a. Buccal.
    b. Lingual.
    c. Occlusal.
    d. Gingival.

Please read the unit menu for unit 2 and continue ➔

Student Notes

Unit 2. Metal and Metal-Ceramic Restorations

CREATING A RESTORATION that meets the patient's functional and esthetic requirements hinges on an accurate wax pattern. The wax pattern is the "template" for the final restoration. It provides you and the dentist the opportunity to assess, and if necessary, change design inadequacies. In this unit, we present information on how to wax patterns for all-metal and metal-ceramic restorations.

2–1. Fabricating Metal Restorations

Fabricating restorations with correct contour and contacts requires a thorough understanding of tooth morphology and oral physiology. If you need a refresher on tooth morphology and oral physiology, refer to volume two, units one and two of this career development course (CDC). In this section, we will discuss how to wax posterior restorations and FDP using the wax additive technique.

805. Waxing posterior restorations

When you are waxing posterior restorations, you must consider a myriad of variables. Some of the more critical concerns are cusp placement and height, as well as contacts, contours, and marginal integrity. Successfully meeting these criteria requires a methodical approach to wax pattern fabrication.

Fixed restoration requirements

Fixed restorations must satisfy the requirements for esthetics, function, and sanitation. Sanitation is the most critical of the three because a restoration must be easy to clean to preserve the patient's oral health. A properly contoured restoration is self-cleansing in two ways:

- Food is deflected by the crown's contours.
- The lips, cheeks, and tongue clean the facial and lingual tooth surfaces during mastication.

We are able to meet the requirements for esthetics, function, and sanitation by recreating proper anatomical form during wax pattern production.

Waxing patterns to anatomical form

You must consider many factors when you are building a restoration using the wax additive technique. We will discuss these five factors as we proceed through the lesson:

- Crown contours.
- Emergence angle.
- Proximal contacts.
- Embrasures.
- Marginal ridges.

In addition, we will look at the actions required to prepare the case, fabricate the pattern, and use the cusp-to-fossa pattern.

Crown contours

Compare the crown contours in figure 2–1. Notice the greater undercut on the overcontoured crown. Plaque collects in this area because the patient is unable to clean this area naturally. Overcontouring also prevents access to the gingival sulcus for cleaning. Eventually, the plaque destroys the periodontium and loosens the tooth.

Figure 2–1. Normal contour versus overcontour.

Crown contours of natural teeth are the best guide to determine the contours for the fixed restoration. Keep in mind, anterior teeth should be esthetic, and posterior teeth should function well while maintaining the patient's oral health.

Emergence angle

A good way to maintain the patient's oral health is to incorporate a proper emergence angle into the restoration. The emergence angle is illustrated in figure 2–2. As you can see, the emergence angle describes the axial contours of the clinical crown as it emerges from the gingival sulcus to the height of contour. Any overcontouring in this area can impinge on the tissue, causing it to recede. A properly trimmed die aids in establishing an accurate emergence angle.

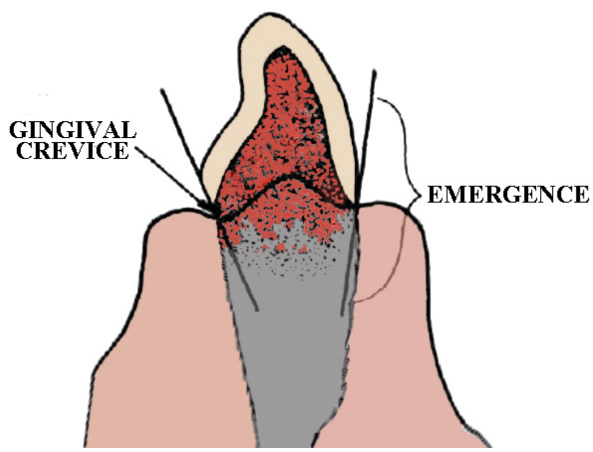


Figure 2–2. Emergence angle.

On the facial surface, the emergence angle ends at the height of contour found in the gingival third of most teeth. The height of contour for most posterior teeth usually extends 0.5 mm beyond the cementoenamel (cervix) junction. This can be seen in figure 2–3. The exception to this guide is mandibular posterior teeth where the lingual height of contour is in the middle third and protrudes between 0.75 and 1 mm.

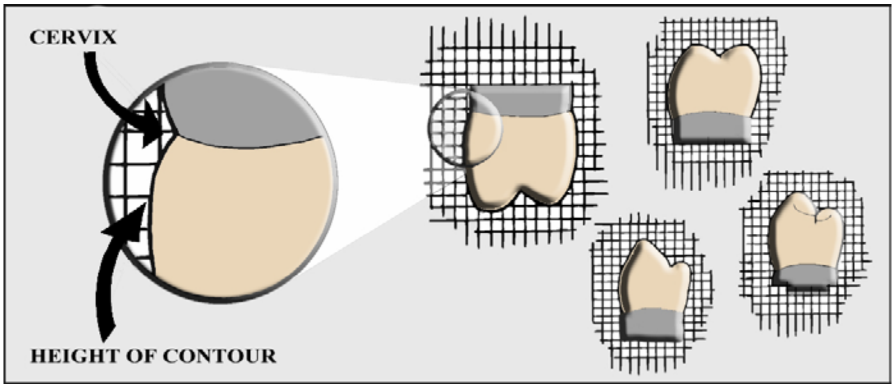


Figure 2–3. Examples of the heights of contour for different teeth.

Overcontouring is not limited to facial and lingual surfaces. The interdental papillae are extremely sensitive to pressure from the teeth's proximal surfaces. Figure 2–4 indicates the areas that should be flat or slightly concave to allow room for the papilla.

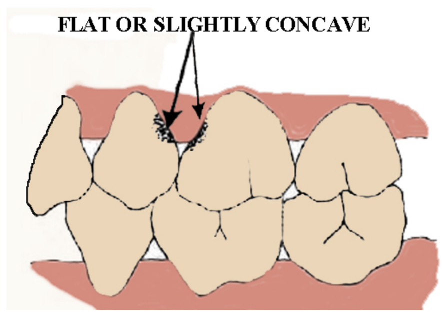


Figure 2–4. Proximal surface.

When you're waxing the restoration, use the adjacent natural teeth to establish facial and lingual contours. Check the restoration's alignment by looking down the facial and lingual surfaces of the teeth. This concept is illustrated in figure 2–5. As you can see, an overcontoured crown protrudes past the other teeth, while an undercontoured crown is not visible.

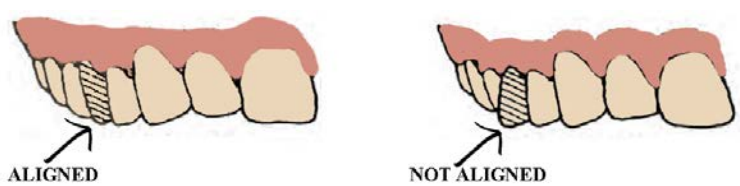


Figure 2–5. Checking a restoration's facial alignment.

The crown contour should also blend with the natural tooth it restores. This is very important with partial crowns and onlays. Refer to figure 2–6, and notice the continuous contour of the restoration with the natural tooth's margins. As you can see, an interrupted contour traps food, which can cause tooth decay.

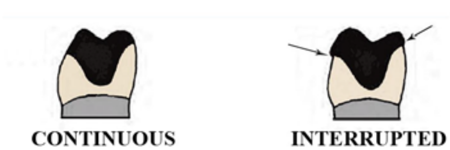


Figure 2–6. Continuous contour.

Proximal contacts

A well-contoured restoration also relies on proximal contacts for esthetics, function, and sanitation. The contacts prevent teeth from drifting and help prevent food impaction in the occlusal embrasure. Proximal contacts should be placed as high as possible in the incisal or occlusal third of the tooth. This is illustrated in figure 2–7. Also, place the contact toward the buccal, as illustrated in figure 2–8. This opens the lingual embrasure more than the facial embrasure to allow food to move to the lingual during mastication.

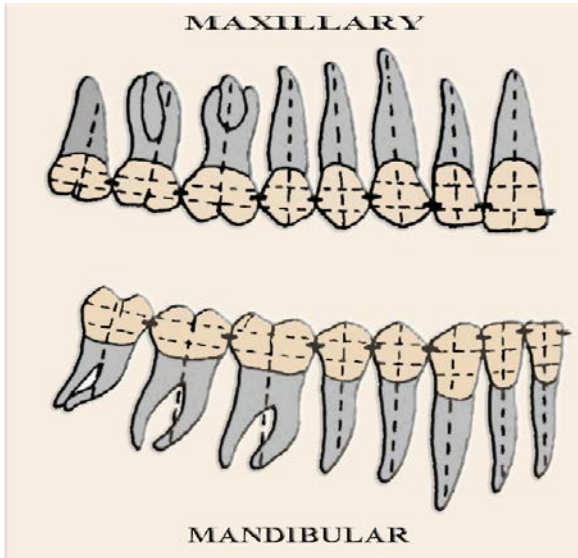


Figure 2–7. Facial view of correct proximal contact placement.

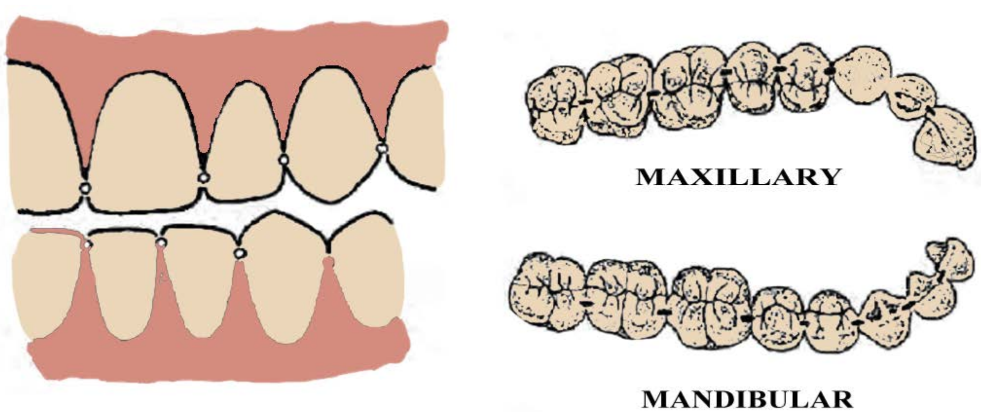


Figure 2–8. Occlusal view of correct proximal contact placement.

To further reduce food impaction, make the contact egg-shaped, not pinpoint. Avoid large contacts that put pressure on the interdental papilla. Figure 2–9 compares properly sized contacts to contacts that are too large. Contacts that are too low or too large can destroy tissue. Place the contacts according to the guidelines for a well-contoured crown. Don't exaggerate the contour to accommodate a contact. For instance, if the natural tooth had a diastema, you may be instructed to duplicate that in the restoration.

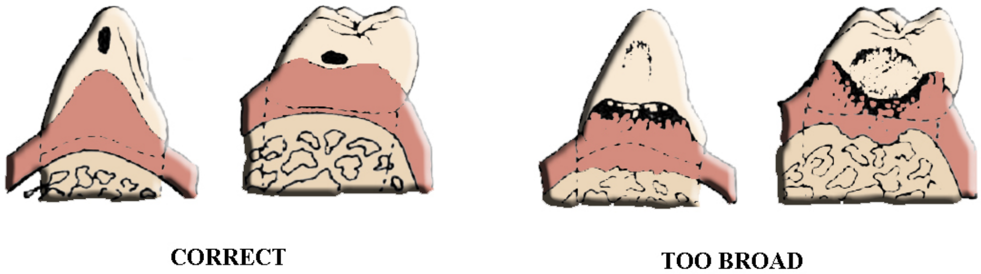


Figure 2–9. Correctly sized anterior and posterior proximal contacts.

Embrasures

Embrasures are another important part of a well-contoured crown. All embrasures should be open for easy cleaning. The gingival embrasure must leave room for the interdental papilla. Figure 2–10 illustrates the types of embrasures and the contact's contribution to the embrasure shape. As figure 2–11 illustrates, embrasures and developmental grooves act as natural spillways to allow self-cleansing.

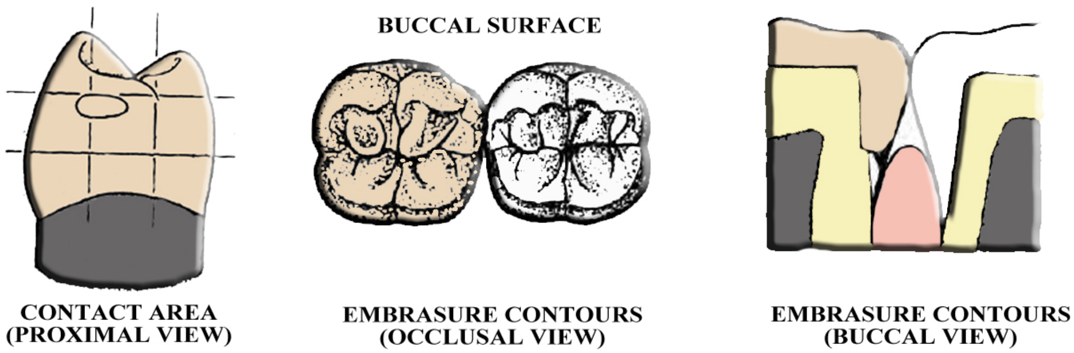


Figure 2–10. Embrasure contours.

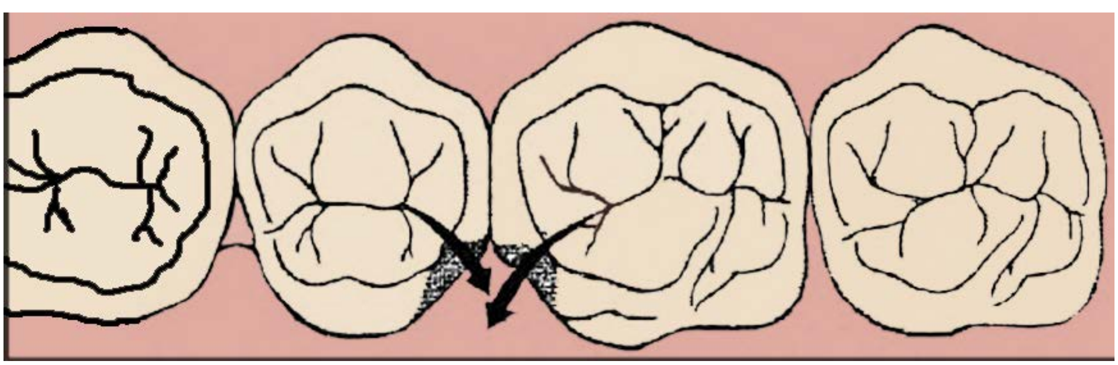


Figure 2–11. Creating a spillway.

Marginal ridges

Along with proximal contacts and embrasures, you must be concerned with marginal ridges. Adjacent marginal ridges must be equal in height to prevent food impaction. This must be done whether or not there are opposing teeth. The ridges help form the occlusal embrasure and must be contoured to allow food to move off the occlusal table to the buccal and lingual embrasures. This is illustrated in figure 2–12, A. The marginal ridges must not be too full and prevent food from being deflected. This is shown in figure 2–12, B; however, be careful to ensure the embrasures don't open too wide. This will reduce the crown's occlusal surface and allow food to wedge between the teeth, as shown in figure 2─12, C.

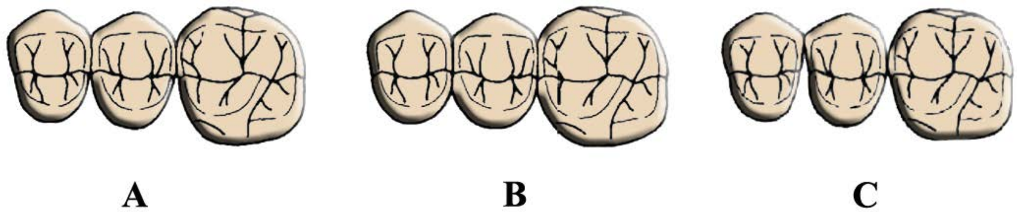


Figure 2–12. Marginal ridges and lingual embrasure contour.

Wax additive technique

The wax additive technique is a step-by-step process that ensures proper contour and cusp placement.

Preparing the case

Before you begin the wax additive process, you must prepare the case. Your first step is to evaluate the occluded casts for malocclusion, insufficient interocclusal space, and the cusp's pathways in eccentric movements. Your next step is to note the location and position of the preparation and adjacent teeth—rotated or isolated teeth may require special attention when waxing. Finally, evaluate the casts based on the goals of restoring esthetics, function, and sanitation. Plan your restoration with these goals in mind.

Pattern fabrication

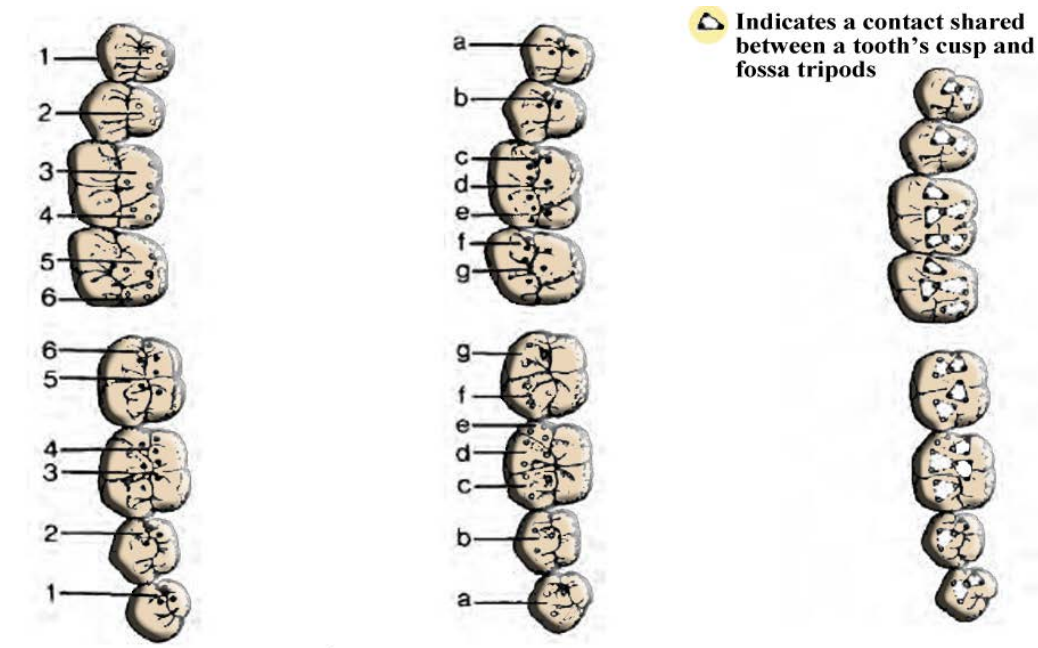
You may begin waxing after adjusting the articulator's settings and preparing the dies. Build the coping with an instrument or by dipping the die into molten wax. The wax should be applied quickly to prevent distortion, and the coping should have a smooth interior surface. Remove the coping and check the interior for smoothness. Reseat the coping and seal it in place. Bulk-wax the gingival and middle thirds into a tentative crown contour. This aids in cusp tip placement and forms the occlusal outline.

The wax additive technique can be used to build either a cusp-to-embrasure or a cusp-to-fossa occlusal pattern. Figure 2–13 compares the two occlusal patterns. With most fixed restorations, you should strive for a cusp-to-fossa pattern.

Figure 2–13. Cusp-to-fossa versus cusp-to-embrasure occlusal patterns.

The cusp-to-fossa pattern

The cusp-to-fossa pattern is a tooth-to-tooth relationship rather than a tooth-to-two-teeth relationship like the cusp-to-embrasure pattern. As you may recall, in the cusp-to-fossa pattern, the stamp cusp contacts the opposing fossa at three points around the fossa's rim. This is "termed" tripodism. When properly positioned, tripodism distributes occlusal forces evenly over the long axis of the tooth. This distribution reduces lateral stress on the supporting and opposing dentition. When creating tripodism in your wax-up, do not create any contacts on the cusp tip. This "mortar and pestle" arrangement on the cusp tip can increase cusp wear and cause damaging eccentric interferences. The occlusal contact points for the cusp-to-fossa pattern can be seen in figure 2–14.



A. + B. = C.

Maxillary stamp cusp contacts in mandibular fossae.

Mandibular stamp cusp contacts in maxillary fossae.

Diagrams "A" and "B" are combined

Figure 2–14. Cusp-to-fossa occlusal contacts.

Cusps must be placed correctly—not only in centric occlusion but also during eccentric movements. Figure 2–15 illustrates the path of travel the stamp cusp makes when leaving its centric position. The dashline (-) represents the working path, and the dotted line (...) represents the nonworking (balancing) path. Stamp cusps pass close to, but never touch, the opposing cusps. The primary and accessory grooves act as pathways for the cusps.

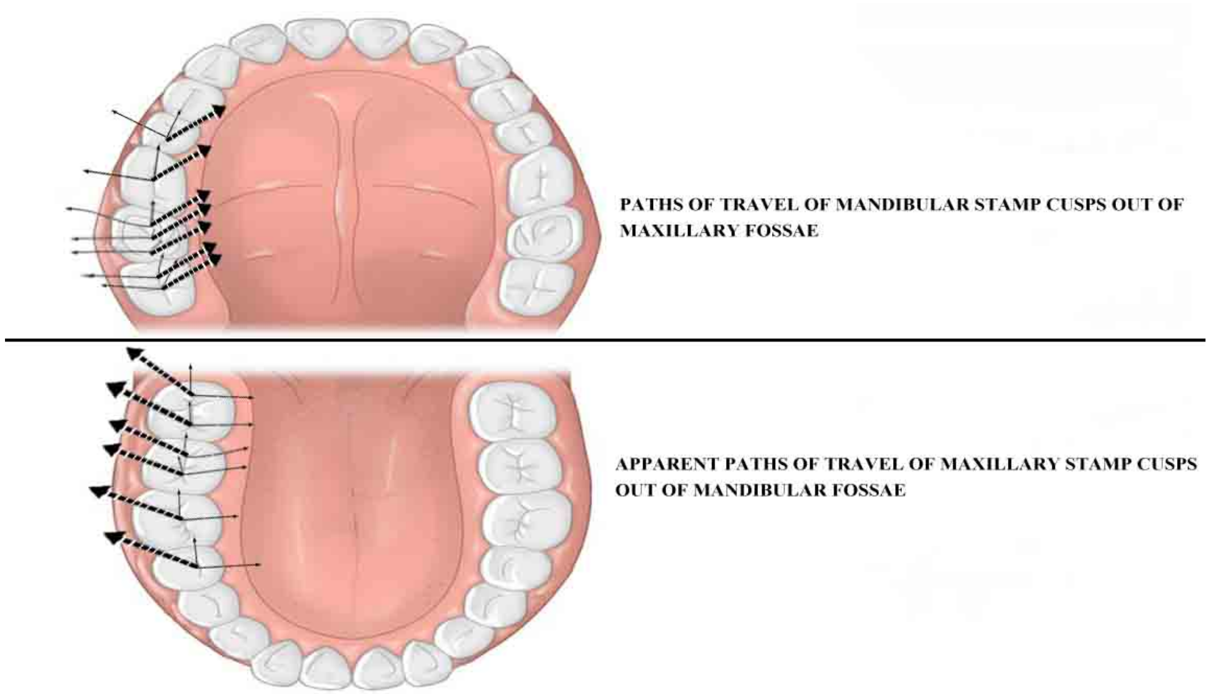


Figure 2–15. Stamp cusp travel paths.

To achieve the cusp-to-fossa pattern, wax the stamp cusps (maxillary lingual cusps and mandibular buccal cusps) in position with a waxing instrument. Cusps in the wax additive technique are initially created as cones, as illustrated in figure 2–16.

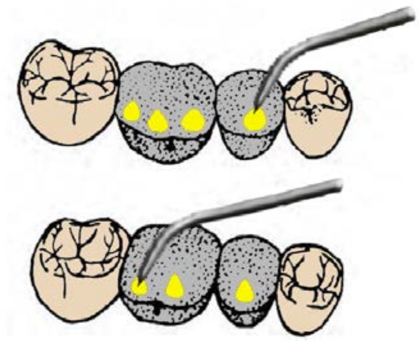


Figure 2–16. Waxing stamp cusp cones.

Position the stamp cusps to the opposing tooth's central sulcus to direct stress along the tooth's long axis. There should be slight contact with the opposing fossa. If there are no opposing teeth, wax the stamp cusps to conform to the anterior-posterior curve, illustrated in figure 2–17.

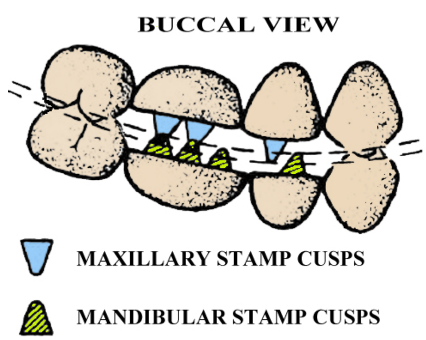


Figure 2–17. Stamp cusp cones conforming to the anteroposterior curve.

Once positioned in maximum intercuspation (MI), check the stamp cusp's path during balancing movement. Mandibular first and second bicuspid stamp cusps pass mesial to the maxillary bicuspid stamp cusps. The maxillary first molar's mesiolingual stamp cusp passes between the mandibular first molar's distobuccal and distal stamp cusp. The opposing second molars have the same relationship as the opposing first molars. These paths are based on a class I occlusion. Remember that the cones should not contact each other when passing.

After refining the stamp cusps, position the shearing cusps. Place shearing cusps as shown in figure 2–18. The adjacent teeth indicate the buccal lingual placement of the cones. The opposing tooth may also indicate placement. The shearing cusps should be shorter than the stamp cusps. Like the stamp cusps, the shearing cusps follow the Curve of Spee, but they also conform to the Curve of Wilson, or the mediolateral curve.

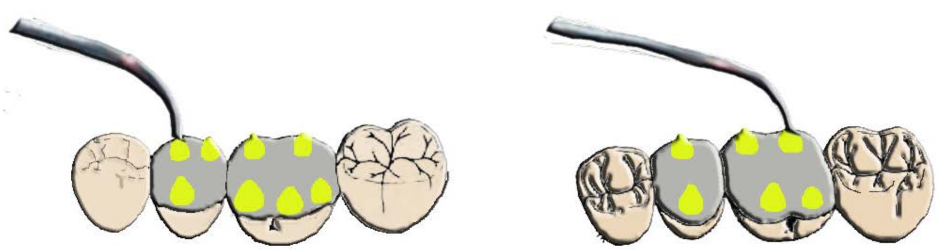


Figure 2–18. Waxing shearing cusp cones.

During the shearing cusp’s nonworking (balancing) movements, the maxillary molars mesiolingual cusps pass between the distal and distobuccal mandibular cones. During working excursions, the maxillary shearing cusps travel distally past the mandibular stamp cusps. Again, this is based on a class I occlusion.

Marginal ridges

Once the cones are in place, it’s time to wax the marginal ridges. Remember to keep the cusp tips as the highest points. Don’t let the ridges fall in as you wax. This reduces the surface area of the occlusal table. On the completed restoration, low marginal ridges lead to food impaction and high ridges can cause porcelain fracture. The opposing tooth could also fracture with a high marginal ridge, especially when opposing an all-metal restoration.

First, wax the maxillary marginal ridges. Then, wax the mandibular stamp cusps together, and check the occlusion with powdered wax or talc. The procedure is illustrated in figure 2–19.

Figure 2–19. Waxing marginal ridges.

Thomas notch

In working movements, the maxillary buccal cusps pass through small depressions on the distal inclines of mandibular bicuspids without interference. This depression is called a “Thomas notch” and can be seen in figure 2–20.

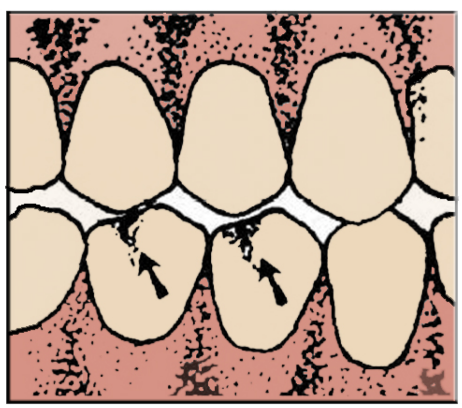


Figure 2–20. Thomas notch found on the distal incline of mandibular bicuspids.

In working, the maxillary molar’s mesiobuccal cusp passes through the mandibular molar’s buccal groove. At the same time, the maxillary molar’s distobuccal cusp passes through the mandibular molar’s distobuccal groove. The mandibular molar’s lingual cusps must be short enough to miss the maxillary cusps during a working excursion.

Controlling the buccal and lingual marginal ridge height also influences the occlusal pattern in eccentric movement. For example, anterior guided disclusion is created when no contact occurs in lateral excursions with opposing cusp ridges or inclines. Conversely, group function is created when you wax mandibular buccal cusp inclines into working side contact with the lingual inclines of maxillary buccal cusps.

Cusp ridges

Finish the contour by waxing cusp ridges, as shown in figure 2–21. Fill the spaces with wax to the desired fullness. Then, use an instrument to smooth the pattern's axial contours, as shown in figure 2–22.

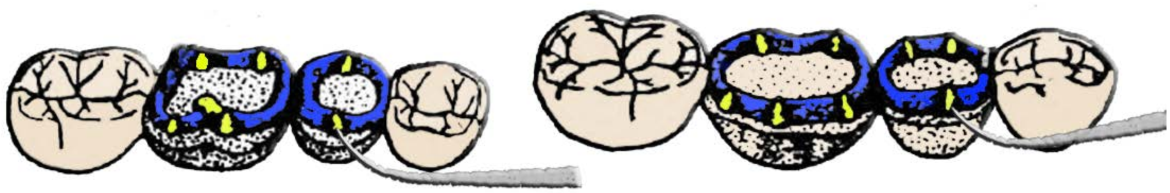


Figure 2–21. Waxing the cusp ridges.

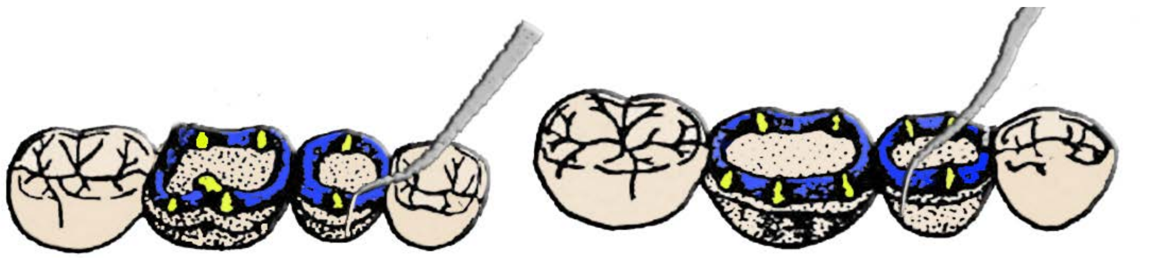


Figure 2–22. Smoothing the contour.

Triangular ridges

With the contour complete, it is time to wax the triangular ridges. Wax the maxillary ridges as illustrated in figure 2–23. The ridges should be broader at the fossa and narrow as they rise to the cusp tip. In addition, the ridge should be slightly more convex at the fossa to establish contacts. Shape the ridges and central sulcus. When you are satisfied with the maxillary ridges, wax the mandibular ridges. Repeatedly close the articulator and check centric and eccentric contacts.

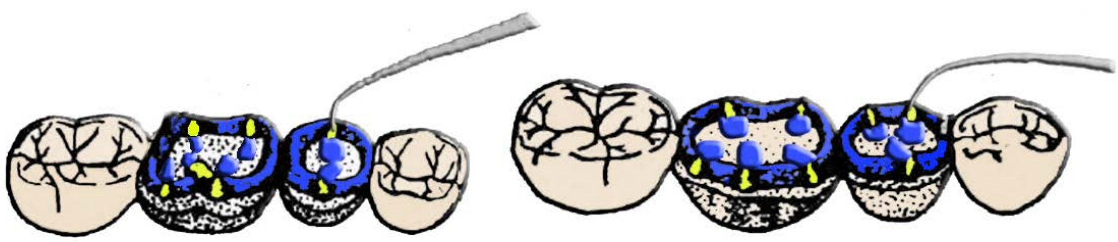


Figure 2–23. Waxing triangular ridges.

Remember that there should not be any nonworking (balancing) contacts. Fixed restorations with balancing contacts cause serious damage to the periodontium. The contacts should resemble the contacts in figure 2−14. Also, wax the triangular ridges to coincide with the cusp's travel paths. Refer to figure 2−15 for the travel paths.

NOTE: If necessary, you should review the unit on oral physiology in volume 2. This unit provides a thorough explanation of the Gothic arch angle.

Contacts

Once the triangular ridges are positioned and the contacts are established, you may notice that some contacts are still missing. These contacts are made by adding supplemental anatomy. Fill in the occlusal voids using an instrument. Then, dust powdered wax on the occlusion and refine the needed contacts to establish tripodism. Adapt the pattern's occlusal anatomy to the opposing natural anatomy.

Next, refine the occlusal contacts with powdered wax. Reduce heavy contacts and add wax to the light contacts. Restore the ridges and grooves as illustrated in figure 2–24. Finally, confirm the presence or absence of eccentric contacts. Figure 2–25 compares the eccentric contacts of an anterior guided occlusion with group function (unilateral balanced) occlusion. The group function illustration shows working excursion contacts between the mesiobuccal and distobuccal cusps. These contacts are absent in the anterior guided example.

Figure 2–24. Restoring triangular ridges and developmental grooves.

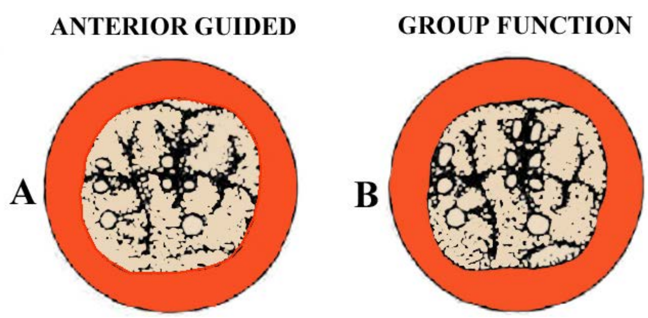


Figure 2–25. Anterior guided occlusal contacts and group function occlusal contacts.

Stress-relief technique

When you are satisfied that the occlusion and axial contours are correct, you can prepare to invest the pattern. You might ask, why now? It is because once the final margin adaptation is complete, the pattern must be invested immediately. The longer the delay, the more the pattern will distort. The distortion occurs as the stress in the wax releases. You can reduce the distortion by using a harder wax (more resistant to heat) in the proximal and marginal areas, as illustrated in figure 2–26.

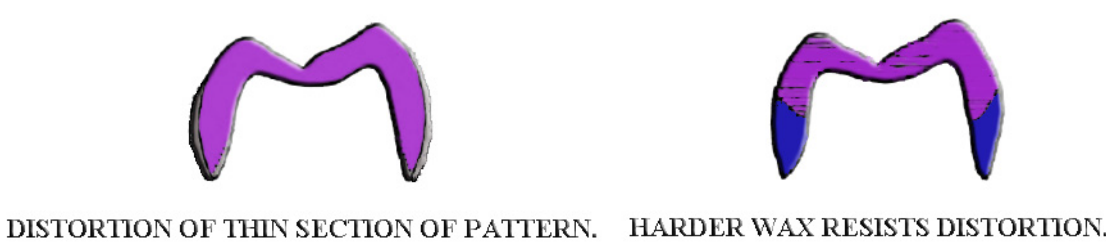


Figure 2–26. Wax pattern distortion.

Distortion can be reduced further by using a soft inlay wax for the initial coping and occlusal anatomy. A soft inlay wax has fewer working stresses than a harder wax, so it distorts less. Distortion is just the wax's attempt to return to its original state. Since soft wax flows and carves easier than hard wax, its atomic structure is more stable after adapting to the die. Because soft wax is easier to work with, it makes sense to use it for occlusal anatomy where good flow characteristics are critical.

The wax additive sequence for the stress-relief technique is to build the coping in soft wax first. The cones are then added with medium wax. The axial surfaces are also built with medium wax. Occlusal anatomy is added with soft wax. Then the margins are replaced with hard wax. This technique takes the same amount of time as the regular wax additive technique, and the cast crown fits better.

Whatever method you use, you will probably replace the margins with hard wax. To do this, gently cut 2 mm of the margin away from the pattern, and remove it from the die. Apply die lubricant to the die and reseat the pattern. Flow the hard wax quickly into the margin. The waxes must adapt to each other to prevent gaps on the internal surface. Burnish the margin with a warm instrument. Further smooth the wax with gentle strokes from a silk or nylon stocking toward the margin. Figure 2–27 summarizes these steps.

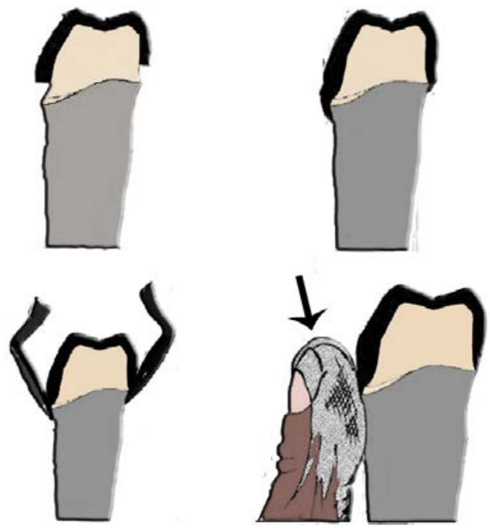


Figure 2–27. Refining the margins.

Before spruing, remove the pattern from the die. To do this, gently grasp the pattern between your thumb and forefinger; grasp the die the same way with the other hand. The grasping fingers of both hands should touch and exert pressure against each other to remove the pattern. Do not put pressure on the pattern. Use a rubber dam on the pattern if it's difficult to remove. Check the pattern's interior. Also, inspect the margin for over or under extensions, thick areas, and ripples. A list of common problems and solutions for refining wax pattern margins is given in the following table.

Wax Pattern Margins		
Problem	**Probable Cause**	**Solution**
Loss of cast detail after trimming	Cast immersed in water too long.	Soak cast in saturated calcium sulfate dihydrate solution (SDS) before trimming, and coat preparations with acceptable separator before trimming.
Pattern has rough internal (intaglio) surface	Wax flowed on die too slowly or wax too cold. Too much die lube.	Keep the wax fluid, and cover the preparation quickly and evenly. Gently blow off the excess die lube.
Margins break when a pattern is removed from die.	Wax is overextended into the undercut below the margin, or the die is inadequate lubricated.	Carve the wax to the margin, and adequately lubricate the die.
Periodontal problems caused by poor margin adaptation.	Axial contours are roughly finished, which collect plaque and irritate tissues.	Smooth the wax pattern.
Overextended crown margins.	Stone margin is abraded when seating and refining crown.	Be sure to properly identify margin and refine in wax prior to casting.

806. Waxing fixed dental prostheses

All-metal and metal-ceramic fixed dental prostheses use the same construction principles. One of the critical principles is assuring the FDP flexural strength. Much of the FDP's flexural strength is dependent upon the connector's design. A poorly designed connector can break under occlusal load. This is more likely to happen with a metal-ceramic FDP because the ceramic veneer cutback may intrude in the connector area, reducing its vertical depth and strength. In this lesson, we will examine the following four FDP subjects: (1) connectors, (2) pontics, (3) requirements for fixed restorations, and (4) FDP pattern fabrication.

Connectors

A metal-ceramic FDP connector must be designed to resist flexing because flexing will fracture the porcelain veneer. On the other hand, an over-contoured connector that creates destructive occlusal interferences can damage the patient's oral health.

Two factors that affect a connector's strength are its width and height. Doubling the connector's width doubles its strength. As figure 2–28 illustrates, doubling the occlusogingival height will increase the connector's strength by a factor of eight. This vertical aspect of connector design is limited by the amount of interproximal space available. Consequently, you should place the connector as high (incisally/occlusally) as possible to allow space for interproximal tissue.

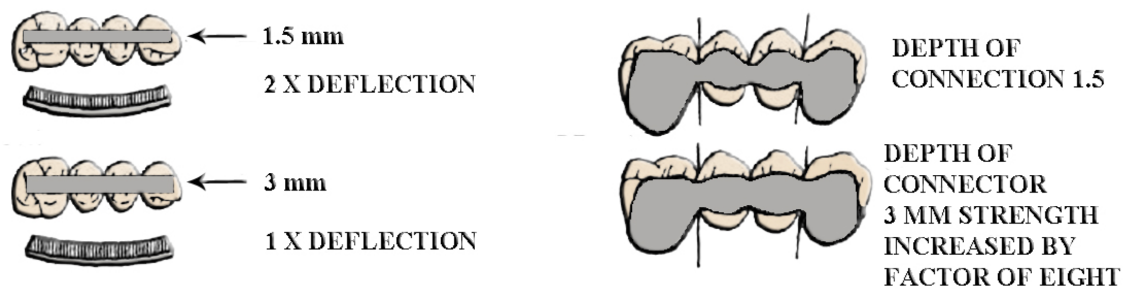


Figure 2–28. Increasing connector strength by doubling its size.

An FDP connector must also be designed to compensate for the length of the restoration. For example, when an occlusal load is equally applied to both a three-unit and four-unit FDP (fig. 2–29), the three-unit FDP barely flexes (fig. 2–29, A), while the four-unit FDP flexes eight times the distance of the three-unit FDP (fig. 2–29, B). To compensate for this, you must double the height of the four-unit FDP connector (fig. 2–29, C). This doubling increases the connector strength by a factor of eight and compensates for the FDP's greater length. The minimum width of a connector is 2 mm. In contrast, the minimum height is 2.5 mm. The connector should also have an inverted triangular shape with slightly rounded corners— as viewed from a mesiodistal aspect.

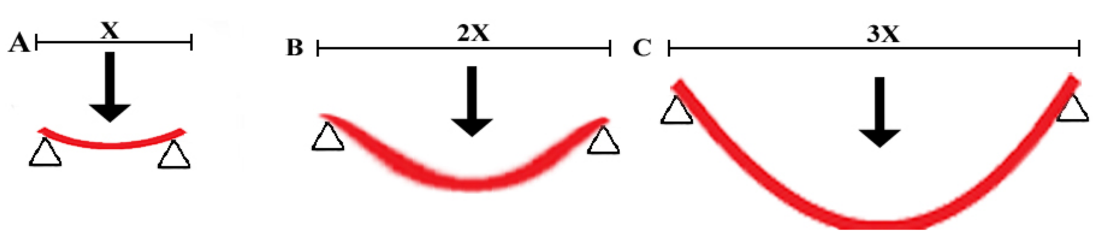


Figure 2–29. Relationship between FDP length and amount of flexing.

Pontics

Pontic design affects patient comfort, oral hygiene, esthetics, and function. There are different types of pontics to accommodate a variety of needs. Below are the most common pontic designs:

- Modified ridgelap.

- Hygienic.
- Ovate.

Modified ridgelap pontic

The modified ridgelap pontic is used in both the anterior and posterior areas of the maxillary and mandibular arches. It is most often used in the maxillary arch since these teeth are visible during speech. The ridgelap adapts to the facial aspect of the edentulous ridge to simulate a natural tooth (fig. 2–30) and is more natural in appearance than a hygienic pontic.

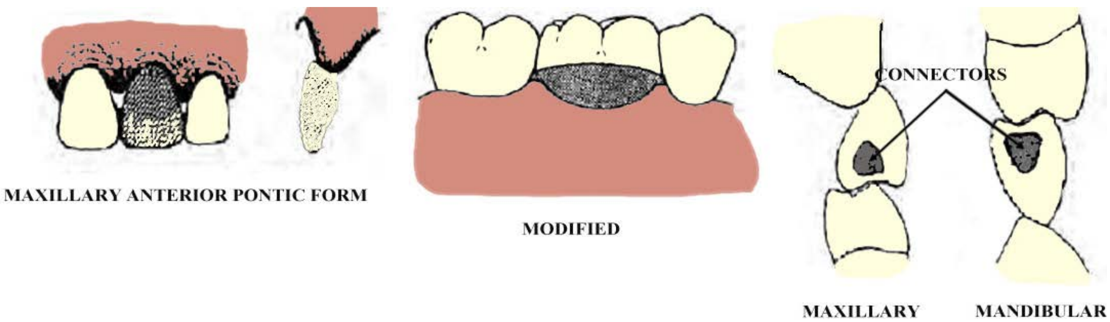


Figure 2–30. Examples of modified ridgelap pontics.

Approximately a third of the pontic's lingual contour should remain intact. This contour is important to deflect food away from the tissue surface of the pontic to prevent food impaction. The remaining natural teeth are a good guide to the lingual contour. Like all pontics, the axial surfaces must be convex and smooth. Overall contour should be the same as a natural tooth, except in the gingival third.

Hygienic pontic

The hygienic pontic is typically used in the mandibular posterior area where esthetics is not a factor. This pontic does not touch the ridge and is easier to clean than the modified ridgelap pontic (fig. 2–31). The hygienic pontic can be modified to increase the connector strength, if necessary, as shown in figure 2–32. The modified hygienic pontic is often called an archway or perel pontic. The pontic is concave mesiodistally, but it maintains a convex buccolingual surface for easy cleaning. This archway design increases the connector depth and can distribute occlusal loads more effectively to the long axis of the abutments.

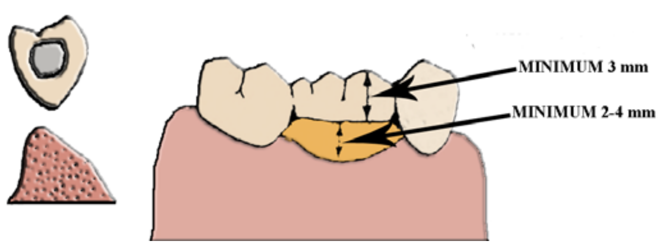


Figure 2–31. The hygienic pontic.

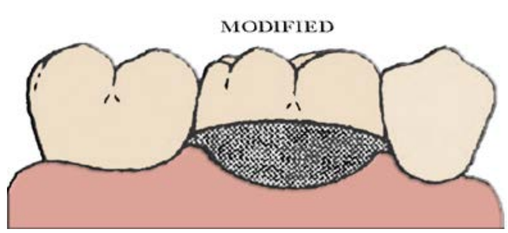


Figure 2–32. Modified (hygienic) pontic.

Ovate pontic

The ovate pontic is an egg-shaped pontic, which is butted against the patient's gum. A depression is created on the ridge of the pontic to simulate the natural shape of the root and crown of the tooth. The important aspect of the pontic is for the lab technician to create an appearance of it growing out of the tissue instead of it just resting on the tissue. This obviously creates a more natural and esthetic look for the patient.

Requirements for fixed restorations

Now, let us go back to the requirements for fixed restorations and see how they apply to pontic design. Remember, the requirements are as follows:

- Cleansability.
- Esthetics.
- Function.

Cleansability

To make a pontic that is both nonirritating to a patient's tissue and easily cleanable, it must be smooth and the tissue surface should be convex. Connectors should be placed as high as possible to allow room for interproximal tissue and so they do not press on the interproximal tissue. If they do, as in figure 2–33, the dentist may be forced to remove the papilla. Again, keep the contacts as high as possible and in the normal contact location. Modified ridgelap pontics should only have a pinpoint contact with the ridge.

Figure 2–33. Modifying the patient's ridge to make room for the connectors.

Esthetics

Esthetically, the pontic must resemble a natural tooth that has erupted from the ridge. This can be difficult to do if the adjacent teeth have drifted, which can narrow or widen the edentulous space the pontic must fill. Figure 2–34 illustrates filling a wide space and a narrow space. If a wide space must be filled, as illustrated in the top portion of figure 2–34, you must modify the pontic's facial surface to create an illusion of less width. Creating this illusion is accomplished by creating a convex facial surface. Shifting the proximal contacts lingually redirects the reflected light, which influences how people view the pontic's appearance. Conversely, a narrow space can appear wider by flattening the facial surface and moving the proximal contacts facially.

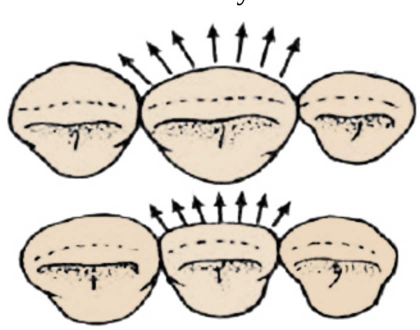


Figure 2–34. Altering the facial surface to create an illusion.

The ridge resorption creates another problem for the pontic. Normally, a natural tooth erupts and stops somewhere around the tooth's cervical line. A pontic does not erupt and can appear too long if the ridge is more than moderately resorbed. Figure 2–35 gives you some idea of the problem. One remedy to this problem is to depress the tooth's neck lingually, and place the pontic's cervical line at the same height and prominence as the adjacent teeth. The more you have to depress the neck, the more prominent the cervical line has to be.

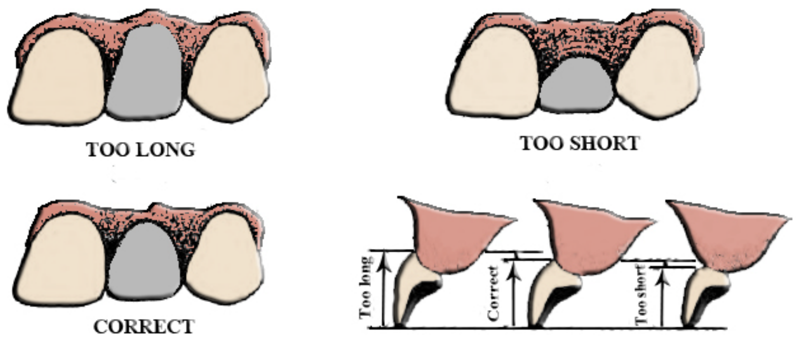


Figure 2–35. Positioning an anterior pontic's cervical line.

Function

The pontic's appearance is also determined by its functional requirements. All excursive contacts between the FDP and opposing arch must occur on the retainers and natural teeth. The pontic must not have any excursive contacts—even light contact on the pontic is discouraged. So it can be said that both esthetics and function determine the incisal, or occlusal, length of the pontic, as well as the vertical and horizontal overlap.

The anterior pontic's facial lingual width should be the same or slightly narrower than the adjacent teeth. This also applies to the occlusal surface of the posterior pontic. The occlusal surface should be wide enough to restore function, but not wide enough to create a food trap on the lingual.

Pattern fabrication

There are nine basic steps for fabricating a pattern for an FDP. They are as follows:

Steps for Fabricating an FDP Pattern	
Step	**Action**
1	Wax the retainers with the additive technique.
2	Wax the axial and occlusal contours to match the natural teeth.
3	Establish all occlusal and posterior contacts.
4	With the retainers complete, wax the pontic using the same techniques you would for waxing a retainer.
5	When complete, refine the retainer's margins.
6	Attach the pontic to the retainer that's most stable on the die.
7	Remove the die, retainer, and pontic from the cast and shape the gingival third of the pontic.
8	Complete the one connector you have already established.
9	Replace the pattern on the original cast, or a solid cast, and wax the remaining connector.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

805. Waxing posterior restorations

1. When waxing posterior restorations, out of the following three requirements: esthetics, function, and sanitation, which is the *most* important? Why?

2. When considering fixed restoration requirements, how is a properly contoured crown self-cleansing?

3. What is the “emergence angle?” Why is it important?

4. When waxing a pattern, why should you create a tentative crown contour?

5. If no opposing occlusion is present, what can you use as a guide to determine the length of the cusp tips?

6. When waxing a restoration, how does a balancing contact affect natural teeth?

7. When waxing a fixed restoration, why is supplemental anatomy waxed into the restoration?

8. After dusting the pattern with powdered wax, what condition *must* be established? How is this accomplished?

806. Waxing fixed dental prostheses

1. When a fixed dental prosthesis is waxed, what factor may increase the connector’s strength eight-fold?

2. What pontic is normally used in the maxillary arch?

3. When a hygienic pontic is designed, what requirements must be considered?

4. How can a pontic be made to appear narrower?

5. When a pontic is waxed, what factors determine the pontic's appearance?

2–2. Wax Patterns for Metal-Ceramic Substructures

Fabricating a wax pattern for a metal-ceramic substructure is done through a series of tasks. Each of these tasks must be carefully completed. In this section, we will discuss the following:

- Substructure design.
- Waxing the substructure.

807. Substructure design

Substructure design is a critical step to fabricating metal-ceramic restorations. A properly constructed restoration begins with a carefully designed substructure. We will discuss these topics in this lesson:

- Porcelain adhesion.
- Substructure requirements.

Porcelain adhesion

Porcelain adheres to metal via three distinct methods—chemical bonding, mechanical bonding, and compression. They are described in the following table.

Methods of Porcelain Adhesion	
Method	***Description***
Chemical	A chemical bond develops through the fusion of the oxide layer on the metal's surface and the porcelain particles.
Mechanical	A mechanical bond results as the porcelain locks into microscopic grooves and undercuts on the metal's surface. A state of compression exists within the porcelain when the cooling metal shrinks.
Compression	The compressive forces, although not a bonding mechanism, add to the strength of the restoration and can be seriously affected by incompatible metal-ceramic combinations. Metal-ceramic compatibility depends on the material's coefficient of thermal expansion. This association minimizes the possibility of porcelain fractures when cooling after firing. Metal has the greater coefficient of thermal expansion. In other words, metal expands and shrinks more than porcelain when heated. Since metal shrinks more, it pulls the porcelain into a compressive state. This is illustrated in figure 2–36. If the entire porcelain veneer cracks, it indicates that the metal and ceramic are incompatible.

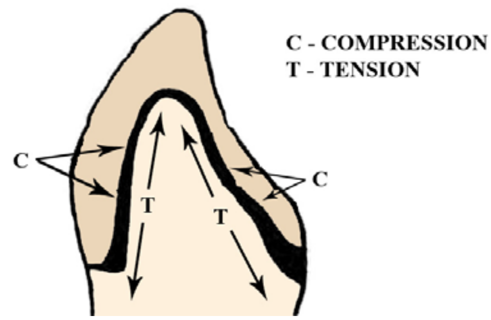


Figure 2–36. Porcelain compression.

Substructure requirements

The substructure must be strong enough to withstand occlusal stresses without flexing. The substructure design and thickness must oppose repeated occlusal loads to support the porcelain veneer. Minimizing the porcelain's internal stress is an essential part of substructure support. The substructure veneer area must be smooth and even to prevent internal stress. An uneven porcelain thickness causes internal stress and results in porcelain fracture. In order to fulfill these requirements, you must be aware of several other substructure factors. The factors are as follows:

- Optimum restoration thickness.
- The cutback technique.
- Occlusal load resistance.
- Proximal contacts.
- Substructure connectors.

Optimum restoration thickness

The combined metal-ceramic veneer thickness should be at least 1.2 mm (1.5 mm is ideal) to meet minimum strength and shade requirements. This is shown in figure 2–37. There must be a 0.3 mm facial metal thickness to prevent metal flexing under load and eventual porcelain fracture. The opaque layer must be 0.2 mm to mask the metal. The body porcelain layer must be at least 0.7 mm to produce the expected shade. Of course, the shade can change if the body porcelain layer is too thick. The dentist must remove 1.5 mm of the natural tooth's facial surface to allow you to reproduce the tooth's normal contours and shade. Pontics must also allow for a 1 mm to 1.5 mm porcelain layer.

Metal-ceramic substructures are made so that porcelain can be applied in a uniform layer. The facial thickness should not exceed 1.5 mm and the incisal should not exceed 2 mm. Try to keep the porcelain to a minimum thickness without sacrificing esthetics. A thin, uniform thickness of porcelain supported by a rigid substructure offers the most strength; therefore, the veneer's contour must follow the metal's contour.

The metal's contour affects the porcelain's mechanical bond. The porcelain veneer area should round gently. There should not be any corners, angles, points, or concavities. Figure 2–38 illustrates this concept. Deep concavities allow the porcelain to pull away from the metal.

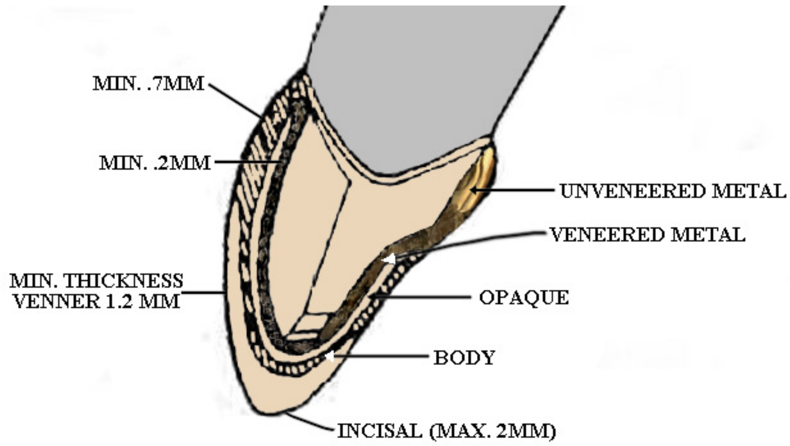


Figure 2–37. Veneer thickness.

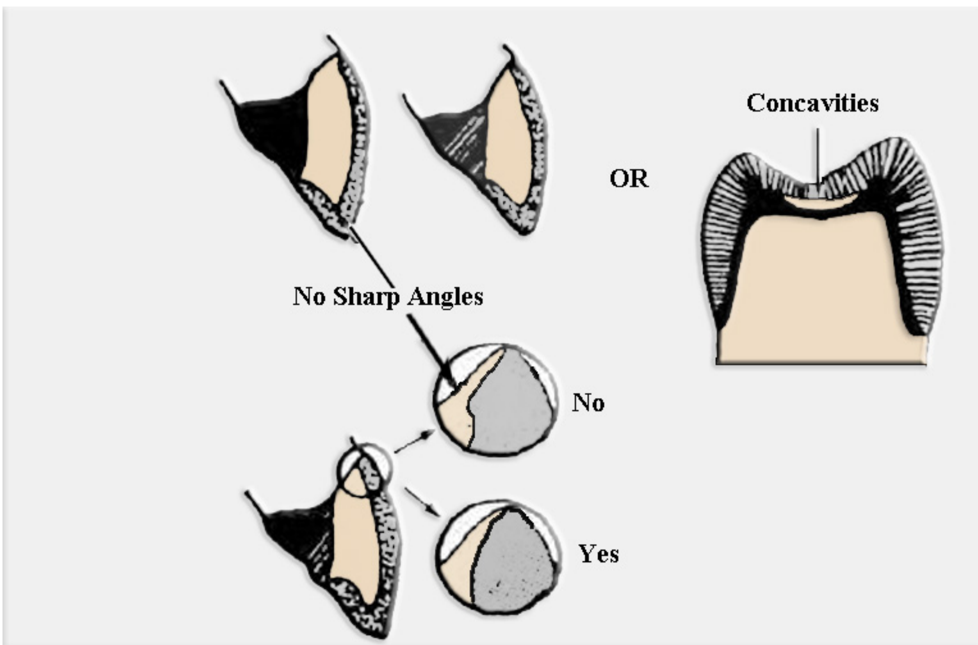


Figure 2–38. Common substructure design errors.

The cutback technique

To achieve an effective substructure, you must begin with a pattern waxed to full contour. The required veneer thickness is then cut back to create the veneer area. This method ensures a uniform porcelain layer (fig. 2–39). As shown in figure 2–40, the finish line's contour is continuous with the porcelain when you use the cutback technique. Figure 2–41 illustrates one of the outcomes if you do not use the cutback technique. As you can see, porcelain subsurface porosity may increase because of an excessive thickness of porcelain, or the porcelain may fracture under load or when exposed to heat due to insufficient metal support.

When cutting back the pattern, place the finish line to take full advantage of porcelain's compressive strength. The porcelain should be allowed to wrap around the substructure, as illustrated in figure 2–42. All porcelain and metal junctions should be as close to a 90° angle (butt joint) as possible to provide good porcelain support, as shown in figure 2–43. Avoid feather edging of the porcelain to prevent chipping. This is the reason for using at least a 0.5 mm facial collar.

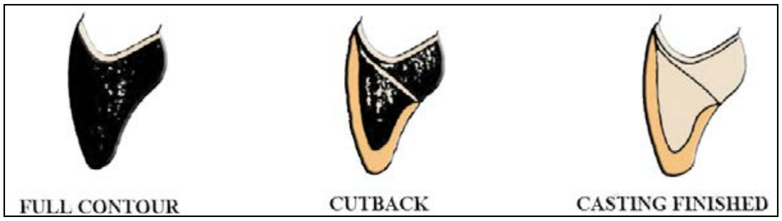


Figure 2–39. Achieving an even porcelain layer with the cutback technique.

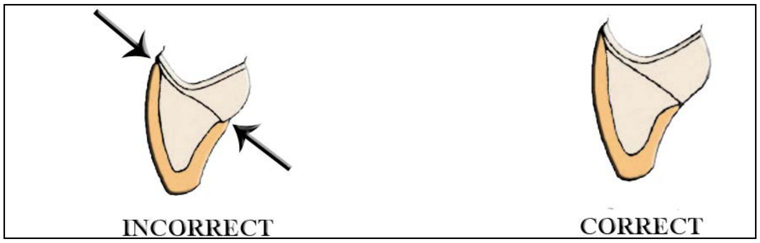


Figure 2–40. Maintaining an uninterrupted contour.

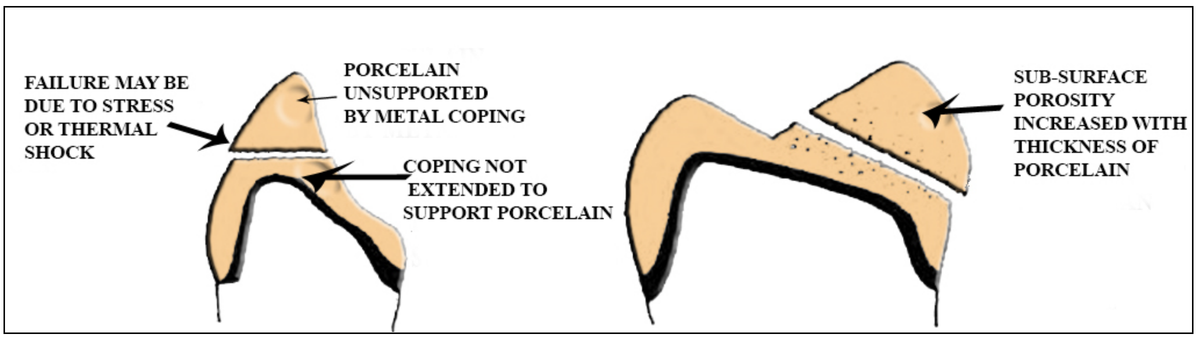


Figure 2–41. Examples of porcelain failure due to insufficient metal support.

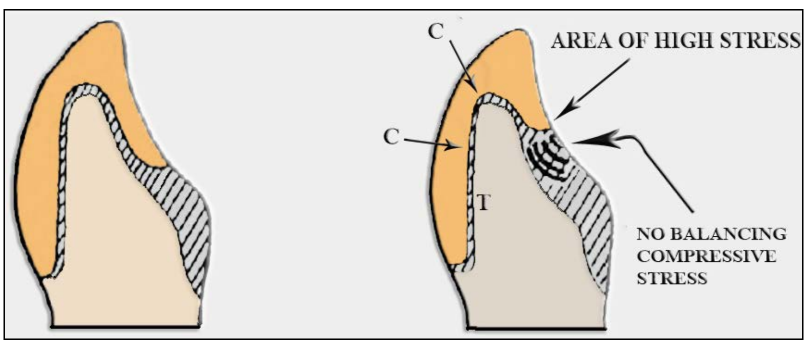


Figure 2–42. Porcelain wrapping around the substructure.

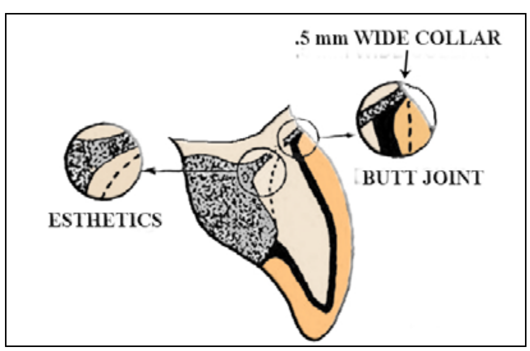


Figure 2–43. 90° angle porcelain butt joint.

The collar can create a dark shadow when the restoration is seated on a subgingival preparation. An alternate method is to make a collarless crown with shoulder porcelain. In this case, the dentist prepares a facial shoulder margin to support the porcelain (illustrated in fig. 2–44). Either of these alternatives is preferable to covering the facial collar with porcelain.

Figure 2–44. Collarless crown with a shoulder margin.

Occlusal load resistance

One of the best ways a substructure can support porcelain is to absorb the occlusal load (force) itself. This is done by placing occlusal contacts in metal. Although this isn't always possible, the opposing dentition should never contact any portion of the porcelain-to-metal junction. This extends to not permitting any excursive contacts across the junction.

With anterior metal-ceramic restorations, the occlusal contact should be on either metal or porcelain, as illustrated in figure 2–45. The junction should be at least 1 mm away from the contact to prevent metal flexing from breaking the porcelain (fig. 2–46).

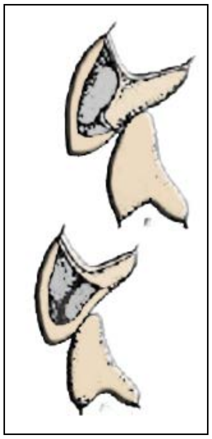


Figure 2–45. All-metal or all-porcelain centric contact.

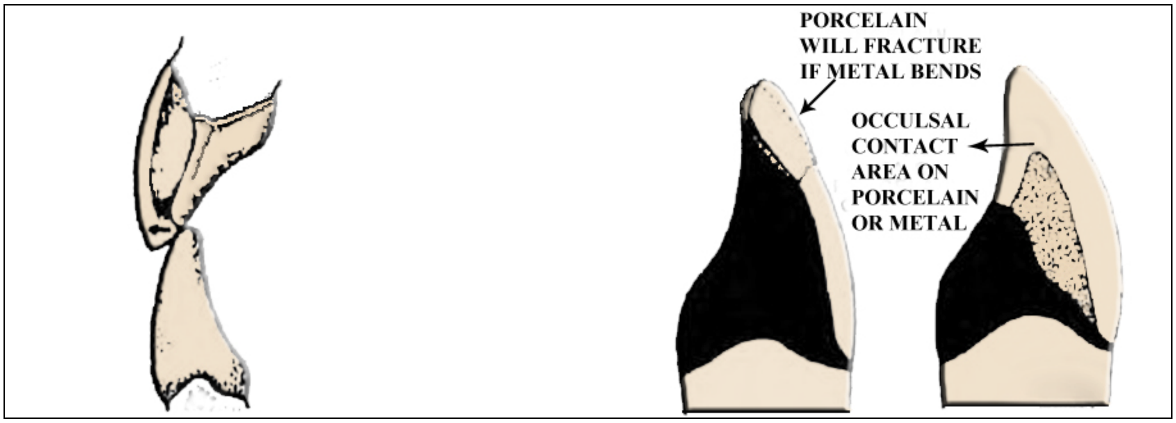


Figure 2–46. Porcelain fracture due to excursive contact.

Posterior metal-ceramic restorations are handled differently depending on whether they're in the maxillary or mandibular arch. Maxillary posterior metal-ceramic restorations are simple since the junction is on the shearing cusp (fig. 2–47).

Figure 2–47. Typical maxillary bicuspid design.

Placing the junction too close to occlusal contacts results in porcelain fracture, as illustrated by the left-hand (incorrect) and center (result) views on figure 2–48. The right-hand view (correct) shows three acceptable locations for the porcelain-to-metal junction. Position 1 shows the junction for a ceramic occlusal. Position 2 places the junction in the sulcus, and position 3 puts the junction buccal to centric contact. All three junction locations avoid centric and excursive contacts.

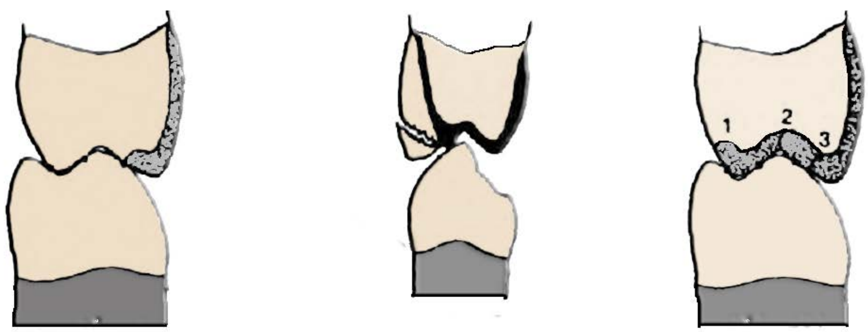


Figure 2–48. Porcelain-to-metal junction placement on posterior metal-ceramic restorations.

Mandibular metal-ceramic restorations may require a central sulcus junction point or even an all-metal occlusal. Some dental laboratory technicians place a centric occlusion metal island in the substructure.

Proximal contacts

Proximal contacts on anterior metal-ceramic restorations should be on porcelain. This is the most esthetic design and offers you the most freedom for contouring the porcelain veneer. A disadvantage of porcelain contacts is that they must be reglazed or polished after the dentist adjusts them.

Proximal contacts are also dictated by the design the prescribing dentist annotates on the DD Form 2322, Dental Laboratory Work Authorization. Sometimes posterior contacts are in metal as in figure 2–49, and other times the contacts are in porcelain as shown in figure 2−50.

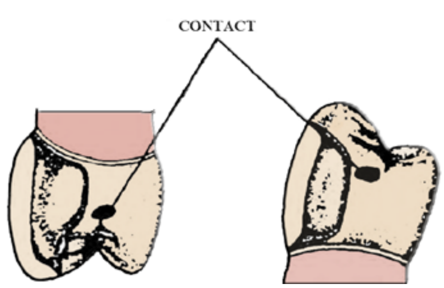


Figure 2–49. Contacts in metal.

Figure 2–50. Porcelain proximal contacts.

Substructure connectors

All previously mentioned design principles apply equally to fixed dental prostheses. Connectors should be strong in order to prevent porcelain fracture caused by flexing under load. A typical anterior metal-ceramic FDP design is illustrated in figure 2–51. Notice the continuous metal strip across the lingual surface. This finish line may be scalloped to allow additional length and bulk for the connectors while allowing occlusal contacts on porcelain. This type of design is also easier to solder.

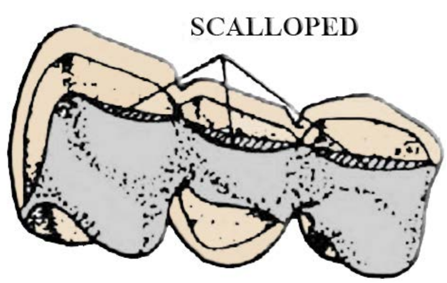


Figure 2–51. Anterior metal-ceramic FDP design.

The pontic's porcelain coverage is the same as the retainer's except that (1) the pontic's veneer is continuous with the retainer's veneers, and (2) porcelain covers the tissue surface for better esthetics and hygiene.

Figure 2–52 is a proximal view of the retainers and pontic. You can see that the metal contour closely follows the porcelain veneer. At least a 1 mm porcelain layer covers the facial surface while a 0.5 mm covers the tissue surface. This design prevents possible tissue irritation by moving the porcelain-to-metal junction away from the tissue. The junction is lingual and incisal to the ridge.

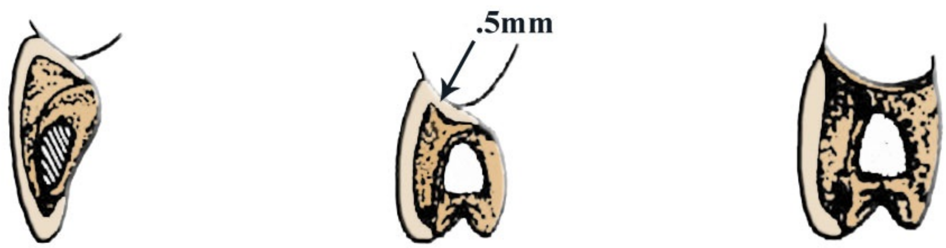


Figure 2–52. Proximal view of retainer and pontic designs.

The following table presents example problems, probable causes, and solutions to some common problems in metal-ceramic restoration design.

Substructure Design		
Problem	***Probable Cause***	***Solution***
Opaque shows through body porcelain when properly contoured.	Body porcelain too thin due to metal's thickness.	Remove porcelain and reduce metal thickness to 0.3 mm.
	Insufficient facial veneer thickness.	Modify opaque or use extrinsic stain.
Facial collar under-contoured.	Improperly waxed or finished.	Slightly over wax collar with excess depth to allow for finishing.
Color of porcelain varies from one unit to another.	Nonuniform thickness of porcelain.	Recontour porcelain and/or remove porcelain and recontour framework.
Proximal areas appear dark.	Porcelain-metal junction positioned too far facially.	Position porcelain-metal junction lingual to proximal contact.
Craze line or fracture visible.	Porcelain applied too thick.	Don't exceed recommended thickness.
	Framework has sharp angles.	Smooth and round angulated porcelain-bearing areas.
Porcelain cracks when restoration is seated.	Framework is too thin and flexes.	Minimum metal facial thickness is 0.3 mm—connectors must be adequately designed to resist flexing.
Porcelain chips near porcelain-metal junction.	Occlusal contacts too close to junction.	Place occlusal contacts at least 1 mm away from junction.

808. Waxing the substructure

Waxing the substructure for a metal-ceramic restoration requires you to perform all the tasks you would do for an all-metal restoration—contour, contacts, and margins. Additionally, you must also consider the physical requirements and limitations of both the supporting metal substructure and the ceramic veneer. In this lesson, we show you two important concepts:

- How to incorporate design requirements for metal-ceramic substructures.
- How to incorporate cutback procedures for metal-ceramic substructures.

Incorporating design requirements

Make the coping the same way you would for an all-metal restoration. To do this, you may apply molten wax with an instrument or use a wax dipping method. Use a specially made wax for wax dipping. Submerge the die past the margin and remove. Next, remove the excess wax, and gently remove the coping for inspection. Check the interior for voids. Then, measure the pattern thickness with a wax thickness gauge. The coping should be a minimum of 0.4 mm thick (some areas will be thicker because the metal must maintain porcelain support). This is the minimum thickness you want regardless of the waxing method you use. The 0.4 mm of wax ensures there is enough metal to finish the substructure. Add wax to thin areas to prevent holes in the casting (fig. 2–53).

Another coping fabrication method is to adapt 26-gauge sheet wax to the die. Either way, use the dual wax technique when waxing, because the harder wax better resists distortion. Also, build the coping in a different color of wax than the wax you use for the full contour wax-up. This helps you stop at the correct thickness during the cutback.

With the coping prepared, wax the restoration to full contour. Check the occlusal and excursive contacts, ensuring the desired occlusal pattern is followed. You may want to duplicate the final wax up of multiple unit metal-ceramic restorations to serve as a guide when building the ceramic part of the restorations.

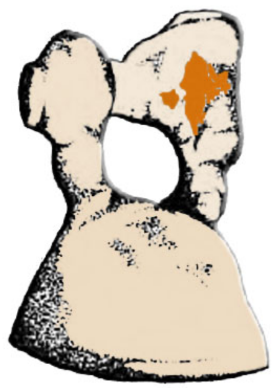


Figure 2–53. Hole in casting caused by a thin spot in the pattern.

You may also want to make a facial index like the one in figure 2–54. The index can be made with silicone impression putty. The facial index is used to indicate the amount of veneer cutback—that is, the final thickness of the porcelain veneer. It can also be used as an esthetic guide when poured as an impression. To check the amount of cutback, cut the index in half horizontally and replace it on the model. The gap between the index and wax-up indicates the amount of cutback.

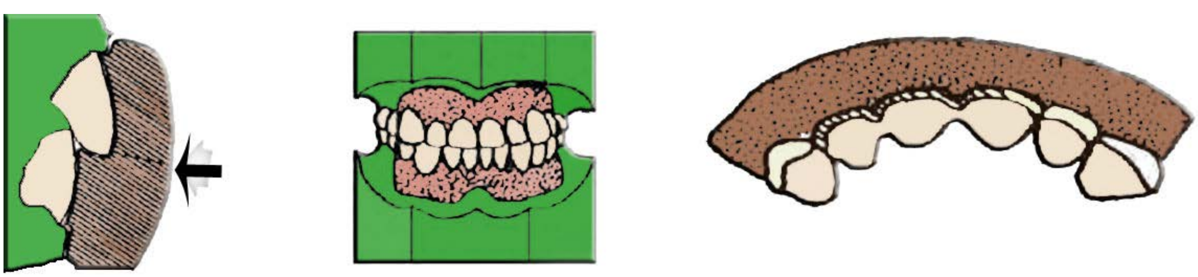


Figure 2–54. A facial index.

With the index made, you may now design the cutback. Begin by outlining the veneer area with a sharp instrument. Then, place the proximal finish lines as far lingual as possible for anterior units. With a sharp instrument, remove 1.5 mm from the pattern's incisal edge, as illustrated in figure 2–55. Reduce the pattern's proximal edges 1 mm, following the pattern's proximal contour. Remember that an anterior unit's proximal contacts are on porcelain, while a posterior unit's contacts are on metal.

Figure 2–55. Cutback technique.

Next, make depth cuts of 1 mm in the pattern’s facial and lingual surfaces with a discoid. Depth cuts establish the amount of wax to remove. Define the collar with the discoid leaving a 1 mm facial collar. This can be reduced to 0.5 mm in metal. Then, remove the rest of the wax with a sharp instrument. Remove the pattern and check it with a wax thickness gauge.

Replace the pattern on the cast and verify occlusal contacts and finish line placement. Check the cutback from all possible angles. Two areas of concern are the mesiodistal facial surface curve and the occlusogingival curve. The pattern should “roll in” on these surfaces, especially anterior units. Finally, adapt the margins before spruing. Then, remove the pattern and check for broken, frayed, overextended, or short margins with a microscope.

FDP metal-ceramic restorations are made in practically the same way as the preceding steps for single units. Retainers are waxed to full contour and cut back. The difference is in reducing the pontic. The pontic can be reduced while attached to a retainer or as a single unit. Be careful when you are replacing the pontic. You want to maintain the occlusal contacts you established in the full wax-up.

There has been disagreement about occlusal contacts in metal-ceramic restorations. Should they be metal or porcelain? Generally, the occlusal contacts should be metal because metal is easily polished after the dentist adjusts the contacts. Porcelain must be reglazed or mechanically polished. Also, tooth enamel is abraded much faster by porcelain than by metal. This is not an absolute rule. If the patient needs porcelain contacts for appearance, and function allows it, make porcelain contacts.

Cutback procedures

To cut back an FDP, first wax it to full contour (fig. 2–56). Follow the steps already discussed for outlining the veneer area and removing wax. Place the occlusal porcelain-to-metal junction out of centric or eccentric contact. The proximal finish lines should be buccal to the proximal contacts. Make the pontic finish lines continuous with the retainer’s finish lines. Place the finish lines as far lingual as possible on the pontic.

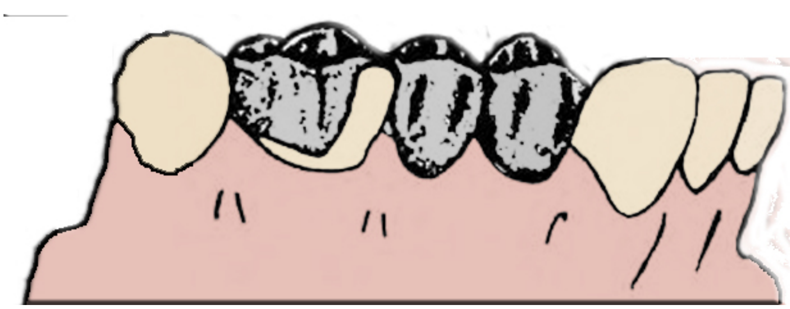


Figure 2–56. FDP full contour wax-up.

Begin wax removal by making depth cuts with the discoid. The procedure is illustrated in figure 2–57. Follow the reduction amounts given previously. Round any sharp corners or lines. Sharpen the finish lines. If you made a facial index, use it now to check the cutback amount (fig. 2−58).

It is important to check the pattern’s thickness and the amount of cutback before refining the wax pattern margins. Inspect the completed wax-up from various angles. Figure 2–59 shows the pattern from the lingual, occlusal, and facial views. Notice how much wax was reduced from the buccal cusps. It is difficult to get good metal support without creating a sharp angle. Also, inspect the amount of clearance for porcelain on the occlusal surface as well as the tissue side of the pontic. The wide area between pontic and retainer gives you room to shape the fired porcelain without exposing the metal substructure.

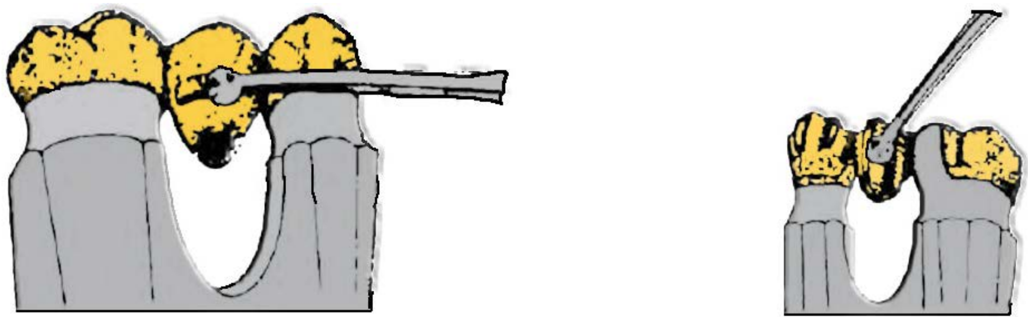


Figure 2–57. FDP cutback technique.

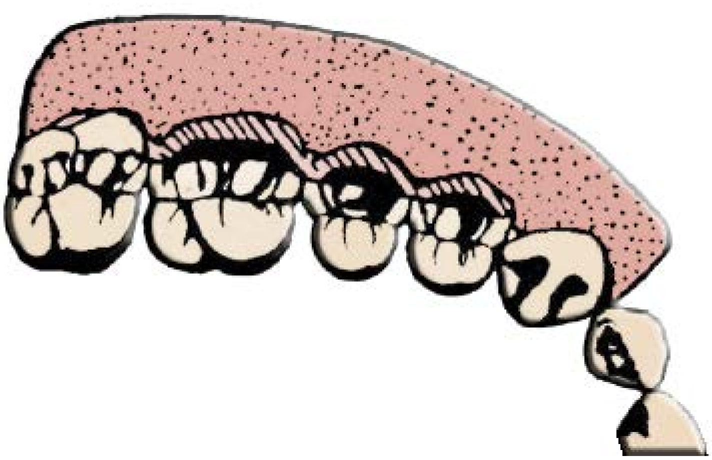


Figure 2–58. Checking the cutback with a facial index.

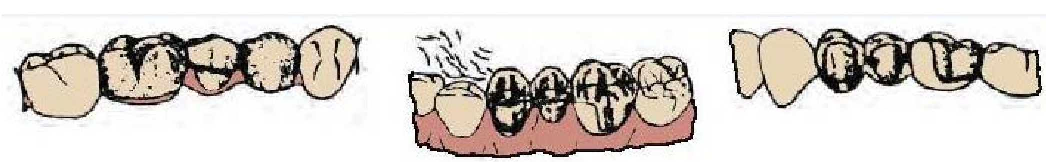


Figure 2–59. Different views of the completed substructure.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

807. Substructure design

1. When porcelain adheres to metal, what bond results from a fusion of the oxide layer on the metal’s surface with porcelain particles?

2. What material has a greater coefficient of thermal expansion—porcelain or metal? Why?

3. What incident may occur when porcelain is fired on an uneven or irregular surface?

4. When optimal restoration thickness is gained, what minimum thickness of metal substructures is achieved? Why?

5. What general rule can be applied to the overall design of a veneer area?

6. When a wax-up is cut back, what design element takes advantage of porcelain’s compressive strength?

7. Why is there a 90° angle butt joint at the porcelain-to-metal junction?

8. What substructure technique can support porcelain by absorbing the occlusal load (force) itself?

9. When a substructure is fabricated, why is it important to scallop a continuous metal strip across the lingual surface?

808. Waxing the substructure

1. When checking coping thickness, what is the desired wax pattern thickness?

2. When a substructure is waxed, what purpose does the facial index serve?

3. When making depth cuts, what waxed areas should be reduced and by how much?

4. What step should be accomplished directly before wax pattern margins are refined?

Answers to Self-Test Questions

805

1. Sanitation, because a restoration must be easy to clean to preserve the patient's oral health.
2. Food is deflected by the crown's contours and the lips, cheeks, and tongue clean the facial and lingual tooth surfaces during mastication.
3. The emergence angle describes the axial contours of the clinical crown as it emerges from the gingival sulcus. Any over-contouring in this area can impinge on the tissue, causing it to recede.
4. To aid cusp tip placement and form the occlusal outline.
5. Wax the stamp cusps to conform to the anterior posterior curve.
6. Fixed restorations with balancing contacts cause serious damage to the periodontium.
7. To provide occlusal contacts.
8. Tripodism. By reducing heavy contacts and restoring the occlusal contours.

806

1. Doubling its occlusogingival depth.
2. Modified ridgelap.
3. Pontic surfaces must be convex and smooth. Overall contour should be the same as a natural tooth, except in the gingival third.
4. Make the facial surface more convex by shifting the proximal contacts lingually.
5. The facial lingual width should be the same or slightly narrower than the adjacent teeth. The occlusal surface should be wide enough to restore function, but not wide enough to create a food trap on the lingual.

807

1. A chemical bond.
2. Metal has the greater coefficient of thermal expansion, causing it to expand and shrink more than the porcelain. Since the metal shrinks more, it pulls the porcelain into a compressive state.
3. It causes internal stress and results in porcelain fracture.
4. There must be a 0.3 mm facial metal thickness to prevent metal flexing under load and eventual porcelain fracture.
5. A thin, uniform thickness of porcelain supported by a rigid substructure offers the most strength. Therefore, the veneer's contour must follow the metal's contour.
6. Allow the porcelain to wrap around the substructure.
7. It provides better porcelain support.
8. Placing occlusal contacts in metal.
9. To allow additional length and bulk for the connectors while allowing occlusal contacts on porcelain.

808

1. 0.4 mm.
2. To indicate the amount of veneer cutback. Also, it can be used as an esthetic guide.
3. 1.5 mm from the incisal and 1 mm from the facial, proximal, and lingual surfaces.
4. Check the pattern’s thickness and amount of cutback.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter.

2. (805) You are waxing a posterior restoration. You want to allow food to move to the lingual during mastication. In order to do this, you locate a proximal contact *more*
   a. incisal.
   b. buccal.
   c. gingival.
   d. occlusal.

13. (805) What *must* be *equal* in height to *prevent* food impaction?
   a. Adjacent marginal ridges.
   b. Adjacent incisal edges.
   c. Triangular ridges.
   d. Cusp tips.

14. (805) In a cusp-to-fossa relationship for waxing a posterior restoration, the stamp cusps *contact* the opposing fossa
   a. in centric relation occlusion only.
   b. in a mortar-and-pestle relationship.
   c. at three points around the fossa's rim.
   d. at a single point at the apex of the cusp tip.

15. (805) What is created when *no contact* occurs in lateral excursions with *opposing* cusp ridges or inclines?
   a. A group function disclusion.
   b. An anterior guided disclusion.
   c. A bilateral balance disclusion.
   d. A unilateral balance disclusion.

16. (806) When waxing a connector on a fixed dental prosthesis (FDP), *doubling* the occlusogingival *height* will *increase* the connector's *strength* by a factor of
   a. two.
   b. four.
   c. six.
   d. eight.

17. (806) When waxing a fixed dental prosthesis (FDP), placing the connectors as *high* incisally or occlusally as possible
   a. strengthens the FDP.
   b. prevents lateral food impaction.
   c. prevents gingival food impaction.
   d. allows space for interproximal tissue.

18. (806) You are waxing a pontic. To do this properly, the axial surfaces must be
   a. concave and smooth.
   b. convex and smooth.
   c. concave and flat.
   d. convex and flat.

19. (806) When waxing a fixed dental prosthesis (FDP), you determine the incisal length of a pontic by
    a. esthetics only.
    b. function only.
    c. anterioposterior curve.
    d. esthetics and function.

20. (807) In terms of a metal-ceramic substructure, what type of porcelain-metal bond is characterized by the *fusion* of an oxide layer on the metal's surface and the porcelain particles?
    a. Tensile.
    b. Chemical.
    c. Mechanical.
    d. Compression.

21. (807) In terms of the design for the wax pattern for a metal-ceramic substructure, porcelain subsurface porosity *may increase* as the result of
    a. an excessive thickness of porcelain.
    b. finishing the porcelain with very coarse abrasives.
    c. improper placement of the porcelain-to-metal junction.
    d. failure to use metal and porcelain with the same coefficients of expansion.

22. (807) What is the probable cause of a craze line or visible fracture in a *metal-ceramic* restoration?
    a. Framework has sharp angles.
    b. Improperly waxed substructure.
    c. Insufficient facial veneer thickness.
    d. Porcelain-metal junction too far facially.

23. (808) When waxing the substructure of a metal-ceramic restoration, you *should* have a *minimum* wax coping thickness of
    a. 0.1 mm.
    b. 0.2 mm.
    c. 0.3 mm.
    d. 0.4 mm.

24. (808) What is used to *indicate* the amount of veneer cutback?
    a. Wax caliper.
    b. Facial index.
    c. Boley gauge.
    d. Microscope.

Please read the unit menu for unit 3 and continue ➔

Student Notes

Unit 3. Casting Fixed Prosthodontic Restorations

NOW THAT YOU HAVE learned how to make wax patterns for restorations, you will transform the pattern into metal. The final restoration must accurately fit the die. This requires great skill and attention to detail. In this unit, we will discuss the procedures for processing a wax pattern. You will learn how to sprue, invest, and cast wax patterns. In addition, we cover actions required to complete restorations. We will discuss finishing and polishing and conclude with a look at the soldering procedures used in completing a restoration.

3–1. Processing the Wax Pattern

Processing the wax pattern is the final series of tasks you will use to transform your wax pattern into a restoration. You must perform each procedure carefully and correctly or hours of work could be lost. In this section, we discuss how to sprue, invest, and cast wax patterns.

809. Spruing wax patterns

Spruing wax patterns is an important step in fabricating an accurate and complete casting. This task requires careful work. If you use improper spruing techniques, you can ruin a casting. In this lesson, we will discuss the procedures for the following:

- Determining the amount of alloy.
- Spruing single unit patterns.
- Spruing multiple unit patterns.
- Preparing the casting ring.
- Spruing metal-ceramic substructures.

Determining the amount of alloy

To determine the alloy amount, weigh the sprued pattern in grams and multiply the weight by the specific gravity of the alloy that you will cast. If you use plastic sprues, multiply the estimated alloy weight by 0.33 and add that value to the final weight. Remember to weigh the sprued pattern with the same weight system in which you measure the alloy. Using the exact amount of alloy for casting prevents the formation of a large button that could cause a miscast. A large button cools quicker than the casting and draws molten metal away from the casting.

Spruing single unit patterns

Sprues can be made of wax, plastic, or metal. The sprue forms a channel through which molten metal flows into the mold. The sprue channel accomplishes three things:

- Allows wax and gases to escape the mold during the early stages of burnout.
- Directs the molten metal from the crucible into the mold cavity.
- Provides a reservoir of molten metal of which the casting may draw upon during solidification.

The sprue diameter increases with the thickness of the pattern. As molten metal cools, it first solidifies near the walls of the mold and sprue, forming a crust around a molten center.

The metal shrinks toward this crust as the molten center cools, leaving a void in the last part of the metal to solidify. This void is called "shrink spot porosity." When you use a long, thin sprue, molten metal freezes in the sprue channel before it solidifies in the casting. As a result, the casting can't draw on the reservoir of molten metal in the channel to compensate for cooling shrinkage. If this happens, expect shrink spot porosity within the casting. If you use the right diameter, sprue molten metal continues to be drawn into the casting as cooling progresses, and shrink spot porosity forms in the sprue instead.

Sprue criteria

Sprues should meet these three criteria:

- Must be SMOOTH, to prevent turbulence during casting.
- Must be SHORT, about 6–8 mm long.
- Must be THICK, same diameter as the thickest cross section of the wax pattern.

Sprue procedures

A 10-gauge (2.5 mm diameter) sprue can be used on most patterns, while a 12-gauge (2.0 mm diameter) is used on small patterns. Large molar patterns and pontics may be double-sprued to ensure a dense porosity-free casting. To reduce the possibility of distorting the pattern, always attach the sprue while the pattern is seated on the die. Also, avoid attaching sprues to anatomical features that are critical to the occlusion you have just developed (stamp cusp tips, fossae). Before attaching plastic sprues, fill the hollow sprues with wax. This prevents the warmed pattern from flowing into the sprue and causing a void on the internal surface.

Although sprue diameter is probably the most important consideration, position is also critical. Place the sprue at the bulkiest part of the pattern, as far away as possible from the margins, and at an angle that will create the least amount of casting turbulence (approximately 45° to the axial surface of the pattern). Figure 3–1 illustrates how to position the sprue on different types of restorations.

Figure 3–1. Spruing different types of restorations.

Join the sprue to the pattern with a small bead of sticky wax. Blend the sprue into the pattern with additional inlay wax.

To attach the sprued pattern to the sprue base, first remove the sprued pattern from the die. This is when you should determine the alloy amount. Lute the sprue to the sprue base. If more than one sprue is used, be sure they meet the sprue base at a common attachment point. Adjust the sprue's length until there is a 3–6 mm space between the top of the pattern and the top of the investment ring. The 3–6 mm layer of investment is of sufficient thickness to keep metal from breaking out of the mold, yet thin enough to let trapped gases escape during burnout and before molten metal enters the mold. The chance of back-pressure porosity, resulting in an incomplete casting, increases if this gas is not fully eliminated. Back-pressure porosity is also caused by improper venting or from a sprue that is too short. The result will be concave depressions in the casting.

The sprue, from the sprue base to the pattern, in most cases, is between 6 and 8 mm in length. If the sprue is more than 8 mm long, decrease the apex of the sprue base to compensate for the extra sprue length.

Pattern placement

The wax pattern must be placed outside the thermal zone. This is illustrated on figure 3–2. After the molten metal is cast into the investment mold, heat is transferred to the investment in the center, and the center of the investment cools last. The molten metal in this area (thermal center or thermal zone) always solidifies last due to this area having the most difficulty transferring heat to the air around the investment. If the pattern is in the thermal zone, the sprue could cool before the casting, which could cause porosity or a miscast. Place the pattern above or to one side of the thermal zone (fig. 3–2) so that the casting cools first, followed by the sprue.

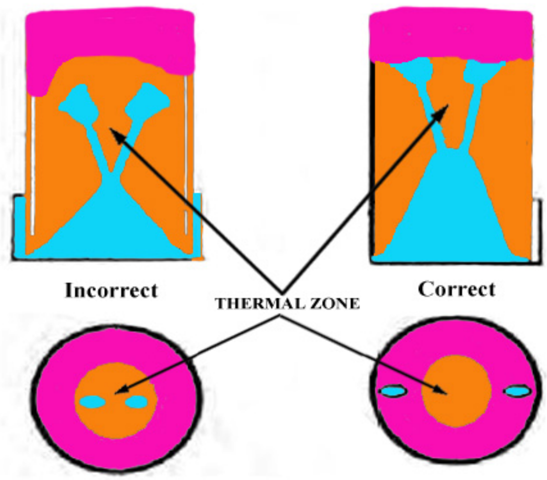


Figure 3–2. Pattern placement outside the thermal zone.

Other methods of ensuring the casting cools first are by using venting and chill sets.

Other Casting Cooling Methods	
Method	***Description***
Venting	A vent is usually an 18-gauge wax rod that extends from the pattern to the sprue base. A vent is used to remove gases from the mold (reduces backpressure) and to ensure solidification begins in critical areas first, particularly in thin areas of the wax-up.
Chill set	A chill set is similar in design and purpose but is shorter—3 to 6 mm—and is useful to help cool (chill) thicker potions of the pattern such as connectors or pontics.

Sprue types

The two sprue types that we will discuss are direct and auxiliary. They are explained below.

Sprue Types	
Type	***Description***
Direct	Most single unit castings can be made with one direct sprue. That's the only spruing option we have mentioned so far. Direct spruing is characterized by a straight, uninterrupted sprue channel between the sprue base and the mold.
Auxiliary	Auxiliary spruing a single pattern is also used to ensure a complete casting. For large patterns or those patterns with two thick areas separated by a thin area (fig. 3–3), use auxiliary sprues (18-gauge wax) to ensure a complete casting.

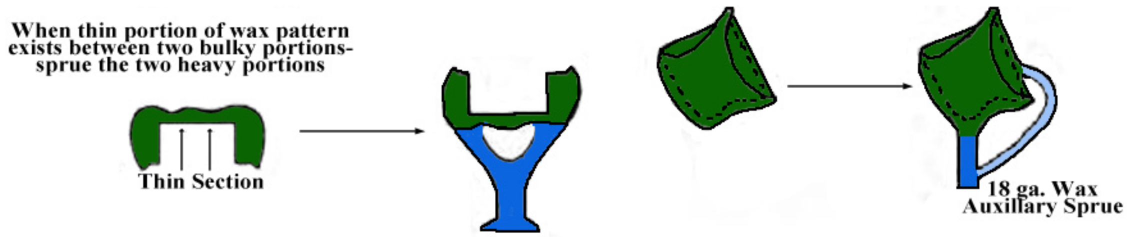


Figure 3–3. Auxiliary spruing.

Spruing multiple unit patterns

In the following paragraphs, we will discuss two methods of spruing multiple unit patterns: direct and indirect.

Direct

When two or more single patterns are sprued with the direct method, the sprues should be attached to the apex of the sprue base. The sprues should not lead off one another.

Indirect

The indirect spruing method is preferred when spruing multiple single patterns or one or more FDPs. The indirect method is the favored method for several reasons:

- There is minimum distortion of the pattern upon removal from the cast.
- Molten metal is evenly distributed to all parts of the casting.
- A reservoir of metal is close to the casting (this “runner bar” is 8-gauge round wax or as thick as the thickest part of the pattern).

Indirect spruing is commonly used for casting multiple units. In contrast to direct spruing, these sprue channels don’t lead straight from the sprue base to the mold. Figure 3–4 shows indirect spruing for a three-unit FDP substructure. Note that the 10-gauge “feed” sprues from the horizontal runner bar to the pattern are offset from the 8-gauge “lead” sprues that connect the runner bar to the sprue base. The runner bar is also made of 8-gauge round wax.

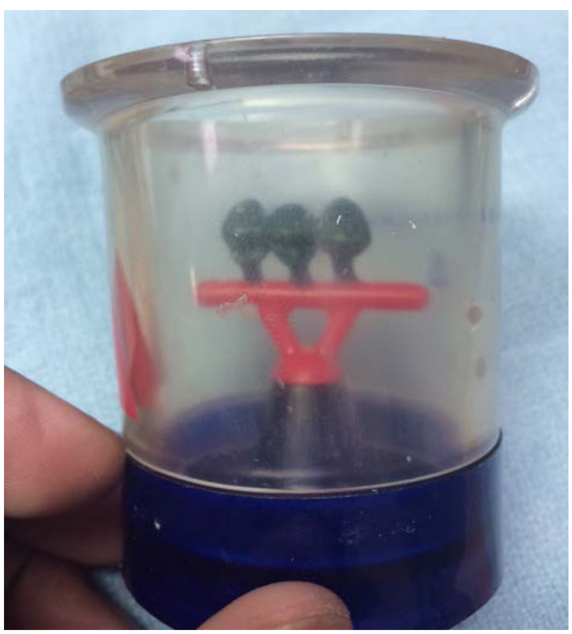


Figure 3–4. Example of indirect spruing.

The indirect spruing technique casts molten metal into the mold so that it simultaneously fills the mold uniformly and, without variations that occur when molten metal hits different areas of the mold at different times. As the molten alloy swirls through the manifold system (fig. 3–5), the temperature of the surrounding investment increases (shaded area). Figure 3–6 illustrates as an alloy begins to solidify, the heat around the runner bar (dark shading) keeps it molten state longer; thus, preventing porosity in the FDP.

Ideally, the metal should solidify in the thinnest sections of the pattern and continue through the thicker sections until, finally, the metal in the sprue freezes. This desired cooling pattern supplies molten metal to the areas that shrink as the casting solidifies. Only then can you be sure that shrink spot porosity will occur in the sprue and not in the casting.

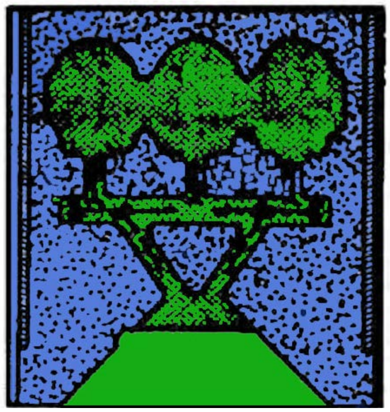


Figure 3–5. Investment temperature increases while the runner bar reduces molten alloy turbulence.

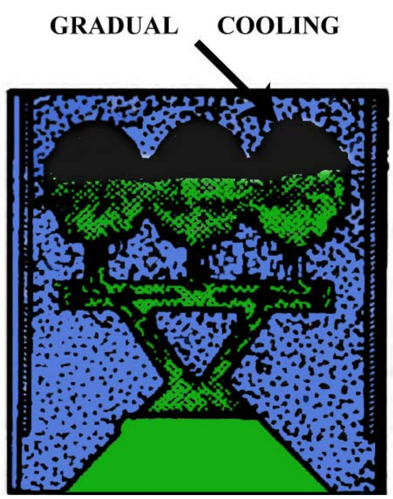


Figure 3–6. Investment heat prevents rapid cooling of the casting.

Research shows, the flow of the molten metal is toward the trailing edge of the mold as it rotates in a centrifugal casting machine. The mold should be marked so that it can be oriented to the area of the casting machine to take advantage of this flow of molten metal. Place a small round dot of wax on the sprue base in line with the runner bar. In addition, the thinnest section (usually facial) of the pattern should trail as the casting arm spins to ensure it casts. In a horizontal casting machine, position the pattern vertically.

Preparing the casting ring

To begin, ensure that the ringless casting ring and base are free of debris. Sprue the pattern(s) to the base of the casting ring. Try the silicone ring on to ensure there is 10 mm of clearance on all sides (fig. 3–7).

Figure 3–7. Prepared casting ring.

Spruing metal-ceramic substructures

All of the spruing principles we have examined also applies to metal-ceramic restorations. The goal is to produce a sound dense casting that exactly fits the abutment tooth. Your main concern in spruing is to eliminate porosity in the casting. Here we will explore two important factors in spruing metal-ceramic substructures: unusual conditions and procedures.

Unusual conditions

For the most part, metal-ceramic substructure patterns can be sprued in the same manner as conventional gold alloys; however, lower density and a higher melting range make the metal-ceramic alloys more susceptible to casting porosity. This porosity, whether it is deep inside the metal or on the surface, can create subsurface bubbles in the porcelain. This can cause the porcelain veneer to fail. Due to the sensitive nature of these alloys, it is better if you adapt the standard spruing, investing, and casting techniques to coincide with the particular metal-ceramic alloy you are using. The quality of the casting is affected more by the spruing technique than any other factor.

In general, the best possible castings are made by following these three principles:

- Sprue diameter should correspond to the volume of the pattern; larger patterns need thicker sprues. The thickest part of the pattern will equal the sprue thickness.
- When you use direct spruing, avoid constrictions in the sprue—unless the constricted sprue is recommended by the manufacturer. Some low-density alloys require a constricted sprue attachment.
- When you use a reservoir, position it within the heat zone and keep the patterns out of the thermal zone.

Do not attach the sprue to a thin area of the wax pattern; instead, sprue single anterior units on the incisal edge as shown in figure 3–8. This way, the sprue is placed at an angle that directs molten metal into the thinnest as well as the thick areas of the casting. If you think the wax is too thin in an area, you can add a small ridge of wax to act as an auxiliary sprue. Normally, the coping is thick enough (0.4 mm) to allow for a complete casting. Spruing in this way positions the sprue away from the margins and makes finishing easier. (The veneer area must be finished anyway.)

Figure 3–8. Sprue directly to the incisal edge.

Due to large bulk, posterior wax patterns should be sprued on the lingual cusp. Try not to obliterate the occlusal contacts if you are spruing the stamp cusp. Most single castings can be made from a single sprue. Rarely a wax pattern will require an auxiliary sprue or even a double sprue. Each case must be judged on its individual merits. Remember that sprue diameter and placement depend on the volume of the wax pattern. If you do need an auxiliary sprue, attach it to the posterior pattern as shown in figure 3–9.

Figure 3–9. Auxiliary spruing a metal-ceramic wax pattern.

Procedures

Choose a spruing system most advantageous to the particular alloy you are using. Make sure the wax pattern is completely seated on the die. Attach the sprue lead approximately at a 45° angle to the wax pattern. Cut all the sprues to the same length (3 mm). Next, bend a section of an 8-gauge round wax rod to conform to the curvature of the restoration. The runner bar should be completely cool before you attach it to the pattern or you can cut through the runner bar and rewax those areas, relaxing the stress. Otherwise, the “memory effect” of the wax can distort the pattern.

Attach the runner bar to the sprue leads, being careful not to distort the pattern with excess heat. Remove the wax pattern by gently grasping the retainers. Do not pull on the runner bar. The runner bar can now be attached directly to the 8-gauge round lead sprues. Place the investment ring on the sprue base and ensure that it is within 3–6 mm from the top of the ring.

810. Investing the patterns

Investing a sprued pattern creates a mold to contain molten metal. Investing can be a simple process. If done correctly, it results in a high-quality precision casting. In contrast, investing improperly can create castings that do not fit, are rough, or with large nodules. In this lesson, we will present information on these investing topics:

- General considerations.
- Expansion techniques.
- All-metal restorations.
- Metal-ceramic substructures.

General considerations

Much of the porosity in castings can be attributed to investment contamination. Therefore, all equipment and hand instruments used in the investing operation must be kept meticulously clean. There should not be any dried or caked investment. Even small particles of set investment can make fresh investment set improperly, leaving it soft and likely to crumble when hot molten metal is cast into the mold.

Porosity is also caused by investment that has absorbed moisture from the environment. For this reason, it is important that you store investment in sealed bags of individual portions of investment.

Expansion techniques

Cast gold shrinks about 1.4 percent, ± 0.2 percent, from the molten to the solid state. This means that if the pattern fit the die exactly when invested, it would be 1.4 percent too small after being cast. To prevent this problem, the investment and expansion techniques compensate for the shrinkage of the cooling metal. Investment expansion largely compensates for this shrinkage. Investments can expand in a number of ways depending on how they are handled. When the investment powder is mixed with water, the gypsum binder expands as it sets. Even more expansion (provided by the silica) takes place during the burnout procedure.

Investment expansion

Investment expansion occurs while the wax pattern is burned out in an oven. As the oven temperature rises, thermal expansion increases. This is known as thermal expansion.

Preparing the investment

To prepare the investment, follow the manufacturer’s instructions. Use the water and powder ratio recommended by the manufacturer as a guide. Keep in mind, less water in the mix provides more expansion in the mold. In contrast, more water creates less expansion. You would want a full gold crown to expand more than an inlay, because the crown fits over the preparation. Less expansion is desired in an inlay or gold post, because it fits into the preparation.

The water should be carefully measured. A significant amount of water is consumed in wetting the mixing bowl. This water does not become incorporated into the mixed mass. To prevent this from happening, dampen the bowl first. Do not leave excess water on the surface of the bowl, but be sure it is damp. The water temperature should be 70°F. Room temperature water can vary according to the area within the laboratory and the season of the year.

NOTE: Water that is too warm or too cool is one of the greatest contributing factors to pattern distortion during investing.

The water should also be distilled to prevent contaminating the investment. Finally, weigh the investment powder if not using preweighed investment.

All-metal restorations

When investing all-metal restorations, ensure that you read the manufacturer's instructions. The steps are below to properly invest the pattern:

1. Secure the ring on the top of the sprue base.
2. Follow the manufacturer's instructions for mixing investment under vacuum.
3. Vibrate the investment into the ring and on the wax patterns.
4. Allow the investment to bench set following manufacturer's instructions.

Paint-on investing

When you are using the paint-on technique, you may either mix the investment by hand or use a mechanical spatulator. The steps for investing with the paint-on technique are listed in the table below.

Steps for Investing with the Paint-On Technique

Step	***Action***
1	Mix the investment as usual, and then vibrate the mix under a vacuum to remove trapped air.
2	Do not touch the brush to the pattern; instead, vibrate a brush load of investment ahead of the bristles until the pattern is covered.
3	Work quickly to finish investing before the investment starts to set.
4	Carefully place the ring on the sprue base, and pour the investment around the pattern.
5	While the ring fills, hold it in your hand and not directly on the vibrator.
6	Allow to bench set according to manufacturer's instructions.

Setting time

Setting times differ among investment brands. Refer to the manufacturer's recommendations.

Ensure the investment is not subjected to vibration while setting. If there is enough vibration during the initial setting period, the investment mold could crack.

After the investment sets for the recommended length of time, remove the sprue base. Carefully twist off the sprue base in a single motion, freeing it from the investment and sprue pin. Remove any excess investment from the ends and side of the ring so the ring fits properly in the casting machine. Break the glaze by scraping the investment at the top of the ring so that gases generated by pattern burnout can escape. Be sure the base of the mold is clean and free of loose investment particles.

Storing invested rings

Most of the time, the rings go directly into the burnout oven after the investment sets. Occasionally, invested rings cannot be burned out immediately and must be stored overnight or longer. Do not let set investments dry out. Free water must be present in the investment to conduct heat evenly throughout a mold. When a mold is dry, the outer edges nearest the heated furnace walls can become much hotter than the mold's inner core. The investment is very likely to crack under these conditions. Store invested patterns in a humid atmosphere. Wrap them in a damp towel and keep them in a plastic bag with a few drops of water. If the ring dries out, soak it in water long enough to reintroduce a uniform amount of water throughout the mold before placing it in the burnout furnace.

Metal-ceramic substructures

Investing procedures for metal-ceramic substructures are almost identical to those used with conventional gold castings; however, phosphate-bonded investments must be used with ceramic alloys because of their high-heat capabilities. Gypsum-bonded investments tend to break down and release gases when heated to temperatures greater than 1,300°F. The strength and accuracy of the investment mold is not only reduced by this breakdown, but the gases can contaminate the alloy. Phosphate-bonded investments use a special liquid to control part of the expansion.

Expanding the mold cavity

There are several ways you can expand the mold cavity of phosphate-bonded investments. Here are three:

- Increase the ratio of special liquid to water (more special liquid, more expansion).
- Mix less fluid with the powder (less water, more expansion).
- Burn out the mold at a higher temperature.

If your castings are too large and you want to decrease the amount of expansion, try the opposite approach with any or all of these methods.

Casting ring size

Another factor that may affect the fit of a casting is casting ring size. Ring size (and not its shape) can affect seating of a fixed restoration. As technicians, we often try to cram as many patterns into a ring as possible. By doing so, we make castings that do not fit the preparations. Instead, we should use larger oval or round rings to produce FDPs. Too many units placed in one casting ring restrict the expansion of all the units—or the expansion is uneven.

Investing procedure

Carbon-free phosphate-bonded investment is recommended for porcelain-fused-to-metal crowns and full gold restorations. Use a separate mixing bowl if you use different types of investment. Particles of other investment types can spoil the mix. Wet the mixing bowl and shake out the excess water. Ensure to follow manufacturer's instructions for the ratio of special liquid to distilled water. Depending on a number of factors (e.g., temperature and humidity), the ratio of special liquid to water can change. One person might use 6 cubic centimeters (cc) of special liquid to 3.5 cc of distilled water, while another might use 7 cc of special liquid to 2.5 cc of distilled water. Experiment with your technique in the lab to find the ratio that yields the best results. You should get consistent results if you premix the liquid and water in quantity, and throw the solution away if it starts to crystallize at the bottom of the container.

Pour the liquid in the mixing bowl and add the powder. Spatulate the mix ensuring all dry investment is properly incorporated with the liquid according to manufacturer's instructions. Hold the mixing bowl on the vibrator for an extra 15 seconds under the vacuum to remove the ammonia gas that is given off as the investment mixes. Some mixing bowls generate heat and cause the investment to harden rapidly. Should this happen, spatulate the mix for a shorter period of time and hold it under the vacuum a little longer. If the pattern is not invested under vacuum, small metal nodules may appear on the underside of the casting—a direct result of ammonia gas escaping from a pattern invested too soon.

The wax pattern can be invested by the paint-on technique. After the ring has been filled, let it bench set according to manufacturer's instructions before you put it in the furnace.

811. Casting the patterns

The casting method you select depends on the type of alloy you use and how the pattern is invested. The wax pattern must be burned out prior to casting. There are several burnout methods. In this lesson, we will look at burnout and casting from these three perspectives:

- Burnout characteristics.

- Burnout and casting with all-metal restorations.
- Burnout and casting with metal-ceramic substructures.

Burnout characteristics

Practically all of the burnout furnaces in use today are electric. Some have features that others don't. Features common to most furnaces include the following:

- A 24-hour timer that turns the furnace on.
- An adjustable rate of rise for the temperature.
- Separate controls to control the burnout times and heat soak times.

In addition, almost all these furnaces operate automatically.

Typically, you set the burnout temperature and heat rate. The oven then increases at the predetermined rate. Once the oven reaches the "set" temperature, the pyrometer maintains this temperature throughout the burnout cycle. To ensure that the pyrometer holds an accurate temperature, calibrate the furnace pyrometer every 3 months. In addition, it is a good idea to check the temperature rate rise and temperature accuracy. If the casting ring is heated too quickly, steam is created that might crack the mold.

Remember, to minimize the chance of investment cracking, the investment should be damp when you place it in the furnace. This moisture ensures uniform expansion. Once you remove the sprue base, place the mold in the oven, sprue hole down. When possible, place the casting rings in the center of the furnace toward the back wall. Placing the ring under the pyrometer guarantees the ring is in the part of the oven that's accurately heated.

You could use a small piece of ceramic material to lift up one side of the ring. This permits the air to pass more freely into the mold cavity to ensure complete burnout of all residual carbon. Some authorities recommend that the casting ring be turned sprue hole up 10 minutes before casting to let air reach the mold cavity and let carbon monoxide gas escape.

Burnout should not be hurried. Follow the investment manufacturer's recommendations for time and temperature. More castings are ruined by hurried burnouts than by any other cause. If you make an error in burnout time, be sure it's on the long side rather than burning out for too short a time. The number and size of the casting rings affect the burnout time. Allow 10 minutes more for each additional ring. Calculate the burnout time from the moment the last ring enters the oven. Patterns with plastic pieces or acrylic resins (Dura-Lay) must burnout longer. These patterns (precision attachments, post and cores, resin-bonded FDPs, etc.) need an extra 30 minutes of burnout time to remove the plastic and resin residue.

All-metal restorations

There are several variations of burnout that consistently produce good results. The two techniques are: (1) high heat and (2) low heat.

NOTE: The following times and temperatures are used as examples and do not apply to every high-heat investment situation.

High heat

The high-heat technique is used with gypsum centric investments (not phosphate-bonded investments), which bench set in air and expand semi-hygroscopically. Starting with a cool oven, increase the furnace temperature to 1,250 °F in 1 hour. After reaching burnout temperature, "heat soak" the mold for another hour. Total time in the oven is 2 hours. After the burned-out mold is cast, let the oven cool to below 900 °F before starting another burnout cycle. Otherwise, the mold can crack. Do not use temperatures above 1,300 °F, because the gypsum-bonded investment material starts to break down, causing rough castings. Excessive burnout temperatures (above 1,300 °F) produce sulfur gases that mix with alloys and make brittle castings.

Casting equipment

Casting equipment is used to melt the alloy and transfer the molten alloy to the burned out mold. There are many different types of casting machines that do an acceptable job, but we limit our examination to the two most common: the induction casting machine and the centrifugal casting machine.

Induction casting machine

The induction casting machine method eliminates the need for a torch and it avoids alloy heating problems. This method is well controlled, accurate, and precise. Some induction casting machines have a straight arm, so they cannot produce as much initial casting force as the broken arm variety.

Centrifugal casting machine

Centrifugal casting uses the broken arm design. This method is less expensive than induction casting and produces reliable results. Using the centrifugal method requires you to use a casting torch to melt the alloy. If you are inexperienced with torch casting, ask your trainer to show you the proper method of casting using the gas-air torch.

Normally, the two gases used to melt type 3 alloys are compressed air and natural gas. These gases are available at most laboratories, and the flame they produce is easily controlled. An alternative to natural gas and air is either natural gas or propane and oxygen. The flame produced with oxygen is much hotter, so you must exercise extreme caution to prevent "burning out" the properties of the alloy. Should you decide to use this method, adjust the oxygen pressure to 6 psi while the pressure of the propane gas is regulated between 6 and 8 psi. Do not hold the flame on the molten alloy too long as you risk overheating the alloy. Overheating can alter the alloy's characteristics because some of the alloy's properties are burned out.

Now let's see how you would cast conventional alloys using a centrifugal casting machine and a gas-air torch. Always keep a "test" casting ring that is of similar diameter and weight to your actual investment ring so that you can balance the casting machine. Use a glazed crucible to aid gold flow. Prepare to cast by issuing the amount of alloy you need. Either new or a combination of old and new alloy can be used for a casting.

NOTE: Do not mix brands or types of alloy, because the physical properties of such blends are unpredictable.

When you are estimating the amount of alloy required for a casting and old alloy is recycled, use at least 50 percent new alloy to replace the metals that are "burned out." Trace elements are "burned out" of the alloy each time it is heated during casting procedures. The 50 percent new alloy will restore the physical properties of the used alloy. Old alloy must be cleaned before use. Air-abrade the old alloy to remove residual investment and surface oxides.

Wind the casting machine for three turns to generate enough casting force. Use an extra turn for small masses of metal or metal with a low specific gravity. Raise the stop rod from the base of the machine and rest the main arm against it. The pressure of the arm holds the rod in an elevated position. The arm won't rotate as long as the stop rod is up.

Casting torches usually have two control valves, one for air and the other for natural gas. Be sure the supply hoses are connected to the right gas sources. Turn on the natural gas flow and light the torch. Then add air into the gaseous mix until you have a pointed flame with two "cones." The outer cone or reducing part of the flame consists of burning gas. The inner cone is unburned gas at a low temperature. Melting must be done in the reducing part of the flame lying between the tips of the inner and outer cones. This is the hottest part of the flame and should be large enough to cover the button of alloy used. The flame, taken as a whole, should always have a reducing nature. This means it has a supply of gas somewhat larger than the available air can completely burn. If the flame doesn't have this reducing character, excess oxygen oxidizes base metals in the alloy and raises the alloy's melting temperature to a point where it's impossible to melt.

Preheat the crucible with a torch or in a burnout oven. Place the alloy in the preheated crucible, and melt it with the reducing part of the flame. If a significant oxide film forms, sprinkle a small amount of casting flux onto the surface of the alloy, as shown in figure 3–10. This should be the only time flux is used.

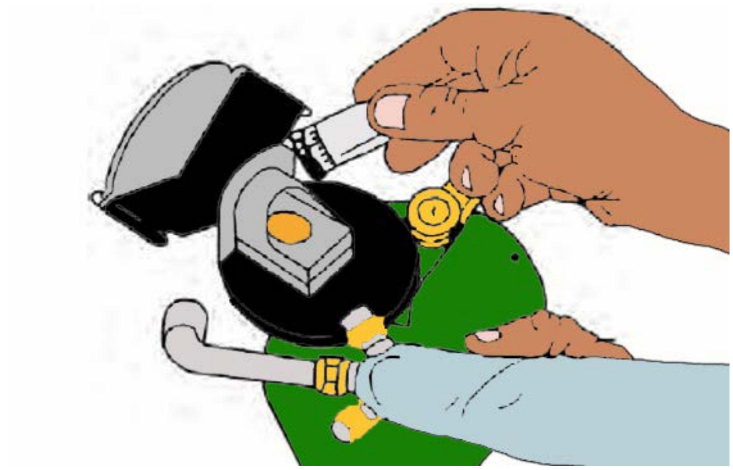


Figure 3–10. The torch casting technique.

NOTE: Never add flux once the ring has been positioned in the casting machine. The rush of gas out of the torch could blow the material into the mold and cause it to contaminate the casting, leading to porosity or a brittle casting.

Keep the alloy as molten as possible while you remove the burned out mold from the oven and insert the ring with the sprue hole toward the crucible. Move the crucible into contact with the ring. The exact time to cast the metal into the mold cavity is determined by its appearance. The alloy is ready to cast when it exhibits a mobile, bright, mirror-like surface.

Grasp the arm of the machine firmly, move it away from the stop rod, and let the rod drop back into the base. Release the arm and hold the flame on the alloy until the crucible starts to rotate. Release the casting arm smoothly; do not let it jerk, or the molten metal will spill.

Remove the casting ring when the machine stops spinning. Place the ring in a safe place on the bench to cool. You can quench most type 3 alloys within 5 minutes after casting to achieve a midpoint between the casting's ductility and strength. (The sooner you quench, the more ductile the alloy.) However, you should follow the manufacturer's directions for heat-treating the alloy. You can find these directions on the alloy package. Quenching also breaks down the investment, making it easier to remove from the casting.

Another viable and more common alternative is to use an air abrasive unit containing aluminum oxide particles. Scrub the casting with a stiff brush to remove particles of investment. Place the casting in a plastic container filled with deoxidizing liquid to remove any investment still clinging to it. To deoxidize is to remove oxide from a casting either by chemical or mechanical means. A 50 percent solution of hydrochloric acid is an excellent solution for deoxidizing; however, its caustic characteristics may preclude its use. Safer deoxidizing solutions are available and are recommended.

Most deoxidizing solutions work best when heated. Using plastic-coated tongs, submerge the casting in the solution. Heat the solution, but do not let it boil. After the casting brightens, take it out of the deoxidizing solution with the plastic-coated tong. Wash the casting with sodium bicarbonate solution, liberally rinse it in clear water, and dry it. Dirty solution leaves undesirable deposits, so be sure to change it often.

Okay, you know how to sprue, invest, burnout, and cast successfully with conventional alloys. Now comes the moment of truth. Is the crown a dense, precise casting, or is it porous and ill fitting? The only way to ensure success is to follow recommended procedures and learn from your mistakes.

The exact cause for a casting failure may not be clear or distinct. One casting failure may be caused by a variety of operator or equipment errors. Your task is to isolate the cause and correct the error. Review the following table for the probable causes of several casting failures.

Casting Failures		
Problem	**Probable Cause**	**Solution**
Porosity	Improper sprue size.	Use proper spruing methods, 10 gauge, no longer than 8 mm, and reservoir placed no further than 3 mm from pattern
	Overheating of metal.	Use reducing zone of flame on torch to heat metal
	Flux blown into ring.	Do not add flux once the ring is positioned in the casting machine.
Rough Surface	Excess wetting agent on pattern,	Remove all moisture from pattern.
	Prolonged overheating of investment.	Use correct heating cycle for burnout; not above 1,300 °F.
Pits	Debris in mold from investment flaking off in front of incoming molten alloy.	Ensure sprue base, sprue lead, and attachment site are smooth.
	Mold temperature too hot; invest binder breaks down producing a weak and easily abraded surface.	Use lower burnout temperature; routinely confirm accuracy of oven temperature through calibration.
Nodules	Inadequate vacuum during investing.	Verify vacuum on mixing equipment; maintain seal throughout entire mixing period.
Fins	Over-vibration during investing.	Reduce vibration intensity.
	Investment heated too rapidly—produces steam cracks in mold.	Slowly heat mold.
	Too many casting arm rotations.	Ensure correct amount of casting arm rotations.

Metal-ceramic substructures

Burnout and casting are fairly standardized tasks. Depending on the type of investment and number of wax patterns, the burnout times and temperature can be adjusted; although, casting metal-ceramic alloys can be a little more difficult than conventional alloy. You must be more aware of the molten metal's temperature before releasing the casting arm. You cannot rely on sight alone; instead, you must sense the "right time" to cast. The only way to get this knowledge is through practice. Do not expect to do it right the first time.

Burnout temperatures

For the most part, the burnout procedure is a simple, routine matter. We have already covered casting ring preparation and placement in the oven. The recommended burnout temperature for most ceramic alloys is 1,300 °F. Follow the investment manufacturer's instructions for all burnout times and temperatures for the particular alloy being used.

The investment must be left at 1,300 °F until the color of investment has completely whitened. A dark shadow in the center of the investment indicates that the ring isn't ready for casting due to residue left in the investment mold. Usually the surface of the investment appears snow white in color.

Nonprecious alloys should burn out at 1,600 °F to completely eliminate all traces of carbon residue. Chromium alloys are easily affected by carbon contamination.

Ceramic alloy casting requires a gas-oxygen torch. While natural gas and oxygen can be used as fuels to melt the alloy, bottled propane and bottled oxygen are better. Bottled propane produces a cleaner, hotter flame under more constant pressure. Problems associated with natural gas, such as the flame flickering, are caused by changes in line pressure.

Physical properties of metal-ceramic alloy

We will now review the physical properties of the metal-ceramic alloy. You may recall metal-ceramic alloys melt at high temperatures (2,300 and 2,480 °F), so casting timing is critical. Due to low density and a sluggish nature, metal-ceramic alloys need a large casting force. To increase the casting force, you can replace it with a stronger one, or you can wind the casting arm an extra turn. Melt a high-heat alloy in a quartz refractory high-heat crucible.

NOTE: Do *not* use flux in this procedure. Casting flux can remove some of the trace elements in the alloy.

Casting procedure

Use a gas-oxygen torch with a multiorifice tip. Regulate the oxygen pressure to 8–10 psi, with the propane gas between 6 and 8 psi. Use caution when you are lighting the torch. Always add oxygen to the gas flame. To do this properly, turn on the gas, light the torch, and slowly add oxygen to the flame. The flame should look like a fairly soft shower flame with multiple small blue cones about 5 mm long.

NOTE: When shutting off the torch, always shut off the oxygen first.

Preheat the crucible to a dull red to drive off moisture and prevent a cold spot at the base of the crucible. Melting ceramic alloys is quite different from type 3 alloys. Ensure you have a separate crucible for each alloy. Ceramic alloys are usually superheated (white hot—about 100 °F above their upper limit) before they are cast.

CAUTION: To prevent injury to your eyes, you must wear dark goggles (NOT SUNGLASSES).

Place the alloy in the crucible's center, and start the melt with the tip about 3–4 centimeters (cm) from the alloy, using the reducing zone of the flame. Continue heating the alloy, watching the alloy change color from red, to orange, to dull white, to a mirror-like white. When the alloy is orange, transfer the ring from the furnace to the cradle. When you are casting an FDP, make sure the pattern is in a vertical position, as indicated in figure 3–11, with the *thinnest* parts of the pattern *towards* the "trailing edge." Keep in mind that the trailing edge is the trailing side of the mold when the casting arm is spinning. When the alloy gets white hot and mirror-like, release the casting arm and let it spin for a couple of minutes; then remove the casting ring.

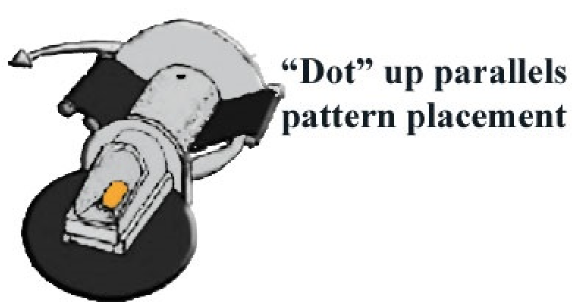


Figure 3–11. Place the pattern in a vertical position.

Bench-cool the ring to room temperature. Do not quench the ring. Quenching interferes with the grain boundaries, cracking and weakening the casting. When the ring is cooled, remove the casting and pick off most of the investment. Carefully sandblast the casting with aluminum oxide to remove the remaining investment.

The following table shows some common problems you may encounter when you are casting metal-ceramic alloys. The table also shows the effect casting can have on the substructure and subsequent porcelain applications. In addition, the table shows probable causes and solutions to various problems:

Metal-Ceramic Castings		
Problem	***Probable Cause***	***Solution***
Rough or cracked casting.	Improper use of wetting agent.	Remove excess wetting agent.
	Overheating alloy.	Avoid prolonged or excessive heat.
	Mold contaminated with debris.	Use clean alloy and ensure sprue leads and attachments are smooth and clean.
	Excessive casting pressure.	Reduce casting force.
Porosity in interproximal areas of casting and/or sprue attachments.	Improper spruing methods.	Use chill sets at interproximal area of FDP and/or use 10-gauge sprue leads and 8-gauge runner bar.
Porosity throughout casting.	Overheated alloy.	Don’t use a hot flame (oxyacetylene) or heat for prolong period.
	Gases trapped in alloy.	Use reducing zone of flame.
	Investment above casting too thick to allow gasses to escape.	Place top of pattern 3-6 mm from top of investment.
	Alloy contaminated.	Clean reused alloys and crucibles.
Distorted castings.	Patterns waxed too thin.	Wax must be at least 0.4 mm thick at thinnest part.
	Removed carelessly.	Remove carefully and invest immediately; long span FDP may need sectioned and cast in two parts.
	Thermal expansion distorted mold.	Don’t exceed recommended burnout temperature.
Casting warped during oxidizing.	Incorrect substructure design.	Follow basic design principles and don’t thin metal below 0.3 mm thickness.
	Weak solder joint.	Use minimum width and depth solder joint dimensions.
Incomplete castings.	Patterns waxed too thin.	Patterns must be 0.4 mm thick.
	Not enough casting pressure.	Ensure casting pressure can compensate for alloys weight.
	Incomplete burnout.	Verify burnout ovens temperature and/or heat mold longer.
	Cold alloy during casting.	Ensure molten alloy is at proper temperature when cast.
Surface nodules on casting.	Residual gases produced by phosphate-bonded investments.	Vacuum mix investment under vacuum.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

809. Spruing wax patterns

1. When spruing, why should you use the conversion formula to determine the exact alloy amount?

2. When spruing, what three things must be accomplished?

3. At what angle should you place the sprue to the axial surface of the pattern?

4. When you wax the pattern to the sprue base, why do you place it outside the thermal zone?

5. When is an auxiliary sprue needed?

6. Why is the indirect sprue technique preferred for multiple unit and FDP patterns?

7. When you prepare the casting ring, what is the *first* step in the process?

8. When you sprue, where should metal-ceramic posterior wax patterns be sprued? Why?

9. When you sprue an FDP, why should you allow the pattern to completely cool?

810. Investing the patterns

1. When you invest, what causes most of the porosity in castings?

2. When you account for cast gold shrinkage, what factors counteract the shrinkage?

3. When you invest, what is one of the greatest contributing factors to pattern distortion?

4. When you allow the invested pattern to set, what causes the mold to crack?

5. When you store investment molds, how must they be stored?

6. What three methods can be used to expand a phosphate-bonded mold cavity?

7. What undesirable outcome may occur if the pattern isn't invested under a vacuum?

811. Casting the patterns

1. How often should you calibrate the pyrometer?

2. During burn out, how much time is added for additional rings?

3. When you use the high-heat burnout technique, what could happen if you heat the gypsum-bonded investment higher than 1,300 °F?

4. When you melt the alloy, what could happen if it is overheated?

5. Prior to casting, why is new metal added to previously cast metal?

6. When heating an alloy, why do you want to melt the alloy with the reducing part of the flame?

7. When is a ceramic alloy ready for casting?

8. Why is quenching a metal-ceramic casting *not* advisable?

3–2. Completing the Restorations

The process of finishing castings has been defined as "a systematic reduction of the large, deep scratches produced with the first coarse abrasive to smaller scratches of such a fineness that they are not perceptible to the human eye."

You must strive to produce high-quality work when you are completing the restoration. A restoration that is poorly finished—full of scratches and defects—can collect debris and eventually become stained and discolored. On the other hand, a smooth, highly polished surface lets saliva wash debris away, keeping the restoration clean and bright.

The lessons in this section present information on how to finish, polish, and solder restorations.

812. Finishing and polishing

Finishing and polishing are the final steps to producing a restoration that meets the patient's biological and functional requirements. Extreme care must be taken to avoid distorting or damaging the contacts or contours of the restoration. In this lesson, we present information about six procedures you will use when working with all-metal and metal-ceramic substructures:

- Casting inspection.
- Fitting the casting.
- Preliminary finishing.
- Occlusal adjustment.
- All-metal restoration polishing.
- Substructure finishing.

Casting inspection

Before finishing the casting, look for any major defects that require the casting to be remade. In deciding whether to repair or remake the casting, consider these questions:

- Will the fit of the casting be altered?
- Will the patient be able to keep the casting clean?

If either answer is no, the casting should be remade. Small defects, such as small holes, nodules, and spot porosity may be repairable. Before test-fitting the casting on its die, examine the internal surface under magnification. Identify and remove all positive defects such as nodules or fins (fig. 3–12). Remove nodules with burs of a similar size as the nodule. Fins may be removed with discs or rubber wheels. Also, trace all the negative angles on the inside of the occlusal surface with the tip of a ½ round bur.

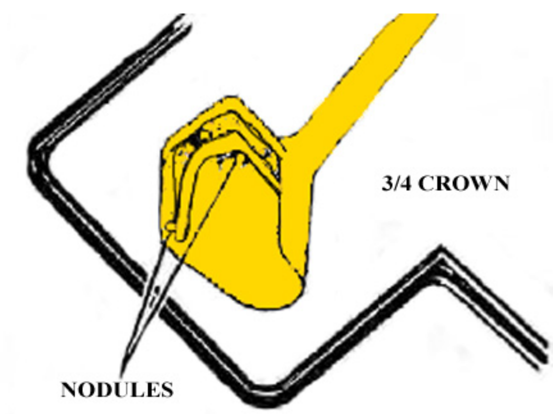


Figure 3–12. Inspect the casting under magnification.

Fitting the casting

After you have removed all the internal surface defects, carefully place the casting on the die (fig. 3–13). The casting should seat completely without using force. It should also be stable on the die with close fitting margins. Be careful not to damage the die during this step. Otherwise, it will be impossible to rewax the pattern.

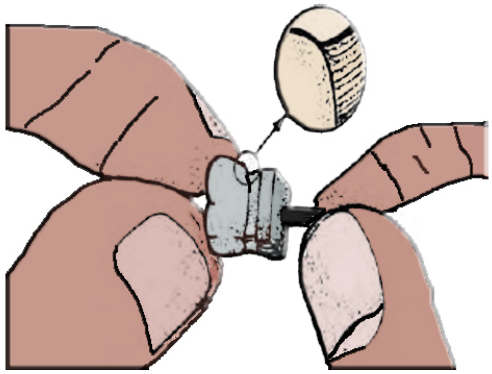


Figure 3–13. Test fit the casting.

If the casting does not seat, try to find the cause. Some type of disclosing medium (occlude spray, liquid die marker, etc.) is useful to indicate high spots. Apply the indicator according to the directions, and inspect the casting's internal surface for interferences. If the casting is warped or otherwise distorted, reject it and start over.

Preliminary finishing

Desprue the casting by making two opposite cuts with a separating disc. Be careful to avoid cutting into the body of the casting or damaging the fine margins. Leave a little of the sprue on the casting to permit proper contouring of that area. Start finishing by reshaping the sprue stump into the general contour of the casting, using a heatless stone followed by a 203 stone. This is a good time to smooth any other areas of the casting that need rough finishing. Next, adjust mesial and distal proximal contacts one at a time. An illustration of this process is shown in figure 3–14.

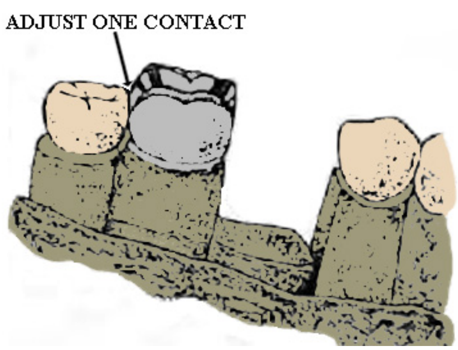


Figure 3–14. Adjusting one proximal contact at a time.

At the time that the working casts were made, the natural teeth adjacent to the preparation site also received dowel pins. Place the die on the working cast, remove one of the teeth next to the die, and try to gently seat the casting on the die.

Mark the adjacent teeth with a color pencil, or use articulating paper between the restoration and the stone tooth to mark the contact. Carefully remove any excess contact with a rubber wheel. After the casting seats, remove the other abutment die and follow the same procedure with the other contact.

Another (and usually more accurate) method of adjusting the proximal contacts uses a solid working cast. In a solid working cast, you do not have the problem of dies or adjacent teeth being forced out of position; however, you do need more time and practice to adjust the contacts. Both contacts have to be adjusted at the same time and it is very easy to "lose" a contact completely.

When adjusting the proximal contacts, do not seat the casting on the die and then seat the die on the cast. The path of insertion for the casting may not be the same as the path for the dowel pin. Also, do not try to force the casting into place. If you do, you will probably force the die or the adjacent tooth out of position.

Occlusal adjustment

Your next step is to make the necessary occlusal adjustments. To do this, place the working cast in position in the articulator. Seat the casting on the die. Restore the vertical dimension of occlusion (centric occlusion) first. Use the thinnest articulating paper available to disclose high spots on the casting. Figure 3–15 illustrates some examples of premature occlusion on the buccal incline, lingual incline, and lingual axial contour. Preserve the occlusal anatomy as much as possible when grinding these premature contacts.

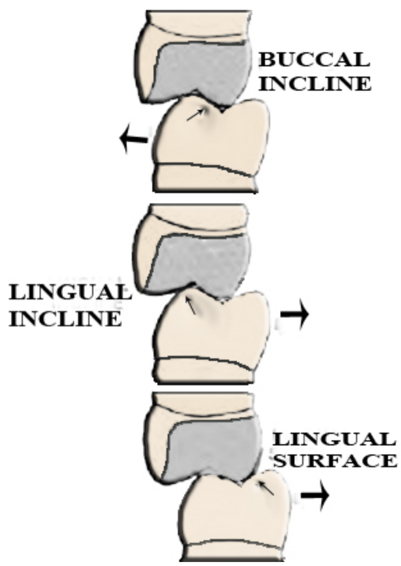


Figure 3–15. Adjusting centric occlusion.

Ideally, an anterior casting should not touch in the centric position. The maxillary and mandibular anterior teeth should just miss by the thickness of the shim stock. Once the adjustment is complete, check the restoration's occlusion using 0.0005-inch plastic shim stock (fig. 3–16). Also, test and compare the occlusion of the adjacent teeth to ensure that centric occlusion has been restored. If the shim stock indicates similar drag with the casting and its opposing occlusion as it does with the adjacent teeth's opposing occlusion, then the occlusion of the casting has been properly adjusted.

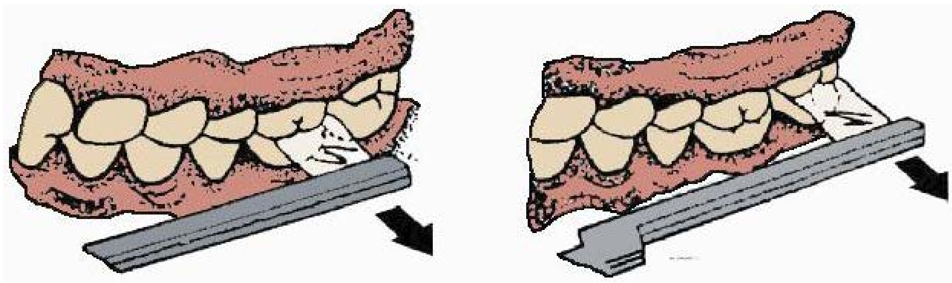


Figure 3–16. Compare the occlusion.

The next step is to check the casting in excursive movements. The casting should conform to the occlusion scheme chosen for the wax pattern (e.g., anterior guidance, group function). As you can see in figure 3–17, maxillary stamp cusps should not contact mandibular shearing cusps on the working side. In addition, there must not be any contact between the upper and lower teeth on the nonworking side (fig. 3–18).

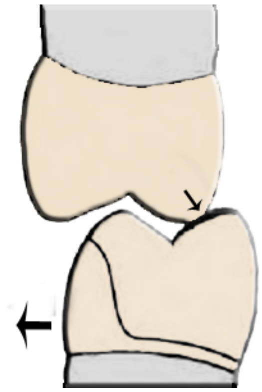


Figure 3–17. Working side interference.

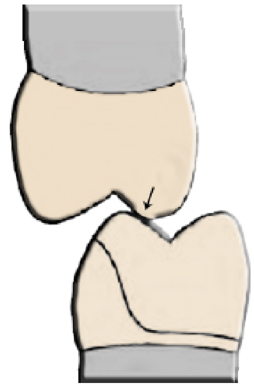


Figure 3–18. Nonworking side interference.

Sharpen the occlusal anatomy by using a small, dull, round bur or a flame-shaped finishing bur. Perform a final smoothing of the casting with fine sandpaper discs, rubber wheels, points, and 203 stone. Avoid rubbering the terminal edge of the margin. If you do, you can cause a void in the marginal seal. If the margin were properly waxed, you only need a minimum of finishing and polishing—preferably with a fine-grade polishing material or paste.

All-metal restoration polishing

There are a wide variety of polishing materials and methods used for final polishing. Some of these materials are listed below:

- Silicon abrasive.
- Tripoli.
- Red and white rouge.
- Polishing paste.
- Bristle brushes.
- Mandrel mounted felt wheels.
- Chamois wheels.
- Buff wheels.

Every dental laboratory technician has his or her own personal polishing technique. The following sequence is just one method you can use. Your trainer may use a different method.

Polishing starts with tripoli on a bristle brush or felt wheel, and continues with rouge on a bristle brush or felt wheel. Tripoli is the coarser of the two abrasives. Remove the tripoli from the restoration with an ammoniated cleanser and continue with the rouge.

When the restoration is tried in the mouth, it is very likely that the dentist will modify the proximal contacts and adjust the occlusion. In effect, you finish and polish the casting twice—before and after the try-in. The occlusal surface is the part most likely to be modified. Some dentists anticipate this and do not require a polished occlusal surface before try-in. In this case, polish and high-shine all axial surfaces and leave a satin finish on the occlusal. The occlusal contacts are easier to see and, therefore, easier to adjust on occlusal surfaces with satin finishes.

Some dentists prefer a matte-finished occlusal surface. The matte finish is produced with aluminum oxide grit (fig. 3–19). Again, their reasoning is that it is easier to see interferences on a casting in the patient's mouth against a dull background than a shiny one. Other dentists prefer a completely high-shined occlusal surface to reduce insertion time.

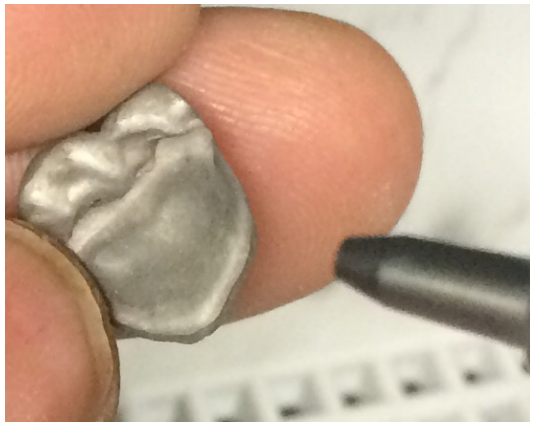


Figure 3–19. Producing a matte finish.

To final-polish after the try-in, remove any gross scratches the dentist produced. The axial surfaces must be highly polished in order to provide a smooth surface that resists plaque retention. Because they are fragile and may be bent or polished away, stay 1 mm away from the margins the dentist established in the mouth.

Polish all the axial surfaces with tripoli or silicon abrasive on a small felt wheel or soft-bristle brush. Be careful not to over polish a proximal contact. Whether or not the dentist decides to leave the occlusal surface with a matte finish or highly polished, it must not be irregular or have any deep scratches. Use caution when you are polishing the occlusal surface. Take care that you do not destroy the occlusal contacts so carefully developed earlier.

NOTE: An alternate technique of polishing gold occlusals uses a mini sandblaster filled with glass beads.

Final-polish the casting with rouge on a soft bristle brush or felt wheel. Finally, apply rouge to the restoration with a chamois wheel to achieve an extremely high luster. Clean off all polishing compounds with a solution of soap, ammonia, and water in an ultrasonic cleaner. The completed restoration should be void of all scratches, properly contoured, and have a mirror-like reflective surface.

Substructure finishing

No matter how careful you are in waxing and investing the pattern, some finishing of the casting is still required. If only light finishing is required, you are in luck. Usually, large areas need to be contoured and the metal thickness reduced to the minimum 0.3 mm. Overall, your objectives in finishing castings for metal-ceramic restorations are as follows:

- To provide clean surfaces for chemical bonding of porcelain to metal.
- To provide an ideal surface texture that increases the mechanical retention between the porcelain and metal.
- To make corrections in the design of the metal substructure and take full advantage of porcelain's physical characteristics (porcelain-to-metal junction preparation, junction placement, and overall framework design).

Use only new finishing stones and burs (or those used exclusively on ceramic metals) to prepare porcelain-bearing surfaces. If the surface is contaminated by using "dirty" stones, the result may be blistered opaque. Since the opaque layer is the first layer of porcelain, it is essential that every procedure is done correctly (to provide a superior bond between the porcelain and the metal).

Use the right abrasive material. Only abrasives that are fused together with a ceramic binder can be used to finish porcelain-bearing surfaces. Do not use rubber wheels or abrasives that are held together with epoxy resins or silica binders. Finishing with such an abrasive can cause metal surface contamination, which can lead to severe opaque porcelain bubbling. If you are unsure about using an abrasive stone or point, place a sample of the abrasive stone in a porcelain furnace and fire it to 1,000 degrees Celsius (°C). If the abrasive does not turn to powder, it has a ceramic binder and, therefore, may be used.

Finishing can be done in almost any order, using a variety of techniques. The methods we mention are only suggested ways to finish. Below is the process of metal finishing.

Inspect the inside of the casting for nodules or fins, and remove them with a half-round bur. You can use the tip of a bur to lightly trace all the negative angles inside the casting. Be careful not to drill a hole through the casting. If you do end up with a hole, repair it or remake the casting. Check the margins under magnification for overextensions and cracks. Carefully seat the casting on the die. Do not force it, but try to find the cause of the resistance. A disclosing medium is helpful in locating the "tight spots" inside the casting. An overextended margin can be removed by careful rubbering.

If you are satisfied that the casting fits the die, desprue the casting with a separating disc. Then use a sandpaper disc to contour the sprue attachment and remove gross amounts of metal from the proximal contacts. Rubber the proximal contacts smooth with light contact against the adjacent teeth.

If the occlusion is high, reduce it to bring the restoration back into centric occlusion. Check the amount of clearance available for porcelain coverage in centric occlusion, as well as working, nonworking, and protrusive excursions. If there isn't enough space, reduce the metal substructure.

Next, you want to prepare the porcelain-bearing surface. Areas that normally require attention are adjacent to the porcelain and metal junction and connector areas. Use a new number 8 carbide bur to prepare the junction. Retrace the finish line, making a 90° angle butt joint. The finish line should be sharp and continuous. Wherever porcelain is applied, it should end abruptly without feathering onto the metal. In addition, this shallow concavity must encircle the metal substructure evenly and smoothly, reducing all traces of sharp angles or points.

Often, a dentist is very conservative in the amount of tooth structure he or she reduces for a metal-ceramic restoration. They retain or maximize tooth structure availability for future preparations. In addition, the risk of exposing the pulp chamber may keep the dentist from reducing the tooth by the required 1.5 mm. If this is the case, then the metal substructure must be reduced to the minimum of 0.3 mm of metal thickness. If you reduce the thickness to less than 0.3 mm, the risk of the substructure flexing and porcelain fracturing is much greater.

Use a metal gauge and measure the thickness of the metal at different spots. Areas of importance are towards the facial-incisal, as excess metal thickness may cause the opaque porcelain and entire lingual surface to be visible, due to limited reduction. Avoid thin areas of metal, as you might accidentally make a hole in the casting. If a casting has a large thin area, it must definitely be remade. The metal substructure will not be able to support the porcelain.

Another area to inspect is under an FDP's pontic. Remember to allow for at least 0.5 mm of porcelain on the tissue-side of the pontic. Grind away large areas of metal by using a double separating disc or Busch Silent wheel. Sandpaper discs are also effective in smoothing large areas and gently rounding the metal's surface such as in gingival embrasures.

Under-contoured metal can create problems with porcelain support and shade control. Porcelain that isn't properly supported is more prone to fracture. If the porcelain is too thick in an area, it can affect the shade—largely because the shade is controlled by the thickness of opaque, body, and incisal porcelains. Too much of one and not enough of the other alter the shade. Figure 3–20 illustrates how an under-contoured pontic can affect the shade. In this instance, the pontic appears lighter than the retainers due to an increase in the amount of body porcelain. If there isn't enough metal support, either incisally or gingivally (on a pontic), light simply passes directly through and the porcelain appears grayer. This happens because there's no opaque porcelain to help control the shade (fig. 3–21).

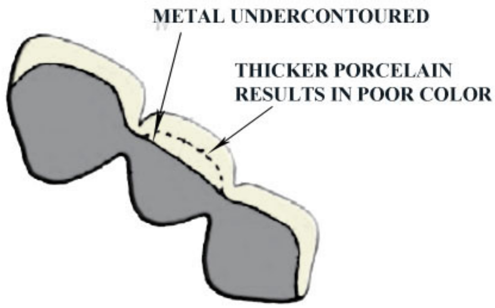


Figure 3–20. Under-contoured substructure affects the shade.

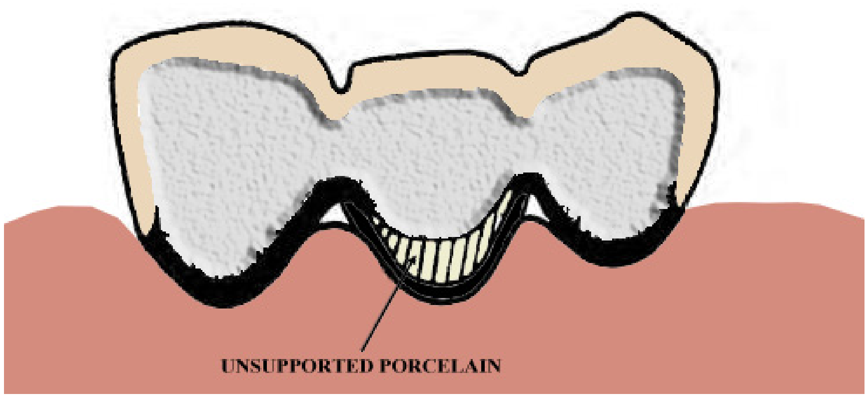


Figure 3–21. Without metal support, porcelain is more translucent.

After reducing the porcelain-bearing area to the correct thickness, you must prepare a satin finish. A satin finish is a description of the surface texture of the metal. The surface texture should allow the porcelain to wet the metal and provide an almost molecular attraction between the mechanical retention. If the surface texture is rough, it can create stresses within the porcelain.

The nonporcelain-bearing areas may need to be finished as well. Confine your finishing of these areas to light finishing only; not polishing. Just rubbering an area adjacent to the porcelain-bearing areas could contaminate the porcelain. Do not finish the margins or adjust the proximal contacts at this time—unless you doubt their completeness. All of the other nonporcelain-bearing areas can be lightly finished with a fine sandpaper disc. Complete contouring of the casting to remove wrinkles and pits at this time.

The last step in the finishing process involves the porcelain-bearing areas. Use a 203 stone to create the satin finish. Start at one point, finishing in one direction, to lightly smooth the surface. Be sure to round over sharp points and line angles. Sandblast the entire framework with aluminum oxide. Once completed, do not touch it with your fingers. If you do, the oil and dirt from your fingers can contaminate the porcelain. Place the casting in distilled water and then in the ultrasonic cleaner for 10 minutes.

813. Soldering

Soldering is often required to produce a proper fitting FDP and is essential to repair single unit crowns and FDPs. In this lesson, we present how-to information on soldering procedures:

- Soldering all-metal FDPs.
- Soldering single units.
- Soldering metal-ceramic substructures.

Soldering all-metal FDPs

First, the solder connector must unite the units of an FDP into a one-piece construction that accurately fits the abutment teeth. If the FDP "rocks," then the soldering procedure must be redone. Second, the solder joint must be strong (i.e., a sound, gas- and oxide-free joint) to resist chewing forces. From an esthetic viewpoint, the solder joint should resemble the proximal contact area of the natural teeth (interproximal properly contoured). The solder joint must be properly located, centered on the contact areas, triangular in outline (with rounded corners), with concave peripheral attachments. An example is shown in figure 3–22. The location of the solder joint is important to the health of the oral tissues. If the connector impinges on the tissue or the patient cannot keep the restoration clean, then serious tissue damage can result. Correct and incorrect views are shown in figure 3–23.

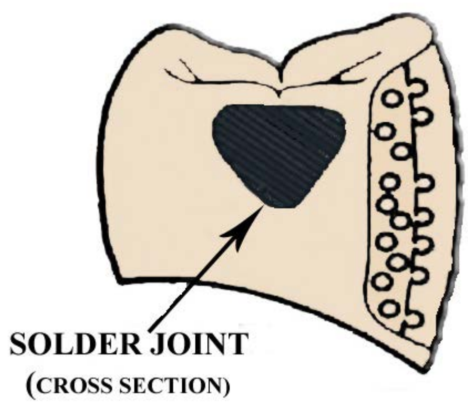


Figure 3–22. Solder joint location and design.

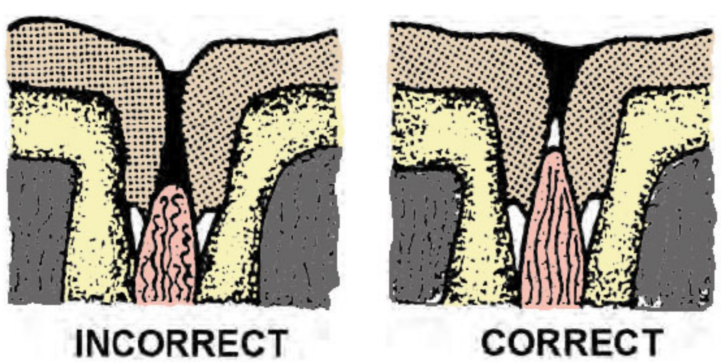


Figure 3–23. Solder joint must not interfere with the tissue.

To prepare the castings, rubber the solder connector areas in an occlusal-gingival direction to produce a smooth satin finish. Use a clean rubber wheel or rubber point free of oxides. The tiny vertical scratches produced by rubbering increase the wetting action (flow) of the solder with the parent metal. Rubber only the areas to be soldered since you will have to blast and rubber the entire casting after soldering. Remember not to go beyond the rubber stage, as any amount of tripoli or rouge acts as antiflux and keeps the solder from flowing.

After you have prepared the retainer and pontic, you are ready to position them on the working cast. A solid cast may also be used at this time. The advantage of using a solid cast is in having dies that won't move. Take special care to make sure that both retainers are fully seated. This requires you to remove all soft tissue near the margin area and to verify closed margins.

Next, examine the space between the units to be soldered. How much space should there be? It depends on the setting expansion of the solder investment, the thermal expansion of the investment, and the thermal expansion of the metal units. When the investment and metal units are heated, the overall effect is a narrowing of the solder gap.

The recommended width for the solder gap at its closest point is about 0.125−0.250 mm. You can check this distance (0.250 mm) by slipping a card of appropriate thickness through the gap while the units are being assembled (fig. 3–24). If the castings touch while heat is applied to the assembly, distortion could occur. Widening the gap (0.30 mm) strengthens the joint, but it also produces more distortion. A narrower gap width (0.15 mm) is better for accuracy, so we compromise and use 0.250 mm as the recommended gap width.

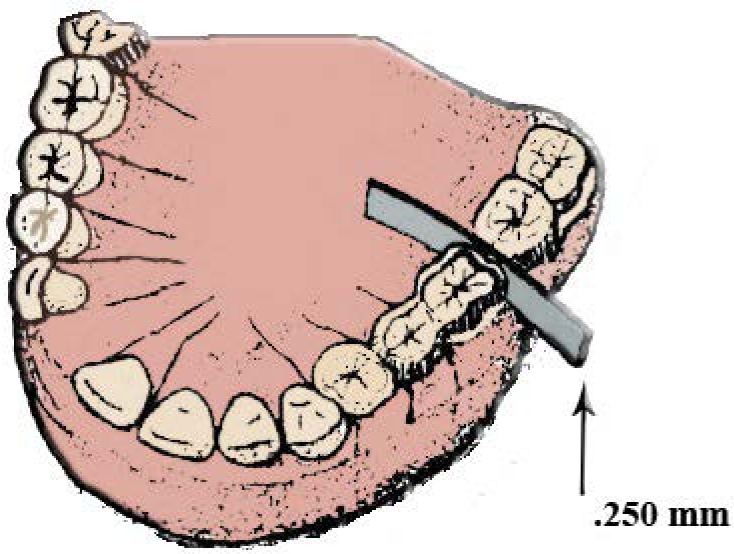


Figure 3–24. Measuring the solder gap width.

Also, keep in mind that the two surfaces to be soldered should be parallel. The reason is there is less chance of distortion when the two surfaces are parallel than when the space between the units isn't uniform. Correct and incorrect views are shown in figure 3–25.

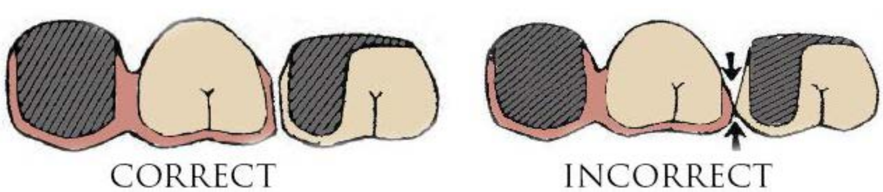


Figure 3–25. Solder gap should be parallel.

With the units prepared, you must record the FDP's position so that the investment patty can be made. The units can be related to each other for soldering by the stone index method or the self-curing acrylic resin method. Either method is acceptable. Both of these techniques hold the units in position until the investment sets.

Proponents of the stone index method argue that the solder joints are stronger, because acrylic resin can contaminate the casting's surfaces. Others argue that the self-curing acrylic resin method is easier and more accurate. With ceramic alloys, it's highly advisable to use self-curing acrylic for the solder relation. At the elevated preheating temperatures, any residual carbon from the acrylic resin burns away.

To make a stone index, wrap beading wax twice around the FDP including a stone tooth at each end. The wax should leave the cusp tips exposed. Apply separator and place an accelerated plaster mix on the area. For anterior FDPs, apply the plaster to the lingual surfaces. An aluminum denture tooth card or baseplate wax can be used as a plaster carrier if you wish.

Remove the stone index after it sets. Remove the rope wax, trim the index, and reposition the units in the index. Sticky-wax them in place, but do not use sticky wax in the solder joint. The wax could distort the FDP when cooling. Instead, fill the joint area with inlay wax, carve the connector's shape in the wax, and apply a separating medium to the index.

To contain the solder patty investment, wrap a sheet of boxing wax around the index (fig. 3–26). Remember that the solder patty must be 15−20 mm thick with a 3 mm border around the FDP. Because of this, make the box a little larger than these dimensions. Prepare the soldering investment according to the manufacturer's directions and paint it in and on the assembly.

Figure 3–26. Box the index.

When the investment sets, separate the assembly from the index by immersing it in boiling water to melt the sticky wax. Trim the investment to the proper dimension, and thoroughly flush away all wax residues with boiling water. Cut V-shaped channels leading from the edge of the investment to the metal parts to be soldered (fig. 3–27). These channels give the soldering flame access to the joint. Steam-clean the joint to be sure there is no loose investment particles between the units.

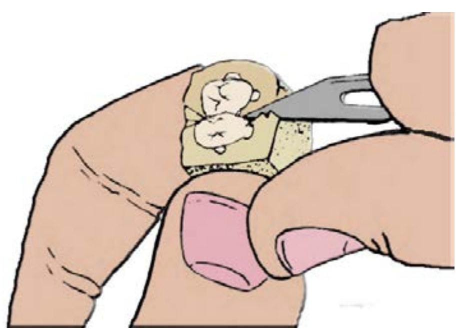


Figure 3–27. Cut V-shaped channels in the investment.

While the assembly is still warm from boiling, apply a small amount of soldering flux onto the metal areas to be joined.

CAUTION: Too much flux causes pits and weakens solder joints.

You must control the solder flow. Do not allow the solder flow to ruin margins or run onto carved occlusal surfaces. You can protect areas where you do not want solder by applying an antiflux. Do this after you apply the soldering flux. Ordinary pencil lead (graphite or carbon) is a good antiflux. You can also make a good antiflux by moistening rouge with alcohol or monomer and painting it on the areas where you do not want solder. Use a small, soft brush to apply a thin coat of this mixture.

With the self-curing resin method, you do not need to mix and apply dental plaster. Instead, the FDP units are sticky-waxed on the cast and a brush is used to apply self-curing resin to the solder gap. Add enough resin to firmly unite the units. It is recommended that you use a bur or segment of wire to strengthen the solder relation. Use Dura-Lay or Caulk's orthodontic resin for the joint because they set and burn out quickly and completely. When set, remove the FDP and check for voids on the tissue surface side. Fill the voids and shape the connector with the resin. Replace the FDP on the cast to allow the resin to polymerize.

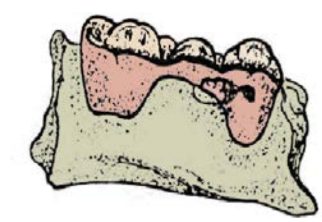


Figure 3–28. Invert the FDP in the solder patty.

Building the investment patty with the resin method is a little different when compared to the stone index method. Mix the soldering investment and build the patty approximately 25 mm high. You can make the patty freehand or contain it in a wax ring. Fill the retainers with investment and place the FDP in the patty. Cover the margins and expose the metal as much as possible (fig. 3–28). Once set, you can prepare the patty as described earlier. Do not boil out the patty; instead, burn out the resin during the preheat cycle.

Select the solder while the patty sets. The solder should be the same color as the FDP and have a melting range 100 °F lower than the FDP alloy. Place a solder strip in the solder gap either prior to oven insertion or after removal from the oven. Applying solder in the solder joint prior to heating allows better control of the solder amount. Feeding the solder during heating is fast, and you are certain to have enough solder to make an adequate joint. With either method, take care that you do not force the solder into the joint. If you do, you may distort the solder relation. If necessary, the solder can be tapered with a rubber wheel to keep it from binding in the solder gap.

Place the patty in a room temperature oven and run the temperature up to 900 °F. Preheat the solder patty in the burnout oven at 900 °F for 30 minutes. During burnout, adjust the oxygen pressure to about 6 psi. Next, adjust the torch so that the reducing part of the flame is slightly larger than the solder gap area. This prevents overheating other parts of the FDP. An overheated unit can expand, cracking the investment and causing distortion. A small flame also prevents releasing sulfur gas from the investment that could contaminate the solder.

Remove the preheated assembly from the burnout oven and place it on a hot soldering frame. Place a small amount of flux in the joint area. Coat a small square of solder with flux and place it in the linguo-occlusal embrasure of the joint area (fig. 3–29).

Figure 3–29. Solder patty on soldering frame.

Solder should melt when it comes in contact with hot castings. Avoid applying heat from the torch directly to the solder; instead, use the reducing part of the flame to heat up the solder patty. After this, heat the units adjacent to the joint area. When the castings are dull red, they're near soldering temperature. At this point, switch from gradually heating a relatively large area to concentrating the reducing zone of the flame around the solder gap area. When you do, the units will become bright red and the solder will start flowing. As soon as the solder flows, remove the flame.

Allow the units to bench cool completely. Rapid quenching causes distortion. Remove the investment and deoxidize the FDP. Restore the correct vertical dimension and the original occlusal scheme (e.g., anterior guidance, group function). Shape the solder joint with a separating disc and knife-edge rubber wheel (fig. 3–30). Polishing is the same as previously mentioned for all-metal restorations.

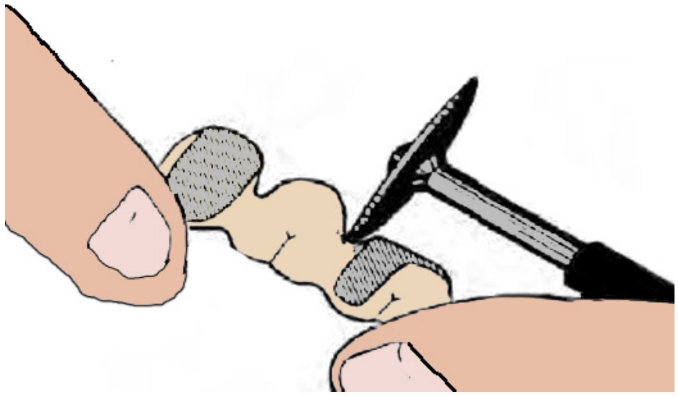


Figure 3–30. Shape the solder joint.

Refer to the following table for a listing of common problems associated with using low-fusing solders.

Soldering Problems		
Problem	**Probable Cause**	**Solution**
Pitting	Excessive heat	Use only a gas-air torch or porcelain furnace method
	Dirt or excessive flux	Clean joint; use flux sparingly
Solder won't flow	Solder gap too wide	Adjust gap to acceptable limits
	Surface of solder area rough	Rubber completely
	Not enough heat	Adjust torch
	Failure to flux	Use correct flux to prevent oxide formation
Solder joint fails	Solder fails to "wet" joint completely	Preheat investment
	Solder gap contaminated	Ensure solder joint is clean
Solder relationship distorted	Assembly distorted before investing in solder patty	Ensure castings are seated and firmly attached
	Prematurely quenching assembly in water	Bench cool

Soldering single units

In addition to soldering FDP connectors, you may make solder repairs to single unit fixed restorations. Here, we'll discuss the two most common repairs: (1) adding a proximal contact and (2) repairing a hole in a casting.

Adding a proximal contact

For some unknown reason, contacts seem to disappear as you finish. One minute they're there, the next minute they're gone. This could be caused by over finishing or by wobbly dies. Whatever the reason, the result is that some contact must be established and the proximal surface contoured. This can be done freehand for a single restoration; but on an FDP, it must first be invested.

The freehand method is by far the fastest and easiest way to add a proximal contact. If you decide that the restoration must be invested, place the restoration in the investment patty so that the area to be repaired is accessible and is in a horizontal plane (it's difficult to place solder on a vertical wall; it falls off!). Also, do not forget that you must preheat the invested case in a furnace before you solder it. If you choose to freehand solder the contact, no investing or preheating is needed.

Let's run through the steps of freehand soldering. Of course, the proximal area to be soldered must first be rubbered smooth. You should also outline the boundaries of solder flow with a graphite pencil. You need a pair of locking tweezers to hold the crown while you heat it. Hemostats or cotton pliers will do, but you could accidentally damage the margins. You can make a pair of soldering tweezers by bending the tip of a pair of locking tweezers (fig. 3–31). Place the bent tip on the inside of the crown to avoid crimping the margin.

Figure 3–31. Soldering tweezers.

Select the solder and cut a piece larger than you actually need. The added bulk of solder will help you contour the proximal surface. Warm the casting slightly over a flame, and apply flux on the surface to prevent oxide formation. Dip the piece of solder into the flux and place it on the crown (fig. 3–32).

Figure 3–32. Solder placement.

Place the casting in the reducing zone of the Bunsen burner flame. Keep it there until the casting glows bright red, letting the solder melt and adapt itself to the casting. Adjust the Bunsen burner carefully to provide enough heat to make the solder flow. Once the solder melts, remove the casting from the flame. Heating the solder far above its melting range will cause porosity. Once the casting loses its glow, quench it in water. Deoxidize the casting and finish it to proper contour.

Repairing a hole in a casting

Soldering a hole in a crown can be a frustrating experience. If the hole is small enough (pinhole, pit, and porosity) you can solder it freehand; however, if the hole is larger than a pinhole, you risk making it even larger if you do not invest the crown. Moreover, simply investing the crown is not enough. The molten solder flows, but it has nothing to stick to. What you need is a backing—a material that aids solder flow and causes the solder to "wet" the area to be filled. Platinum foil is used because it has a strong attraction for molten precious alloys. Platinum foil provides the backing that bridges the gap so the solder can mend the hole.

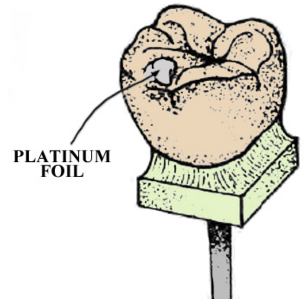


Figure 3–33. Adapt platinum foil under the hole.

Start by adapting a small piece of platinum foil to the die on the area under the hole (fig. 3–33). Seat the casting on the die, and sticky wax the foil to the casting through the hole. When the wax has cooled, remove the casting from the die. Check to ensure that the foil stays in place inside the casting. Fill the casting with solder investment, and place it in a small investment patty, like the one in figure 3–34.

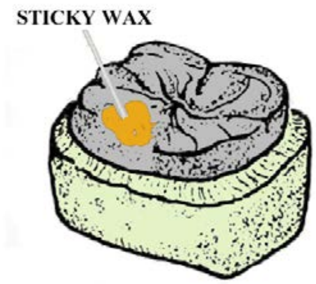


Figure 3–34. Invest the crown and foil.

After the investment hardens, remove the sticky wax. Outline the area to be soldered with a graphite pencil. Apply a small amount of flux to the hole, and preheat the assembly in a furnace at 900 °F for 30 minutes. Place a square of solder (slightly larger than the hole) over the hole, or touch a strip of solder to the casting as the procedure nears completion. Remember to heat the casting, not the solder. When the solder flows, remove the flame. When the crown loses its glow, quench it in water. Finish and polish the casting in the usual manner.

Do not forget to remove the platinum foil from the inside of the crown. If you do not remove the foil, it can keep the crown from seating completely. Simply grind the platinum away with a small round bur.

Metal-ceramic substructures

Soldering metal-ceramic substructures can be difficult depending on the FDP alloy. Two procedures are involved: (1) preveneer soldering and (2) postveneer soldering.

Preveneer soldering

Ceramic alloys must use compatible solder called presolder. Presolder describes solder that has a fusing temperature above that of porcelains. This is required for metal-ceramic substructures since they will be exposed to porcelain firing temperatures. Some ceramic alloy presolders have melting ranges very close to the melting ranges of the parent alloys and require very careful soldering. Follow the manufacturer’s directions precisely.

The preveneer solder technique joins the units of a metal-ceramic fixed dental prosthesis before porcelain is applied. This technique can also be used to correct a distorted FDP. The FDP is separated and soldered in the correct relation. Another reason for preveneer soldering is that some spans are simply too long to be cast accurately in one piece.

Preveneer soldering metal-ceramic units take solder with a much higher fusion temperature (about 2,000 °F) than type 3 gold solders. Remember that the solder joint must be able to survive the porcelain firing temperatures. Be sure the presolder you are using is recommended by the parent alloy’s manufacturer.

Preveneer soldering principles and theories differ somewhat from those used for conventional soldering. The strongest preveneer solder joints are those prepared so they need the least amount of solder. This is contrary to what we said earlier for conventional golds. Trying to bridge a large gap, especially if the presolder has been overheated, can result in a weak joint. The proper amount of solder gap for presoldering is 0.1 mm. The area of the solder joint must also be rubbered smooth before you make the matrix.

One method of separating the units of an FDP is to make a diagonal cut through the pontic. The cut can be made with a separating disc through the casting or by making a diagonal cut with a warm razor blade through the wax pontic (fig. 3–35). This creates a solder joint that's long and thin, resulting in a much stronger joint. Ideally, the connectors should be cast metal for strength. Therefore, the connector is not as good a location for a preveneer solder joint.

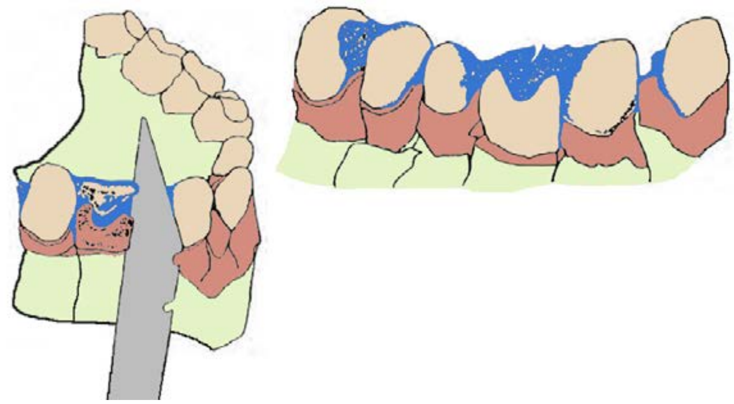


Figure 3–35. Preparing the preveneer solder joint in wax.

To make the solder matrix, seat the units on the cast and sticky-wax them in place (fig. 3–36). The procedures are the same as for joining a conventional alloy FDP with self-curing resin. Use a special high-seat solder investment or phosphate-bonded casting investment mixed with distilled water rather than the special liquid to limit the expansion to an absolute minimum. Mix the investment thick; a thin mix can weaken the investment, causing it to crack at high temperatures. Place investment inside each retainer using a bladed instrument. Next, place a patty of investment on a paper towel and invert the assembly onto the patty. The paper towel absorbs moisture, which helps to control slumping.

Figure 3–36. Assembling and investing the FDP for preveneer soldering.

Make sure that the margins are covered and the metal is supported. This does not mean burying the casting. The investment slows the heat transfer, preventing the solder from melting. You might overheat the casting trying to melt the solder. On multiple units, never solder more than two joints at a time.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

812. Finishing and polishing

1. When inspecting a casting, what two factors determine when to remake the casting?

2. When adjusting the occlusion, how can you best check the occlusion of a fixed restoration?

3. When polishing an all-metal restoration, why create a satin finish on the occlusal surface?

4. State three objectives for finishing metal-ceramic substructures.

5. When finishing the substructure, what abrasive material must be used in finishing the porcelain-bearing areas?

6. When a satin finish is created, what bond is created by the surface texture?

813. Soldering

1. When a solder gap is prepared, why should you only rubber areas to be soldered?

2. When you prepare a solder patty, what are the solder patty dimensions for a conventional gold alloy FDP?

3. What time and temperature is recommended for preheating a conventional gold alloy restoration when soldering?

4. What backing material is used to solder a hole?

5. When preveneer soldering, what produces the strongest preveneer solder joint?

6. What solder gap width is recommended for presoldering an FDP?

7. What undesired outcome could happen if you bury castings in solder investment?

Answers to Self-Test Questions

809

1. Using the exact amount of alloy prevents formation of a large button that could cause a miscast.
2. Allows wax and gases to escape the mold during the early stages of burnout. Directs the molten meatal from the crucible into the mold cavity. Provides a reservoir of molten metal of which the casting may draw upon during solidification.
3. Approximately a 45° angle.
4. This placement allows the cast restoration to cool first.
5. Auxiliary spruing a single pattern is also used to ensure a complete casting. Patterns that have two thick areas separated by a thin area may require an auxiliary sprue.
6. The indirect method produces minimal distortion, molten metal is evenly distributed to all parts of the casting, and there is a reservoir of metal close to the casting, allowing the mold to fill uniformly and simultaneously.
7. To begin, ensure that the ringless casting ring and base are free of debris.
8. On the lingual cusps; due to their large bulk.
9. Because the "memory effect" of the wax can distort the pattern.

810

1. Much of the porosity in castings can be attributed to investment contamination.
2. The investment and expansion techniques compensate for the shrinkage of the cooling metal.
3. Water that is too warm or too cool.
4. If there is enough vibration during the initial setting period, the investment mold could crack.
5. Store invested patterns in a humid atmosphere. Wrap them in a damp towel and keep them in a plastic bag with a few drops of water.
6. Increase the ratio of special liquid to water (more special liquid, more expansion), mix less fluid with the powder (less water, more expansion), and burn out the mold at a higher temperature.
7. Small metal nodules may appear on the underside of the casting. A direct result of ammonia gases escaping from a pattern invested too soon.

811

1. Every 3 months.
2. Add 10 minutes for each additional ring to the burnout cycle.
3. *Do not* use temperatures above 1,300 °F, because the gypsum-bonded investment material starts to break down, causing rough castings.
4. Some physical characteristics could be altered because some of the alloy's constituents are burned out.
5. To replace metals that have been burned out of the alloy.
6. This is the hottest part of the flame. There is also less chance of oxidizing the metal with this part of the flame.
7. When the alloy is white hot and mirror-like.
8. Quenching interferes with the grain boundaries, cracking and weakening the casting.

812

1. When repairing the casting will alter its fit, and when the patient won't be able to keep the restoration clean.
2. By using a 0.0005-inch plastic shim stock to compare the adjacent teeth's occlusion.
3. The occlusal contacts are easier to see and therefore easier to adjust.
4. (1) Provide clean surfaces for chemical bonding.
   (2) Provide ideal surface texture that increases the mechanical retention.
   (3) Make corrections in the design of the metal substructure.
5. New burs and finishing stones (or those used exclusively on ceramic metals) with a ceramic binder.

6. The surface texture should allow the porcelain to wet the metal and provide an almost molecular attraction between the mechanical retention.

813

1. Because you will need to blast and rubber the entire casting after soldering.
2. 15-20 mm thick with a 3 mm border around the casting.
3. 900 °F for 30 minutes.
4. Platinum foil.
5. Using the least amount of solder.
6. 0.1 mm.
7. The investment slows the heat transfer, preventing the solder from melting. You might overheat the casting, trying to melt the solder.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter.

25. (809) When attaching a sprued pattern to the sprue base, placing the pattern in the *thermal zone* can cause
    a. the pattern to cool first, producing an ideal casting.
    b. shrinkage in the casting due to overheating of the metal.
    c. the sprue to cool first, which could cause porosity or a miscast.
    d. expansion in the casting due to gas directed into the mold by the torch.

26. (809) When two or more single patterns are sprued with the direct method, the sprues should
    a. be attached to the apex of the sprue base.
    b. be attached to the length of each sprue.
    c. be made to lead off one another.
    d. converge in the heat zone.

27. (809) What is the preferred method for spruing multiple single unit patterns?
    a. Direct.
    b. Indirect.
    c. Auxiliary.
    d. Chill set.

28. (809) Due to large bulk, where should posterior wax patterns be sprued?
    a. Cusp tip.
    b. Buccal cusp.
    c. Lingual cusp.
    d. Triangular ridge.

29. (810) Why should you scrape the top of an investment ring?
    a. To remove the glazed surface and allow gases to escape.
    b. So that the ring can be positioned in the casting machine.
    c. To reduce the amount of investment covering the pattern.
    d. So that the ring touches the furnace muffle to distribute the heat.

30. (810) What investment material *must* be used with ceramic alloys?
    a. Silica-bonded.
    b. Gypsum-bonded.
    c. Phosphate-bonded.
    d. Bicarbonate-bonded.

31. (810) What is the result when a wax pattern is *not* invested under vacuum?
    a. Too much expansion.
    b. An incomplete casting.
    c. Pitting on the lingual surface.
    d. Small metal nodules on the underside of the casting.

32. (811) When you are using plastic patterns, how many minutes should be *added* to the burnout?
    a. 8.
    b. 15.
    c. 30.
    d. 45.

33. (811) What type of gas is created when a gypsum-bonded investment is exposed to temperatures *above* 1,300 degrees Fahrenheit (°F)?
    a. Sulfur.
    b. Silicon.
    c. Ammonia.
    d. Carbon monoxide.

34. (811) When casting a restoration, melting of the alloy *must* be accomplished with what part of the flame?
    a. Neutral.
    b. Reducing.
    c. Oxidizing.
    d. Luminous.

35. (811) When casting, what is the probable cause of fins on the casting?
    a. Alloy turbulence.
    b. Overheating of alloy.
    c. Mold temperature too hot.
    d. Over-vibration during investing.

36. (811) What temperature should nonprecious metals be burned out at to eliminate all traces of carbon residue completely?
    a. 1,300 degrees Fahrenheit (°F).
    b. 1,400 °F.
    c. 1,500 °F.
    d. 1,600 °F.

37. (811) When casting fixed dental prostheses (FDP), what part of the pattern is placed towards the "trailing edge"?
    a. Thinnest.
    b. Thickest.
    c. Occlusal.
    d. Buccal.

38. (812) When finishing and polishing a restoration, what shim stock thickness do you use to check the occlusion?
    a. 0.005 inch.
    b. 0.010 inch.
    c. 0.0005 inch.
    d. 0.00010 inch.

39. (812) When you are finishing and polishing a restoration, why would you prefer a matte finish on the occlusal surface?
    a. Equilibrates the opposing teeth.
    b. Eliminates the mirror-like glare from the occlusal surface.
    c. Allows you to clearly see interferences and eliminate them.
    d. Allows you to prevent the hit-and-slide effect associated with polished occlusal surfaces.

40. (812) What is used to create the satin finish on porcelain-bearing surfaces?
    a. 203 stone.
    b. Green stone.
    c. Brown stone.
    d. Fissure stone.

41. (813) When preparing a fixed dental prosthesis (FDP) for soldering, how thick should the patty border be?
    a. 1 millimeter (mm).
    b. 2 mm.
    c. 3 mm.
    d. 4 mm.

42. (813) In order to properly solder a fixed dental prosthesis, you *concentrate* the
    a. oxidizing zone of the flame on the gold units.
    b. reducing zone of the flame on the gold units.
    c. oxidizing zone of the flame on the solder gap area.
    d. reducing zone of the flame on the solder gap area.

43. (813) When using solder to repair a hole in a crown, what backing material is used to aid solder flow?
    a. Gold foil.
    b. Platinum foil.
    c. Solder investment.
    d. Casting investment.

Please read the unit menu for unit 4 and continue ➔

Student Notes

Unit 4. Dental Ceramics

PRODUCING A VITAL life-like restoration requires that you understand the characteristics and composition of dental porcelain before you can successfully manipulate and contour porcelain; however, first, you must understand the concept of esthetics. In this unit, we discuss how to build and complete a metal-ceramic restoration.

4–1. Fabricating Metal-Ceramic Restorations

When you are fabricating most restorations, you must try to duplicate the patient's original tooth form, color, and texture. It is indeed helpful if the dentist sends a diagnostic cast of either the patient's original tooth structure or the temporary prosthesis. If a diagnostic cast is not available, you will have to rely on personal knowledge and experience. Sometimes certain subtle changes or even a major change may be indicated to optimize the patient's esthetics and function.

As we go through the lessons presented in this section, you will learn how to construct a metal-ceramic substructure. We begin by with a process called oxidizing, or opaquing, the metal framework, which is done for function as well as appearance. Next, we discuss the special handling and care of a very hard and translucent material called dental porcelain. Finally, we come to special effects—a skill that requires creativity, artistry, patience, and experience.

814. Shade selection

Creating a life-like restoration is probably one of the most important aspects of dentistry. To accomplish this task, you must understand shade analysis, as well as how optical illusions can be created using light reflection, refraction, and restoration contour.

Shade analysis

Shade matching can be very involved and subjective. Achieving consistency can be difficult because of the influence of lighting variables and each person's visual perception of color. Fortunately, a life-like restoration does not need to be an exact color duplicate of the surrounding teeth; instead, it needs only to blend with the surrounding dentition. Typically, more than one person will help determine the proper shade match for a patient. It may be helpful to review the lesson on color in volume 2 of the CDC before continuing this part of the lesson.

Often, the dentist has an assistant select a range of possible shades from which the dentist makes the final selection. Additionally, some dentists may want the lab technician's opinion on how well their shade selection reflects the patient's natural tooth value, chroma levels, and special modifiers.

To make an accurate shade match, it may be necessary to reduce undesirable color influences. If possible, all colors outside the gray or light blue range should be covered or blocked.

This is done to prevent the eye from misperceiving the actual color of the patient's tooth. Usually the dentist "rests" his or her eyes by focusing on a gray-blue surface immediately before doing a shade match.

The gray-blue color range balances all the color sensors of the retina and resensitizes the eye to the yellow color of a tooth.

The shade analysis should be conducted in the lighting conditions the patient is most often seen in. For example, if the patient spends most of his or her time outdoors, match the shade outdoors. The tooth shade varies depending on the environment—you may remember this is called metamerism. When the conditions are correct, determine the value, hue, and chroma of the tooth.

When selecting a shade, there are several shade guides available, such as the Vita guides, when you are analyzing color variables. Determine value first, since teeth usually have the same value level. The value order for the Vita classical guide is B1, A1, B2, D2, A2, C1, C2, D4, A3, D3, B3, A3.5, B4, C3, A4, and C4. Squint your eyes to reduce the amount of light entering them. This reduces the effectiveness of the cone cells and helps you see the value level better.

After you have determined the tooth's value, your next step is to determine the tooth's dominant hue and then chroma. When you are determining a tooth's color, do not stare at the tooth; instead, glance at a gray-blue card and back to the tooth. Doing this maintains your sensitivity to the tooth's natural yellow hue. You may want to use a shade guide that has had the necks removed from the tabs. Removing the necks allow you to see the tabs' true colors.

NOTE: The necks have higher chroma levels than the rest of the tab and can cause you to misjudge a shade.

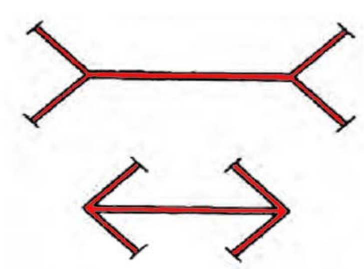
For a more detailed analysis, you may want to make your own shade tabs from the porcelain you are using. This prevents having to cross-match shades between two porcelain systems when one company makes the shade guide and another makes the porcelain. In addition, each guide from the same manufacturer varies somewhat since shade guides are made from different batches of porcelain.

In addition to using shade tabs, the dentist can also specify characterization in different parts of the tooth. For example, the dentist may want a blue highlight in the mesial incisal third of the tooth, with a higher chroma orange in the mesial cervical third on a base shade of B2. Instead of relying on a written description, you or the dentist may draw an outline of the tooth and section it into thirds, with the location and size of the special effects illustrated on the drawing.

A color-corrected light, with a color-rendering index (CRI) of 90 or higher, should be used. This allows an accurate color match when you are cross-matching shade guides and staining the restoration. The dentist should send the shade tab used to determine the shade to the laboratory. This reduces the chance for error when deciding if the restoration matches the desired shade.

Optical illusions

Have heard the saying, "Things aren't always what they appear?" Figure 4–1 illustrates how illusions can be created by altering lines, angles, and curvatures. In dentistry, we create illusions that make restorations more appealing and natural. Your responsibility is to help the dentist improve the patient's function and appearance.



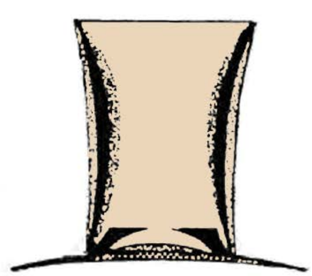


Figure 4–1. Examples of illusions used in dentistry.

Light reflection

Light reflection is a very important part of esthetics. In a metal-ceramic restoration, an opaque layer is needed to mask the metal's surface. When this opaque layer is covered with translucent body and incisal porcelain, the restoration becomes highly reflective. This is why many restorations stand out from their adjacent natural teeth. To keep this from happening, some dentists use shades with a slightly lower value, making the restoration appear more translucent and not quite as reflective. A higher value restoration is more prominent in comparison to a lower value restoration.

Contour

A tooth's surface form and outline should match the patient's natural teeth. The tooth's length depends on the patient's age and tooth position in the arch. Youthful teeth lack wear (as shown by the teeth's full length in fig. 4–2). At middle age, central incisor incisal edges are worn, but the laterals show only minimal wear. In later years, the lateral incisors begin to wear, resulting in a straight line extending from lateral to lateral. Therefore, the patient's age can be helpful in achieving an esthetic result. You can create a more passive appearance by rounding the labial line angles (the junction of two tooth surfaces) and softening the teeth's arrangement. The opposite is also true; an aggressive appearance can be created with sharp line angles.

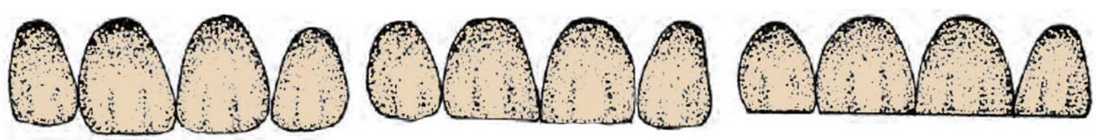


Figure 4–2. Patient's age effect on incisal edges.

Earlier, we said you should study the wax-up from different angles. Look at a tooth's profile. The tooth's gingivoincisal profile may be straight, convex, or slightly concave. The mesiodistal profile may also be straight, convex, or concave depending on the zygomatic arch's shape. Of course, the labial surface rounds in at the incisal third. This reduces the forward light reflection and prevents the incisal edge from protruding.

The contact area's proper location also has a pronounced esthetic effect. Because of this, any change in the area's location must be done very carefully. Figure 4–3 shows some examples. Teeth with square outlines have contact areas longer than those with a more tapered outline. When more separation between teeth is desired, a shorter contact area can be made, exposing more space and tissue in the interproximal (fig. 4–3).

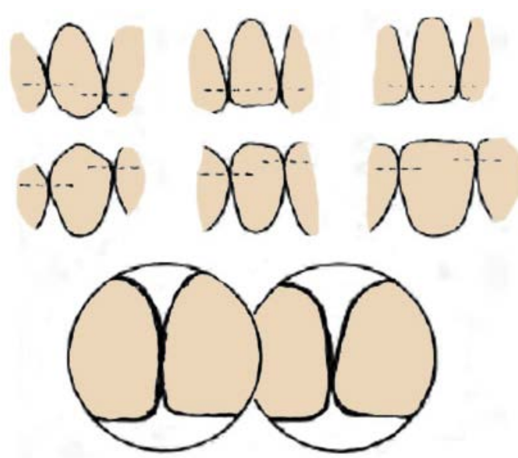


Figure 4–3. Contact area placement and its effect on appearance.

The restoration’s surface texture should be slightly more emphasized than that of the natural adjacent teeth. A textured surface diffuses and reflects (scatters) light in an irregular manner.

Surface texturing may help to conceal slight differences in color and make the restoration appear more natural. Small horizontal lines on the labial surface make the tooth appear wider.

Conversely, vertical lines appear to increase the tooth length. Deep developmental grooves in the facial surface create a harsh, vigorous tooth form and appearance (fig. 4–4). All these techniques are useful tools as you work to match the restoration to the natural dentition.

Figure 4–4. Deep labial grooves create a vigorous appearance.

The original tooth’s exact size is usually reproduced in the restoration. The maxillary central incisors are at least 8 mm wide, with the laterals 2 mm narrower (and the cuspids about 1 mm narrower) than the centrals. These dimensions help to determine the anterior teeth’s relative sizes. Whenever possible, the restoration should have a mesiodistal width equal to the original width.

Placing a normal width restoration in a narrow space can be addressed by overlapping at the incisal edge (fig. 4–5). Another way to treat the same problem (make the restoration appear wider) is to flatten the facial surface and move the contact facioincisally (fig. 4–6). On the other hand, when the space is wider than normal, the problem is more difficult. Figure 4–7 shows how you can treat this wide space by rounding the facial surface and moving the contact gingivally. This moves the visible labial line angles to the tooth’s center, giving the illusion that the tooth is narrower than the space it occupies.

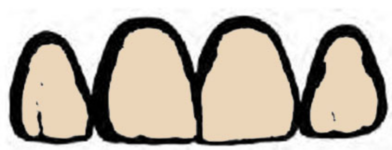


Figure 4–5. Overlap the central incisor to fit the restoration in a narrow space.

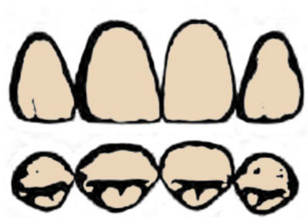


Figure 4–6. Giving a narrow restoration a wider appearance.

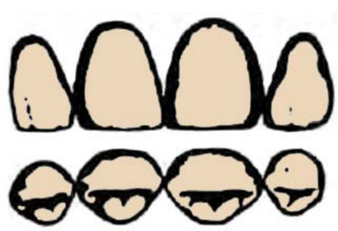


Figure 4–7. Giving a wide restoration a narrow appearance.

The proximal contours (incisal view in fig. 4–8) affect the restoration's labial form. A contact located labially on adjacent teeth causes the restoration to appear wider; the opposite happens when the contact is moved lingually. Sometimes, the space is so wide that trying to establish contact would make the restoration unusually wide. Maybe the patient has a naturally occurring diastema and must be treated in a specific way.

If the patient wants the space closed, then it may be possible to either reposition the teeth orthodontically or try to contour the restoration in a lingual direction and move the contact areas toward the lingual. If the patient wants to keep the diastema, pay special attention to the dentist's instructions to make sure the diastema is the proper width.

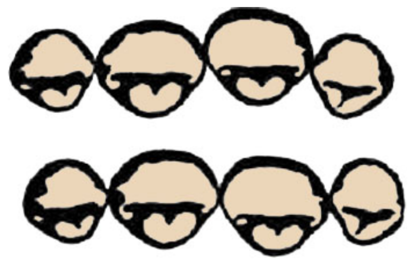


Figure 4–8. Contact area location and apparent width.

A narrow edentulous space in the posterior region can be contoured to give the restoration a normal appearance when viewed from the anterior. This is accomplished by positioning the facial ridge (developmental lobe) so that the mesiobuccal cusp arm is longer than the distal cusp arm.

Conversely, a wide space can be "filled" by lengthening the distal cusp arm of the restoration (fig. 4–9). The combined effect is a restoration that appears to have normal width when viewed from the anterior. This type of "illusion" is possible because the human eye can't accurately gauge depth.

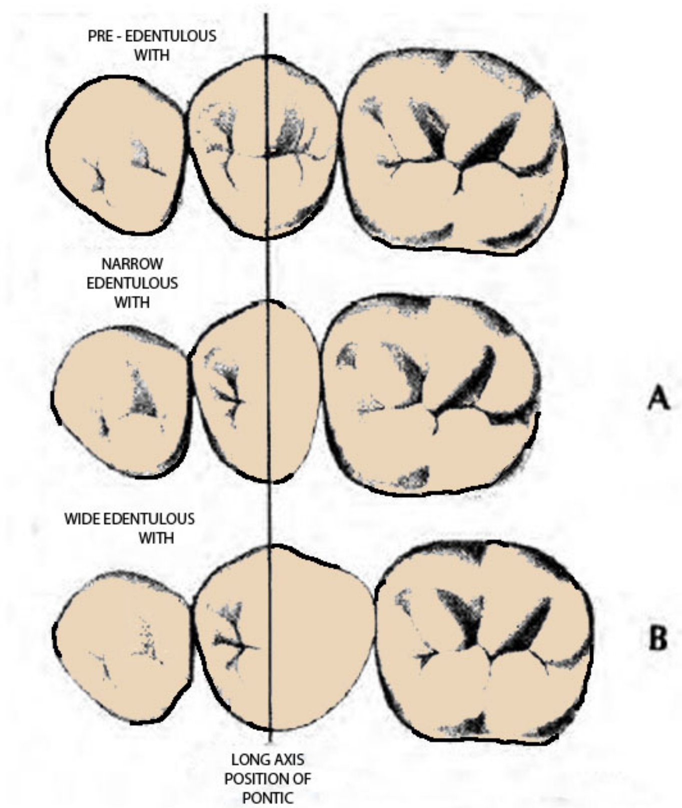


Figure 4–9. Posterior restoration shaped for a narrow and wide space.

As technicians, we often tend to make the restorations too long. The restoration's length may seem correct, but there could be interference in a working or protrusive movement. In this case, you must meticulously adjust the incisal edges to the right length, which is established by mandibular movements and indicated by visible wear (wear facets). If you are uncertain of the proper length, consult with the dentist.

Periodontally involved teeth can present unique problems. Teeth, as such, have extra-long clinical crowns (the natural crown of the tooth), but a restoration can be made to appear shorter by carving a very definite cervical line. As you can see on figure 4–10, adjacent natural teeth and overall restoration length determine cervical line location. You can make the restoration seem even shorter by adding gingival stain to the root portion. An alternative approach is to reduce the cervical collar and add gingival shade porcelain to restore the contour. This gingival shade porcelain may be supplied by a porcelain manufacturer or made by combining various amounts of modifiers to body porcelain. Another use for gingival shade porcelain is in the gingival embrasure area between a pontic and retainer. Tissue resorption may be so severe that a black space is visible in the interproximal. To close the hole, use gingival porcelain to make an artificial papilla.

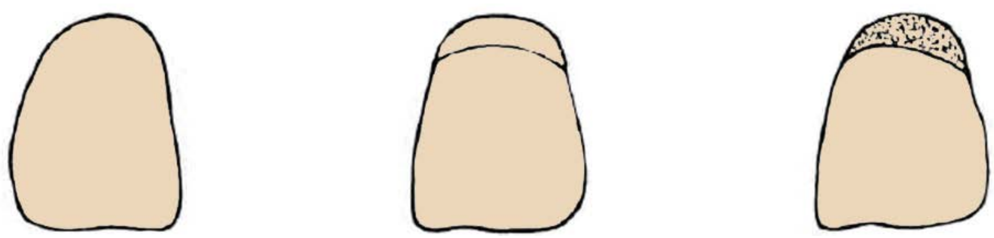


Figure 4–10. Cervical collar and shading used to shorten crown length.

Because it can be difficult to achieve good results with gingival stains and porcelains, always check with the dentist before choosing these methods (fig. 4–11).

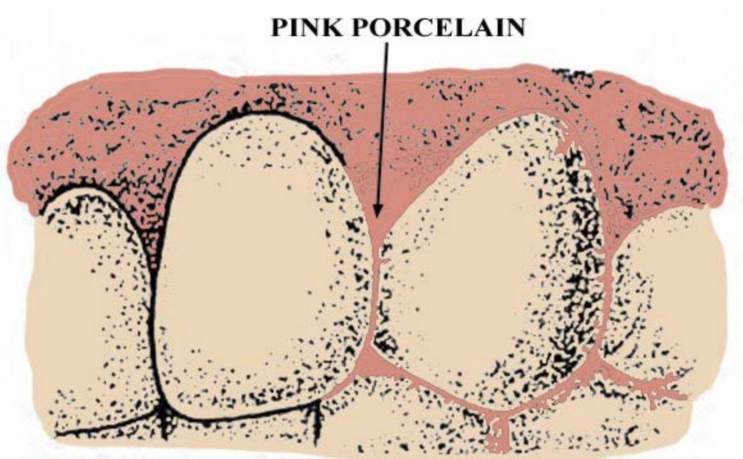


Figure 4–11. Pink porcelain papilla.

Short teeth can be made to seem longer by adding vertical lines or a vertical concavity to the surface texture. These procedures can give the illusion of length, but only to a limited degree. A greater increase in length can only be made by surgical repositioning of the gingival margin.

The tooth's position and alignment within the arch may be more important than the actual tooth form itself. This can be demonstrated by comparing three sets of teeth of the same mold and shade. If each set were arranged into three different arch forms—square, tapering, and ovoid—the teeth in the squarely aligned arch would appear square; the teeth in the tapering alignment form would appear tapered, and the ones in the ovoid arrangement would appear ovoid.

When a tooth is rotated about its axis, an overlap is created, which allows you to place a wider tooth into a smaller space. Subtle axial rotation is shown on figure 4–12. This rotation gives a natural appearance to a tooth's arrangement; however, if you take it to the extreme, it has an opposite effect. Figure 4–13 shows how dramatic this change might be if the six anterior teeth's distals are rotated in and mesials are rotated out. Notice how much narrower the teeth appear, even though they occupy the same relative positions.

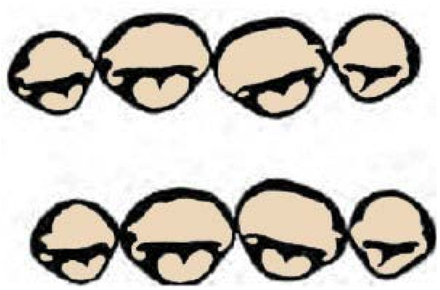


Figure 4–12. Subtle rotation to achieve a natural appearance.

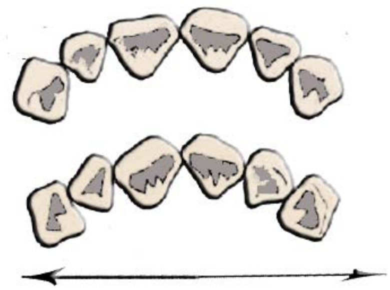


Figure 4–13. Rotation's effect on apparent width.

The restoration's long axis should be in line with the root eminence's inclination. It helps if you scribe a line on the cast to indicate this inclination. When a restoration doesn't have the same inclination, it looks unnatural.

Many believe that the restoration's midline should match the opposing arch. This may be the case in a complete denture where the midline is used as a guide for teeth arrangement, but not in fixed restorative work. The exact midline position relative to the opposing arch is not as important when it is compared with the teeth's size and arrangement. At a glance, you would probably remember the teeth's arrangement and size before noticing anything else.

815. Opaquing the substructure

Opaquing the substructure is a critical step in matching the patient's natural dentition. Opaque influences the hue, chroma, and value of all the proceeding porcelain layers. In this lesson, we present information on how to prepare the substructure and apply the opaque.

Prepare the substructure

We begin with a properly finished metal substructure. The next step is to oxidize this framework. There are two reasons for oxidizing the metal framework. First, a controlled oxide layer, on the metal, ensures an adequate chemical bonding with the porcelain veneer. Second, higher firing temperatures dispel gases absorbed by metal during casting. If these gases are not released before you apply porcelain, they could make an opaque bubble at the porcelain-to-metal interface. These gas bubbles will eventually migrate to the veneer's surface, where they will be visible. These holes can sometimes be repaired, but each time the porcelain is fired under vacuum, the risk of escaping gas increases. The only sure way of correcting this situation is to strip the framework, refinish the metal, and start the process again.

Follow the alloy manufacturer's instructions to oxidize the framework. Commonly, your first step is to microblast and steam-clean the framework or you may flush and brush the casting under running tap water to remove abrasive particles. Then, place the casting in an ultrasonic cleaner with distilled water for 10 minutes. Next, remove the casting and position it on the firing table. Now, oxidize the casting under the vacuum for 2 minutes, remove it, and let it bench cool.

CAUTION: To prevent contamination from finger contact, always use tweezers when you handle the casting.

Each ceramic alloy manufacturer provides specific instructions on oxidizing procedures. Each alloy, when it is oxidized properly, has a characteristic appearance. Some alloys produce an oxide layer that is too thick, which may actually cause a bond failure. This excess oxide must be removed before you apply the opaque porcelain.

Apply opaque porcelain

The opaque porcelain layer is the initial porcelain application. It serves three purposes:

- Mask or hide the underlying metal's color.
- Simulate the dentine of a natural tooth and complement the body shade porcelain.
- Combine with the metal surface oxide to form a strong chemical bond.

You must clean the castings before you start to apply opaque porcelain. Inspect the casting and remove excess oxides by sandblasting with aluminum oxide.

Under running tap water, flush and brush the castings to remove abrasive particles. Steam-clean the castings or place them in an ultrasonic cleaner for 10 minutes. Then, keep the castings covered from dust until you are ready to apply the opaque porcelain.

Opaque porcelain can be applied with a brush, spatula, or airbrush (spray-on technique). What you use is not as critical as how you use it. You make the decision; it is simply a matter of preference.

If time permits, experiment with all three. Once you have selected the applicator, you are ready to apply the opaque. One method is to apply one thick coat of opaque porcelain, ensuring that there are no gray areas visible through the opaque. Another is to apply two thin coats instead of one thick coat. The latter method is preferred because it is much easier to apply and control the fired opaque thickness, which should be about 0.2 mm. In addition to these two methods, it is a good idea to apply an initial, thin wash coat of opaque known as "bonding slurry." This initial application increases the opaque's wetting action to the metal. Here are the procedures:

Steps in Applying Opaque Porcelain

Step	Action
1	First, measure out the correct amount of opaque powder onto a flat glass slab or ceramic dish.
2	Mix the powder with modeling fluid to a creamy consistency using a glass rod. Modeling fluid is a combination of glycerin and distilled water that prevents the porcelain from rapidly drying out.
3	Using a brush or opaquing instrument, slightly moisten the framework with modeling fluid and apply a thin opaque slurry. Gently vibrate the opaque porcelain to smooth and condense the surface.
4	Place the casting on the porcelain furnace platform.
5	Fire the opaqued framework according to the porcelain manufacturer's directions.
6	Once the framework cools, apply additional opaque with a brush or opaquing instrument, and let it lightly contact the metal surface beginning at the cervical collar. Move the brush gently down the metal and the porcelain will follow it in a thin film. At no point during this procedure should the brush tip contact the metal. Continue to repeat this procedure until the entire porcelain-bearing area is covered. It is important that you work quickly so that the opaque covers evenly, and thick areas are eliminated while the opaque is still wet. Again, gently vibrate the opaque porcelain to smooth and condense the surface.
7	Dry the opaque in front of an open furnace door.
8	Remove any opaque porcelain from the restoration's interior and nonporcelain-bearing areas.
9	Place the framework directly on the firing platform. Insert the case into the furnace and start opaque firing cycle. Most opaque firing temperatures are set around 1,760 °F with a temperature rise rate of 58 °F per minute, but the *manufacturer's directions may differ*.

If a furnace is properly calibrated, the fired opaque should have a slight sheen similar to an eggshell surface. If the opaque has a glazed appearance, it was fired at too high a temperature; rough opaque means it was fired too low. After the first initial firing, inspect the casting for gray areas. Apply a thin second layer of opaque to ensure all gray areas have been covered. Once you cover all surface areas, fire the second opaque layer in the same manner as the first. When gray areas are visible through the porcelain, an unacceptable splotchy appearance will result.

The following table lists the common problems in applying opaque porcelain to the framework. Since this initial opaque layer provides most of the bond strength for the veneer, it is critical to the metal-ceramic restoration's success.

Opaque Failures		
Problem	**Probable Cause**	**Solution**
Blistering or bubbles.	Opaque overfired; high temperatures cause opaque to bloat.	Calibrate furnace; fire to manufacturer recommended temperature.
	Incorrect finishing methods.	Finish in one direction.
	Surface contaminated by incorrect finishing or handling.	Clean surface before opaque application.
	Gases escape from casting.	Abrade with aluminum oxide grit, clean, and reoxidize.
Cracks and surface defects.	Opaque applied too wet.	Allow opaque to reach a viscous state; apply second layer to fill in cracks.
	Opaque dried too fast.	Dry opaque slowly before firing.
	Metal or porcelain contaminated by dust, particles, or oils.	Cover opaque or casting when not applying porcelain.

816. Processing the porcelain veneer

While you are applying porcelain to a metal framework, you must constantly be mindful of many factors. At all, times be aware of the amount of moisture in the porcelain buildup and monitor the manner in which you apply the porcelain. In this lesson, we will provide specific information on a variety of topics including the following:

- Instruments.
- Condensation techniques.
- Basic build-up techniques.
- FDP construction.
- Occlusal anatomy construction.
- Porcelain margin metal-ceramic restorations (collarless restorations).
- Firing stages of porcelain.

Instruments

Porcelain is applied with a variety of instruments. Some ceramists prefer the brush method because the brush is flexible, retains moisture, and can be shaped for specific uses. The drawback to this method is that the brush may incorporate air in the porcelain if used incorrectly. Other ceramists like applying porcelain with a hard instrument such as a spatula. The spatula method allows quick porcelain application, but requires precise moisture control in the porcelain mix.

You can have the best of both methods when applying porcelain, or as we say, "stacking." For example, the body and incisal porcelains can be quickly applied with a spatula to ensure a dense mass. The brush can be used for intrinsic staining and blending the incisal porcelain into the body porcelain. Experiment with these methods to develop your own porcelain application style.

Condensation techniques

Packing the porcelain particles together and removing the water is known as "condensation." Condensation has three purposes:

- To improve the contact between the metal framework and porcelain.
- To decrease bubbles in the porcelain mixture in order to enhance the translucency, esthetics, and strength.
- To reduce the distance between porcelain particles—reducing porosity—which increases strength and lowers firing shrinkage.

Effective porcelain condensing helps determine porcelain shrinkage after the first "bake" or firing.

Slight porcelain overbuilding also helps compensate for fired porcelain shrinkage. The shrinkage amount is related to the porcelain powder's particle size and shape.

Porcelain powder contains several particle sizes to reduce the shrinkage amount. On the average, the porcelain's shrinkage by volume is between 30 and 40 percent. This can be misleading, though, because the linear shrinkage amount is only about 14 percent. Usually, you would be concerned only with the linear shrinkage since most shrinkage is noticeable in the restoration's overall length.

Some porcelains are fine-grain porcelain powders, while others are coarse grain. It is to your advantage to select a fine-grain porcelain because it shrinks less and has improved handling characteristics. Porcelain always shrinks toward the greatest bulk. As you can see on figure 4–14, these areas are found at the incisal, interproximal, and at the supra-bulge area.

NOTE: Pay careful attention to the line and point angles during the bulk porcelain buildup because they shrink the most.

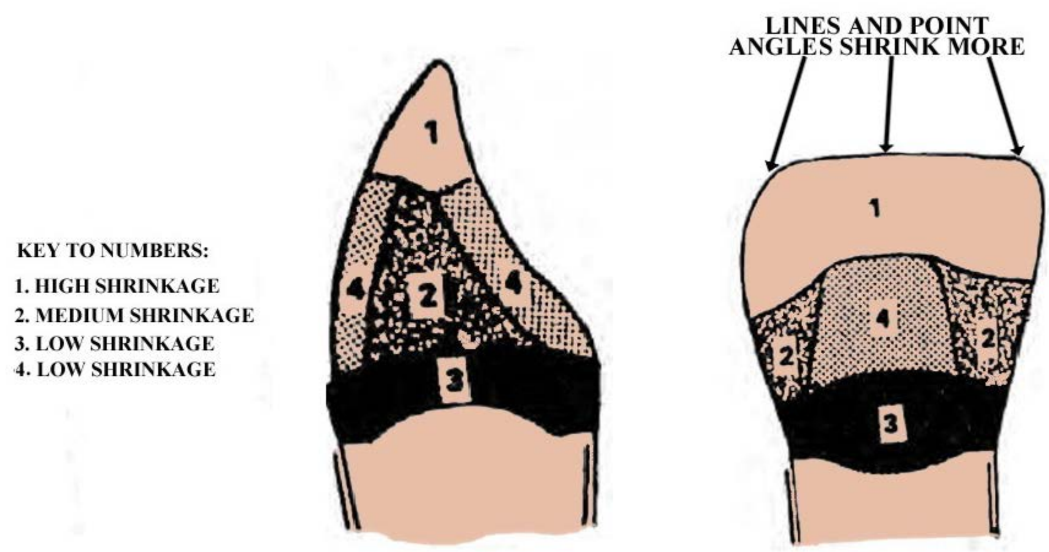


Figure 4–14. Porcelain shrinkage areas and volume.

Your ability to condense porcelain affects the shrinkage amount and the fired porcelain's color. If you do not condense the porcelain enough, air spaces between porcelain particles may cause the buildup to shrink more and generate a darker appearance. In contrast, porcelain that is condensed too much is exceptionally hard, brittle, and appears saturated with color or milky. Over-condensed porcelain is color-saturated because various body and incisal porcelains "mix" and lose unique qualities. In either case, never let the porcelain dry out during application. Layering "wet" porcelain over dry porcelain can trap air and cause large voids in the final restoration.

Next, we will examine four methods of condensing porcelain: (1) vibration, (2) capillary action, (3) pressure packing, and (4) whipping.

NOTE: All four methods remove water from the porcelain while increasing the surface tension within the porcelain buildup (fig. 4–15).

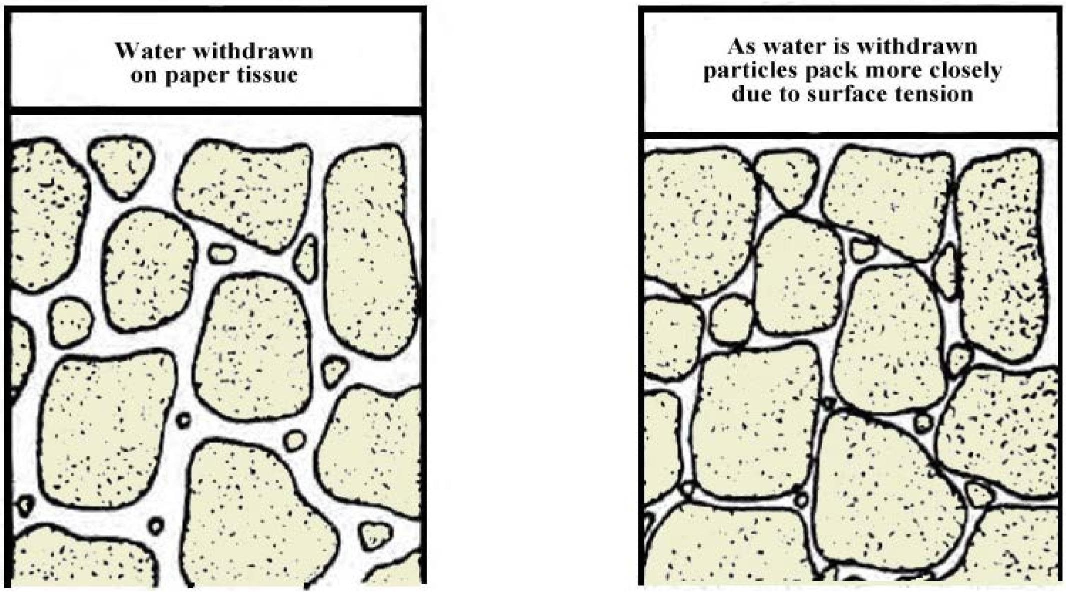


Figure 4–15. Condensing wet porcelain.

Methods of Condensing Porcelain	
Method	**Description**
Vibration	Vibration is accomplished using hemostats and a small dental instrument (a serrated instrument or brush handle). The hemostats are used to hold the metal framework and to transfer energy generated from vibration. The vibration is created by tapping the hemostats with the dental instrument. Vibration of the porcelain buildup should be gentle and minimal. When performed properly, vibration eliminates large air bubbles or spaces within the porcelain mass.
Capillary action	Capillary action is done by using a clean and dry multi-layer tissue. The tissue is placed on the lingual surface drawing the particles closer together from a facial-to-lingual direction.
Pressure packing	Pressure or spatulation is done by gently patting or tapping the surface of a porcelain build-up with the flat surface of a porcelain carver. This type of condensation should only be performed for minor shaping and contouring. If you use excessive pressure, you can displace the underlying porcelain mass and cause large voids and cracks in the porcelain build-up.
Whipping	Whipping or brushing is used to dry and shape the surface of the porcelain build-up. This condensation method is typically used in the final stages of the build-up process. Whipping is accomplished by using a large dry soft brush to fill in surface voids by redistributing small amounts of porcelain particles over the surface of the restoration.

Basic buildup technique

The application of body and incisal porcelain is commonly referred to as the buildup. The following table covers procedures for the buildup technique:

<table>
<tr><th colspan="2">Steps in the Porcelain Buildup</th></tr>
<tr><th>Step</th><th>Action</th></tr>
<tr><td>1</td><td>Begin by making sure the cast is clean.</td></tr>
<tr><td>2</td><td>Seal the surface contact areas of the working cast with clear fingernail polish or cyanoacrylate glue to prevent moisture absorption and porcelain contamination.</td></tr>
<tr><td>3</td><td>Accurately seat the opaqued casting on its dies.</td></tr>
<tr><td>4</td><td>Measure out the body and incisal porcelain onto a glass slab or ceramic dish.</td></tr>
<tr><td>5</td><td>Using a nylon spatula or glass rod, mix the body powder with distilled water to a thick consistency.</td></tr>
<tr><td>6</td><td>If the mix is too wet, blot the excess moisture away from the powder bed with a clean tissue.</td></tr>
<tr><td></td><td>NOTE: Porcelain failure is often caused by air bubbles that remain in the mixture. You should also be able to pick up small increments of porcelain with an instrument or brush. The mix should not be so thin that it drips off the instrument. If you use color modifiers in the buildup, you can simplify their placement by dyeing the separate mixes with food coloring. Instruments used in building porcelain vary from fine-blade spatulas to sable hairbrushes. As we said earlier, what you use is a matter of preference. For our procedure, we will use sable hairbrushes, since they work well with the finer grained porcelains.</td></tr>
<tr><td>7</td><td>Using a brush, pick up a porcelain bead from the edge of the mix. Starting at the cervical collar, flow the mix onto the opaque. Place each porcelain increment with a gentle pushing and tapping action.</td></tr>
<tr><td>8</td><td>Absorb excess water with a clean, dry tissue.</td></tr>
<tr><td>9</td><td>Gentle cast vibration helps to condense the buildup. Avoid heavy vibration because it tends to make the porcelain slump and it may displace internal color modifiers.</td></tr>
<tr><td>10</td><td>Build the body (dentine) porcelain by placing each increment exactly where it's needed. Do not let the porcelain dry out.</td></tr>
<tr><td>11</td><td>Control slumping by pressing a tissue on the lingual surface to draw the moisture through the porcelain. As water is withdrawn, the particles pack closer together.</td></tr>
<tr><td>12</td><td>Slightly overbuild the porcelain mass to allow for shrinkage. At this point, the porcelain should be compact and moist, ready for the enamel porcelain addition.</td></tr>
<tr><td>13</td><td>Using a blade, cut back the interproximal and incisal third, as shown in figure 4–16. The cutback is made at an angle, removing a majority of the body porcelain from the incisal edge and feathering out to nothing at the incisal blend line. Do not allow the porcelain to dry out.

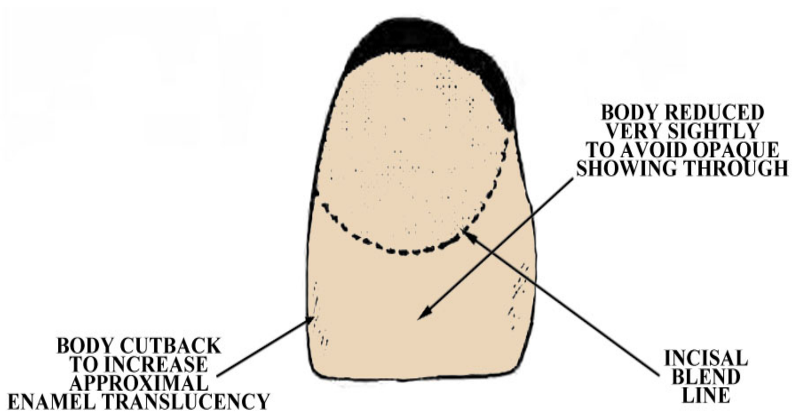
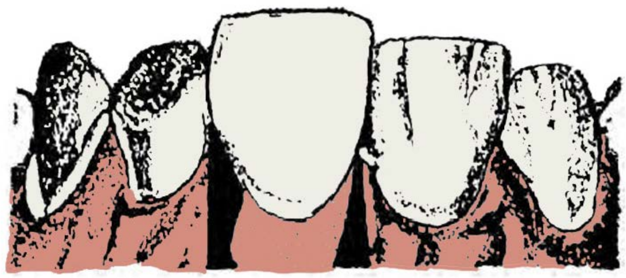
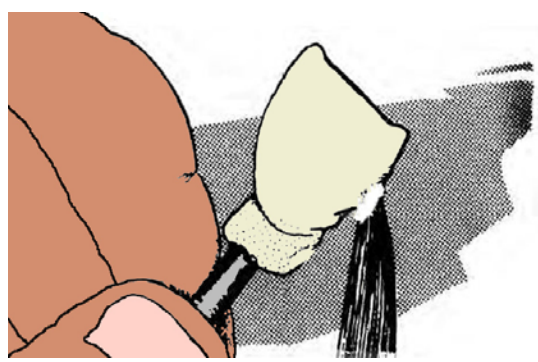


Figure 4–16. Cutback to accommodate incisal porcelain.</td></tr>
<tr><td>14</td><td>Mix the incisal porcelain a little thinner than you did for the body application. If the buildup is too dry, moisten it slightly before you apply the incisal. Trying to add wet porcelain to an already dry buildup can trap large air bubbles and cause blotchy opacity.</td></tr>
<tr><td>15</td><td>Pick up an incisal porcelain bead and apply it to the buildup.</td></tr>
</table>

Steps in the Porcelain Buildup	
Step	**Action**
16	Continue to build up the incisal area until you establish the original contour. The final buildup should extend 1 to 1.5 mm past the desired length. The incisal porcelain should blend well into the restoration's middle third, or for some shades, into the gingival third. This incisal overlay prevents a visible line of demarcation and creates an illusion of depth. Incisal buildup completion appears in figure 4–17.  **Figure 4–17. Incisal edge should be extended 1 mm.**
17	Using a thin blade, remove any porcelain from below the contact area that might be in an undercut.
18	Carefully remove the buildup restoration from the cast.
19	Remove dirt particles that might be present, since they are visible through the porcelain.
20	Moisten the buildup's mesial and distal contact areas, and apply clear or enamel porcelain to these areas, as shown in figure 4–18.  **Figure 4–18. Add clear porcelain to contacts before firing.**
21	Smooth the completed buildup with a large dry soft brush to remove any loose particles.
22	Clean excess porcelain away from the porcelain-to-metal junction, as well as porcelain particles from inside the restoration.
23	Check the buildup's overall outline, contour, and length.
24	Place the restoration to be fired on a sagger tray and fire the restoration according to manufacturer's instructions.

FDP construction

Building an FDP is much the same as building a single unit—with a few exceptions. The two main exceptions are the cutback and the ridge area. Prior to any porcelain application, use a wet brush to adapt a clean piece of tissue or rice paper over the ridge area. This keeps porcelain from adhering to the cast and helps when removing the buildup. As far as the buildup and cutback, one dental technician may prefer to build and cut back each unit separately, trying to be as uniform as possible. In contrast, another technician may build the entire FDP in body porcelain, cut back the entire buildup, and then complete the buildup applying the incisal porcelain. Still, someone else might prefer to apply body porcelain and only cut back half of the buildup. In this way, the incisal porcelain can be added to the cutback using the adjoining buildup as a guide.

The next step involves removing the restoration and overbuilding contact areas. Start by removing any porcelain that may be in an undercut. You can remove the restoration from the cast by gently pushing up on the retainers. If a minor amount of porcelain should break off, it may be added back; however, larger amounts may require the unit to be restacked. Next, add porcelain to the mesial and distal contacts and the ridge area. Be careful that you do not make the porcelain slump when you are vibrating. Some porcelain manufacturers recommend that each unit be separated by cutting down to the opaque with a sharp instrument such as a razor blade.

On long-span fixed partial dentures, this is done to relieve stress and prevent the framework from warping. This space is later filled in during the corrections step.

Occlusal anatomy construction

Porcelain occlusal anatomy should be built in a cusp-to-fossa pattern. This reduces the potential for porcelain fracture. The articulator must be programmed with the patient’s mandibular movements. If not, the dentist has to adjust the occlusion, and the restoration must be glazed again. The articulator also must be opened approximately 2 mm. This allows the porcelain occlusion to be overbuilt to compensate for firing shrinkage. Build the anatomy following the additive technique you learned earlier.

Most of the anatomy can be built with body porcelain, covered with a layer of incisal porcelain. Older patients have a thinner enamel surface due to abrasion. Simulate this by applying a thinner incisal layer to the occlusion.

Porcelain margin metal-ceramic restorations (collarless restorations)

Some patients and dentists prefer a porcelain facial margin to the less attractive metal collar. The alternative to the conventional metal-ceramic design is the collarless crown, created with porcelain butt margins.

In designing the “collarless crown,” you have to consider the preparation type. A preparation with a facial chamfer or bevel is primarily designed for use with a metal collar. There is not enough space at the facial margin for an adequate porcelain thickness; therefore, a chamfer or bevel “prep” requires a metal substructure with a metal facial margin. Metal substructures designed to have “disappearing metal margins” must be avoided since the metal and porcelain are reduced to a featheredge at the margin. This design is not mechanically sound due to the flexing that is likely to occur at the margins. Most Air Force dentists are aware of the inadequacies of this design and will not request this type of restoration.

The butt preparation is standard for collarless crowns. The ideal preparation for a collarless crown margin is a 90° shoulder preparation on the facial that extends from one proximal surface to the other. This type of preparation lets you butt the porcelain directly to the shoulder area. Since it is harder to process porcelain to this marginal design accurately, apply the porcelain in two steps. There are several ways you can do this, but the method we give here takes the least equipment and has the fewest chances for error.

Start by waxing, investing, and completing the substructure in the usual manner. Ensure that the interproximal finish line meets the cervical margin abruptly at a 90° angle to reduce distorting the metal during firing.

Next, apply a thin coat of die sealer or cyanoacrylate glue to the facial shoulder area to seal the surface. After the glue has dried, apply a light coat of castor oil, mineral oil, *or* commercial separator to this area to act as a release agent for the raw porcelain, especially for the shoulder porcelain. Prepare the metal coping as usual and apply all opaques. Apply the porcelain margin a minimum of two different times, as illustrated in figure 4–19, A. Once the shoulder porcelain is processed, build up the remaining porcelain so the final restoration is contoured as in figure 4–19, B.

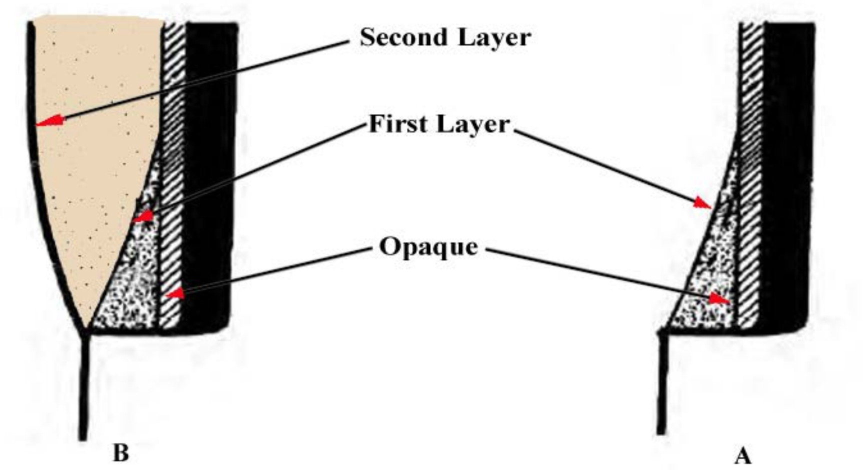


Figure 4–19. Porcelain butted against the cervical margin.

A more detailed construction sequence is shown in the following table:

Constructing Porcelain Margin Metal-Ceramic Restorations	
Step	**Action**
1	Apply porcelain separator to the master die and seat substructures.
2	Mix margin porcelain to paste-like consistency on a glass slab.
3	Apply margin porcelain to the cervical area using porcelain brush.
4	Condense the porcelain by gently vibrating die; tap or serrated.
5	Blot excess moisture from margin porcelain using facial tissue.
6	Smooth the porcelain towards the margin using a whipping brush.
7	Remove excess moisture and over-extensions.
8	Press on the substructure in a downward motion and remove with the margin intact.
9	Place the substructure on a sagger tray and fire according to the porcelain manufacturer's instructions.
10	Remove substructure from furnace and let cool to room temperature.
11	Using a microscope, inspect the porcelain margin for over extensions or positive nodules. Also, inspect the inside of the substructure for porcelain particles. Remove all interferences prior to reseating the substructure on the die. **NOTE:** Stone die margins are prone to chipping at this point.
12	Mark the facial margin on the die using a wax pencil and reapply the porcelain separator.
13	Replace the substructure on the die and repeat the porcelain margin application procedure to correct any discrepancies.
14	Remove the substructure from the die with the porcelain margin intact.
15	Place the substructure on the sagger tray and fire according to the porcelain manufacturer's instructions.
16	Remove the substructure from the furnace and let it cool to room temperature.
17	Finish the porcelain margin using diamonds, stones, etc.

Firing stages of porcelain

Many porcelain furnaces are available. They range in complexity from the very simple glazing furnaces to the more complicated computerized furnaces. If the porcelain furnace you are using is automated, you select the program, press a button, and the furnace does the rest. However, if your porcelain furnace is manually operated, then you must transfer the work and make all the adjustments. To help you better understand porcelain firing, we will discuss the manual method.

NOTE: The temperatures cited in the following text are used only as a guide; specific firing temperatures are provided by the manufacturer.

Drying times are incorporated into the firing time in the furnace programs. This prevents steam release that causes the veneer to crack. Drying time depends on the amount of moisture, which you can judge by the porcelain density and the elapsed time from initial application. In addition, setting the entrance temperature too high can fracture the porcelain. Dry and preheat the porcelain gradually by moving the restoration closer to the muffle's hot zone in stages. The entire drying, preheating, and inserting process usually takes 3−5 minutes, depending on how many units are fired. Of course, you would allow more time for a six-unit FDP than for a single unit. Correct firing times and temperatures will depend upon the specific porcelain in use. Always use the porcelain manufacturer's recommended settings on your porcelain firing programs. It is essential that you understand basic firing procedures in order to set the parameters (time and temperature) on your porcelain oven. Because of this, we will describe some typical settings.

The entrance temperature should stay at 1,112 °F during this entire process. Center the restoration in the muffle or firing platform, and close the muffle door. Seal the vacuum chamber and start the vacuum pump. Do not increase the temperature until you get a full vacuum of 26−29 inches of mercury. Set the amperage control for the rise rate at 58 °F per minute. Set the temperature control for the porcelain maturing point at 1,724 °F. When the restoration reaches 1,724 °F, release the vacuum and remove the fired porcelain. Let the restoration cool completely before handling it. Reset the temperature control to the entrance temperature, 1,112 °F. The final steps—staining and glazing—will be addressed in the next section. The following table lists common problems associated with applying veneer porcelains to the framework.

Common problems associated with applying veneer porcelains to the framework		
Problem	**Probable Cause**	**Solution**
Surface porosity	Glazing under vacuum.	Glaze without vacuum (air-fired only).
	Overfired; too high or too long of a temperature exposure.	Avoid raising temperature beyond manufacturer's recommendation—you may prolong exposure at same temp—by 30 seconds.
	Surface contaminated.	Abrade with aluminum oxides and clean before reapplying porcelain veneer.
Sub-surface porosity	Glazing under vacuum.	Air-fire only.
	Inadequate vacuum.	Confirm furnace reaches recommended vacuum.
	Contaminated porcelain.	Ensure porcelain isn't contaminated; ensure all mixing and application instruments are uncontaminated.
Enamel fails to fuse to dentin	Failure to moisten dentin porcelain prior to applying enamel.	Moisten porcelain before adding to build-up.
	Failure to extract moisture from opposite side of build-up.	Hold tissue on opposite side of additions and allow fluid to draw particles together.

Common problems associated with applying veneer porcelains to the framework		
Problem	**Probable Cause**	**Solution**
Porcelain pulling away from margins and metal junctions	Improperly condensed or contoured or faulty framework design.	Uniformly cover framework with porcelain and condense properly—porcelain shrinks towards greatest bulk.

Special effects in dental ceramics

Creating the desired "effect" in a porcelain restoration may require more than a basic build-up. Instead, special effects may be required. These special effects can be enhanced using the layering technique and intrinsic staining.

Layering technique

This porcelain buildup method is different from the basic technique. The layering technique simulates a natural tooth's layered structure. Layering allows intrinsic effects to show through the surface. The tooth structure is built adaptively with the intrinsic staining technique. The special effects are shaped with the brush, and the remainder of the restoration is added around the special effects. To ensure the effects are precisely located, the effects are fired into position and then the remainder of the restoration is built to contour.

The metal-ceramic restoration is opaqued as usual. Effects are then added at the exact location and size. Some of these effects are stained cervical dentine, dentine mamelons, and darker proximal. A stained dentine is made with opaceous dentine placed in the restoration's cervical area to reduce the porcelain's translucency. The opacious dentine is placed as a roll in the cervical area. It can also be placed interproximally to reduce the amount of light showing through the proximal surfaces.

To help differentiate one effect powder from another on the unfired buildup, you may want to color each effect powder differently. Do this by adding a small amount of food coloring to the modeling liquid, using a unique color for each powder. These liquids are then mixed with the damp-effect powders. Be sure you dry the buildup completely in order to burn out the food colors. The buildup should not have any food coloring present before firing the restoration.

With the effects in place, layer the body porcelain over the initial buildup. The restoration can be further improved by adding a clear porcelain layer over the porcelain to simulate natural enamel. Ensure the clear porcelain you are using is really clear. Some manufacturers claim to produce a clear porcelain that is actually only a milky, translucent porcelain.

Intrinsic staining

Special effects in dental porcelain are used to duplicate a natural tooth. Natural teeth are not perfect. They may display cracks, degrees of calcification, and varying enamel thicknesses. Sometimes you have to put porcelain modifiers in the buildup at a certain depth to get the right effect. Porcelain stains can be applied internally or externally to simulate nature's defects. The restoration's root and cervical areas deserve special attention if they are to blend harmoniously with the gingival tissue. Here we deal just with the restoration's internal characterization.

The intrinsic staining on fired opaque can help you provide a basic color background to the restoration. It should not be used to simulate special effects such as check lines or decalcification marks. These special effects are better placed in the body and incisal porcelain. Most opaque staining is at the cervical and incisal areas. Porcelain manufacturers supply special opaque powders to create opaque effects.

The following are of some of the colored opaques:

- White – for lightening the standard opaque or adjusting the color at the incisal edge.
- Gray – for gray shading both in the body and incisal areas.

- Pink – for reddish discoloration and to produce a warmer tone in the standard opaques.
- Brown – for increasing the brown color at the opaque's cervical area.

If these special opaque powders are not available, you might try using another standard opaque powder or even porcelain stains.

Depending on your patient's age, some cervical staining may be necessary. The effect may range in color from light brown to dark brown with varying amounts of other modifiers mixed in (e.g., orange and pink). For restorations that combine a body shade and a separate incisal shade, you must prepare two separate opaque mixes and apply them as necessary. To lighten the incisal, mix white opaque with the standard opaque shade or use a lighter shade opaque porcelain. To create more translucency at the incisal, mix gray opaque with the standard opaque porcelain. Figure 4–20 shows some areas where you might apply opaque effects.

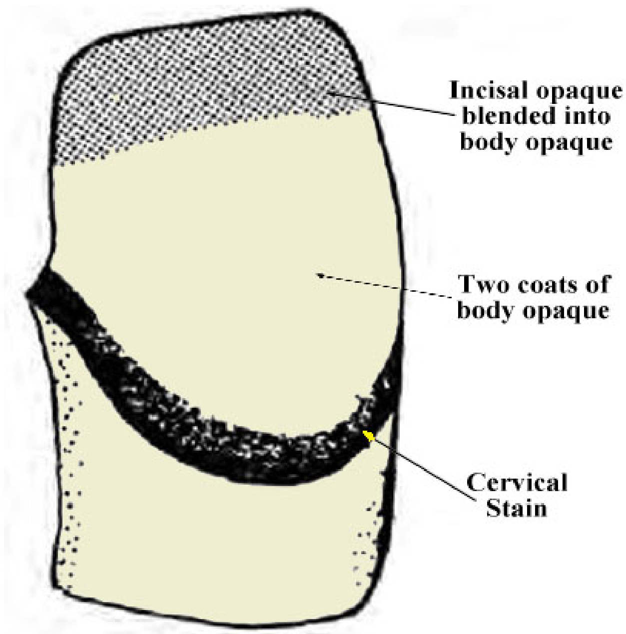


Figure 4–20. Types of opaque effects.

You can create dentine effects in the body porcelain with porcelain powders called effect powders or modifiers. You can also use porcelain stains, but it is hard to control their intensity. Dentine effects range from changing the entire restoration shade to placing discolored fillings.

You can make basic hue and chroma changes in a small area of the body porcelain or on the entire facial area of the restoration. To increase the chroma in a small area, start by building the porcelain to full contour, then carve away the porcelain in the effect area. Next, apply the effect powder to that area, tapering the porcelain onto the sides. This procedure is shown in figure 4–21.

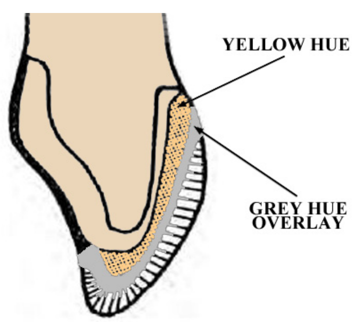


Figure 4–21. Increasing chroma in a specific area.

The dentist may request that the entire gingival shade be altered, changing the restoration's hue. To make a predominantly gray shade appear more yellow, first cover the opaque with a porcelain layer that has a yellow hue (fig. 4–22). Follow this layer with a porcelain layer that has the gray hue. You can tell the dominant hue for a given shade of porcelain by looking at the shade guide. Whatever the desired effect, it can be made by combining different porcelain shades; however, this knowledge can only be gained through experience.

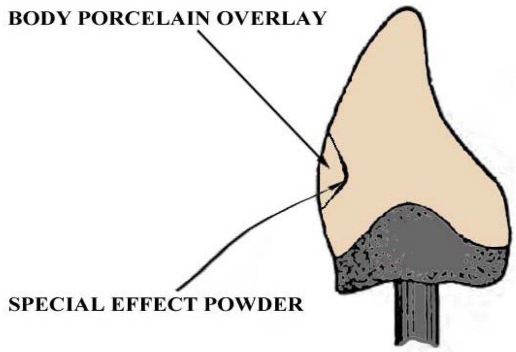


Figure 4–22. Altering the basic shade with a porcelain overlay.

In many cases, the incisal edge may be separated by three finger-like dentine extensions. These dentine mamelons originate during the tooth's formation. To simulate this effect, build the porcelain to full contour and then cut two grooves into the incisal third (fig. 4–23). Next, place a small amount of colorless porcelain in each groove. This increases the translucency in these areas.

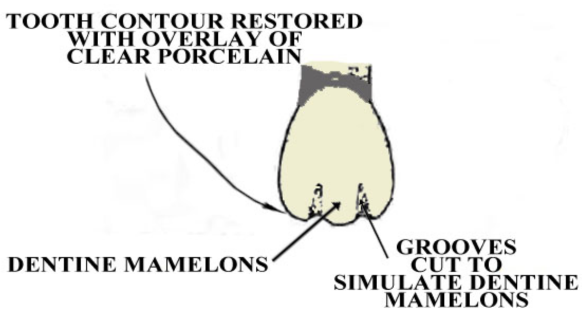


Figure 4–23. Simulating dentine mamelons.

A discolored filling is a composite or plastic restorative material that has discolored. It is usually an opaque material with brown discoloration marking the filling's boundaries. Build the porcelain to full contour and hollow out the area to be filled. Lightly coat the cavity walls with yellow-brown stain. Then fill the cavity with opacious dentin, followed by clear porcelain (fig. 4–24).

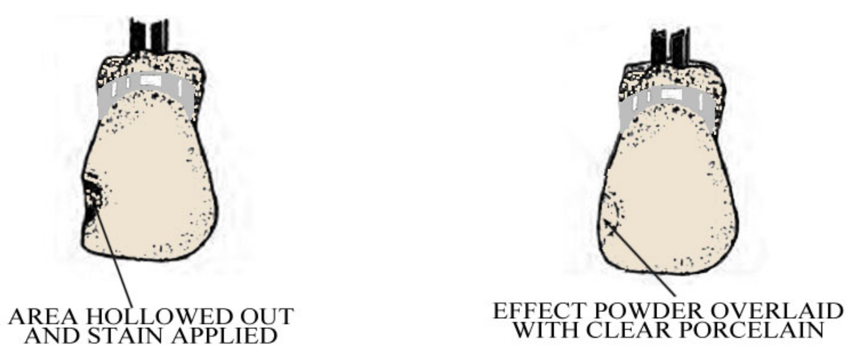


Figure 4–24. Simulating a discolored filling with the intrinsic technique.

Incisal effects can range from fine white check lines to strong orange hues. Subtly shading the incisal can dramatically affect the restoration’s appearance.

Enamel check lines are difficult to reproduce with surface stains. To simulate a natural check line or crack adequately, it should be reproduced in depth; therefore, the wedge technique should be used to create this three-dimensional effect. Begin by building up the entire restoration, including body and incisal porcelains. Cut a V-shaped wedge in the incisal third (fig. 4–25), and keep the wedge slice to reposition it later. Apply a yellow-white stain to the vertical wall with one light stroke and remove any excess on the facial surface with a clean brush. Do not work the stain into the porcelain. Gently replace the wedge slices, and seal the cut by lightly tapping the cast on the bench top. Failure to seal the cut could lead to fissure cracks during firing.

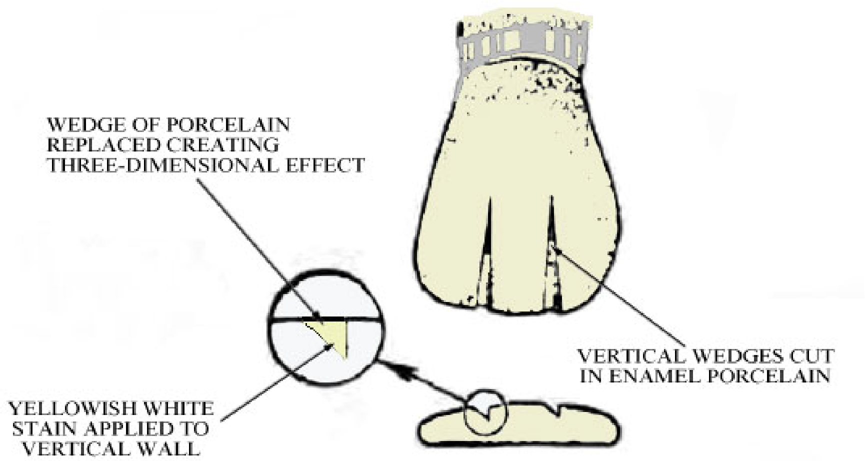


Figure 4–25. Simulating an enamel check line with the intrinsic technique.

White hypocalcified areas are also hard to reproduce with surface stains. Often these areas appear as a series of white dots that do not look like natural hypocalcification. This effect is better treated using white modifiers or effect powders in the porcelain buildup. Figure 4–26 shows how hypocalcified areas can be created in the incisal area. White effects are better created if they are applied in two or three layers. Use a fine brush tip to pick up the white powder and gently rub it into place. Then cover the white powder with enamel porcelain and repeat the process.

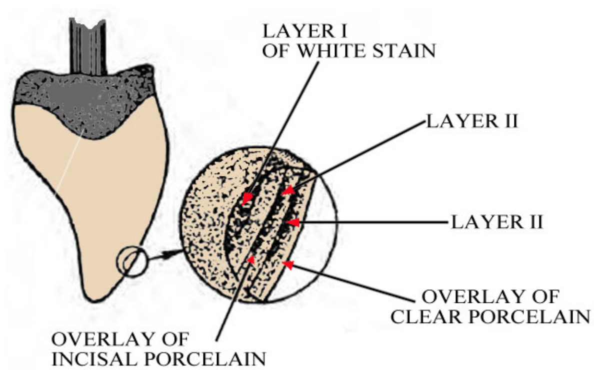


Figure 4–26. Simulating a hypocalcification with the intrinsic technique.

Natural teeth often appear more translucent at the mesial and distal incisal edges. To create this effect, remove a small amount of incisal porcelain from the mesial and distal proximal surfaces (fig. 4–27). Apply blue stain to these areas with a light stroke, and overlay them with clear porcelain. You must be careful not to remove too much incisal porcelain. If you do, you can cause the blue effect to be lost because the clear porcelain appears gray.

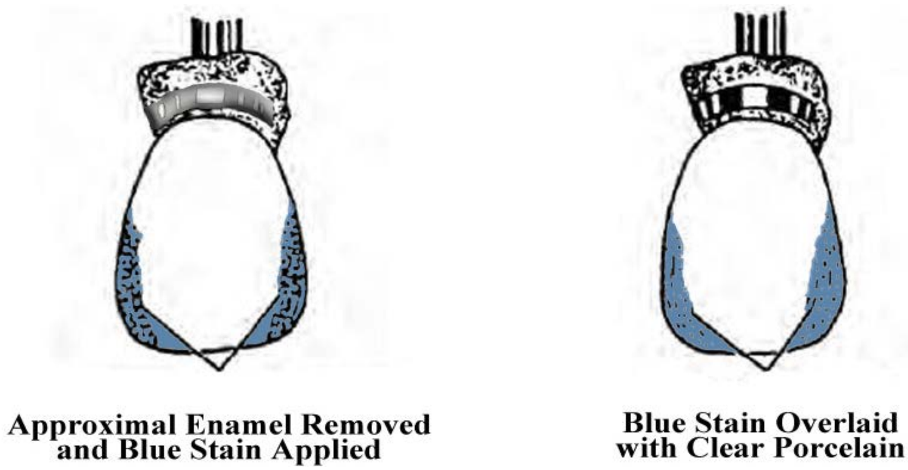


Figure 4–27. Simulating increased translucency with the intrinsic technique.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

814. Shade selection

1. When trying to make an accurate shade match, what must you try to reduce?

2. While arranging teeth, how can you create a more passive appearance?

3. What may help conceal slight differences in color and make the restoration appear more natural?

4. Placing a normal width restoration in a narrow space can be addressed by overlapping at the incisal edge. What is another way to treat the same problem (make the restoration appear wider)?

5. If a restoration is too long, what must be adjusted?

6. How can a longer restoration be altered to look shorter?

7. What kind of rotation gives a natural appearance to a tooth's arrangement?

815. Opaquing the substructure

1. When you apply an opaque porcelain layer, what three purposes does the initial layer serve?

2. What thickness is required after an opaque layer is fired?

3. How do you condense opaque porcelain?

4. When inspecting a casting, how do you correct gray areas in the fired opaque?

5. List the most common causes of opaque porcelain blistering.

6. What problem may result when a wet, opaque porcelain layer is quick-dried?

816. Processing the porcelain veneer

1. How do you compensate for fired porcelain shrinkage?

2. What condensing method will most likely eliminate large air spaces in the porcelain mass?

3. How do you prevent moisture absorption by the cast?

4. Why is it necessary to moisten a dry buildup area before you add wet porcelain?

5. What is the ideal preparation for a collarless crown?

6. When firing a porcelain crown, why are drying times incorporated into the firing time in the furnace program?

7. What is the best way to ensure special effects are precisely located?

8. How can you reduce body porcelain’s translucency and high value in the cervical area?

9. How can you increase the translucency between the dentine mamelons?

10. How can you create a discolored filling in the body porcelain?

11. What technique should be used to create an enamel check line?

4–2. Completing Metal-Ceramic Restorations

Your goal in completing metal-ceramic restorations is to create anatomical contours that look as natural as possible. To do this, you must study tooth anatomy, arrangement (that is not artificial), and function. We already presented these three areas in other lessons, but we will review them here. Often, the process simply involves exactly duplicating the corresponding teeth on the arches opposite side. At other times, you might copy the anatomical form from a diagnostic cast. On larger units, you may even be responsible for the esthetic arrangement. The final stages of creating a restoration require you to contour and glaze the fired porcelain material.

817. Contouring the restoration

Your last opportunity to create subtle surface details that enhance the vital appearance of a restoration occurs when “fired” porcelain is contoured. There are several important steps to be taken towards the successful completion of the restoration. In this lesson, we will look at these steps:

- Finishing instruments.
- Establishing contour.
- Surface texture.
- Fixed dental prostheses.

Finishing instruments

Use abrasives designed for finishing and polishing porcelain surfaces to shape a veneer. Each abrasive has a specific function. For example, diamond impregnated rubber wheels and points are used to smooth and polish. In addition, bulk-reducing wheels can be used for overall contouring of the restoration. These abrasive wheels remove porcelain quickly and abrade at about the same rate as the porcelain, making them ideal for roughing out the restoration’s form. Various shaped diamond-cutting instruments can also be used for shaping and characterizing the surface. When they are new, these devices cut very quickly; use them cautiously. Alternatives to diamonds are mounted stones and points. Avoid using abrasives that have been used on other materials.

Establishing contour

Initially, inspect the restoration’s interior for fired porcelain particles or other interferences that might keep the restoration from seating on the die. Seat the restoration on the die and verify its marginal accuracy. Sometimes the metal may distort upon firing, lifting away from the margins. This is known as metal creep or metal lifting.

NOTE: Metal may appear to have lifted but it is probably porcelain inside of the crown.

If possible, adjust each contact separately until the restoration is completely seated on the cast. This process is shown in figure 4–28. Contact areas can be disclosed using a wax pencil, marking paste, or articulation paper. When you are through making adjustments, the restoration should be in light contact and smooth. The surface can be rubbered smooth or lightly finished with a diamond disc.

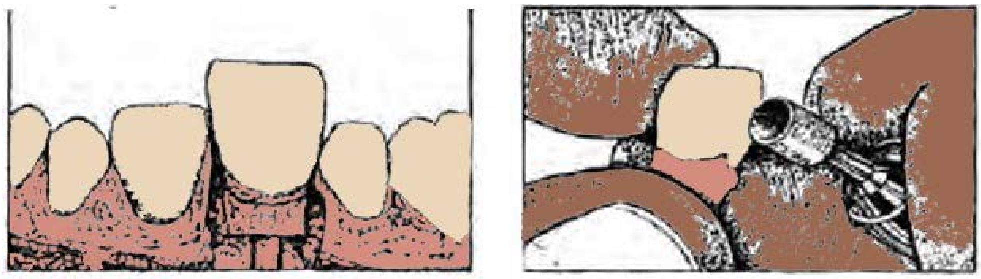


Figure 4–28. Adjusting contact areas.

Next, restore the restoration's functional occlusion according to the dentist's prescription (i.e., group function or anterior guided). Restore centric occlusion first; then adjust the restoration in working, nonworking, and protrusive excursions. When you are adjusting the restoration in excursive movements, be careful not to over-reduce the restoration's length. When you are satisfied that the occlusion has been refined and is in harmony with the patient's mandibular movement, it is time to focus your attention on the restoration's appearance.

To contour the restoration, use the facial surface contour, and the line angles and locations of a similar tooth as an example. Using a bulk-reducing wheel, grind away enough porcelain from the facial surface until the curvature matches the adjacent tooth. The mesiofacial and distofacial line angles are especially important. Almost all anterior teeth exhibit a rounding-in effect at their distofacial surface. From an incisal view (fig. 4–29), inspect the incisal edge's facial contour and alignment.

Figure 4–29. Checking the facial contour.

It is a good idea to contour the facial aspect before adjusting the incisal length. Often, the incisal edge will be a sloping surface—highest at the incisal facial edge. If the incisal length is adjusted first, the subsequent facial reduction of the incisal third (rolling this area back to match adjacent teeth) will reduce the crown's length. When the facial contours appear correct, adjust the incisal edge length until it matches the adjacent tooth (fig. 4–30). Also, consider the incisal edge's linguoinsical line angle. The angle may be steep or shallow, showing visible wear or wear facets.

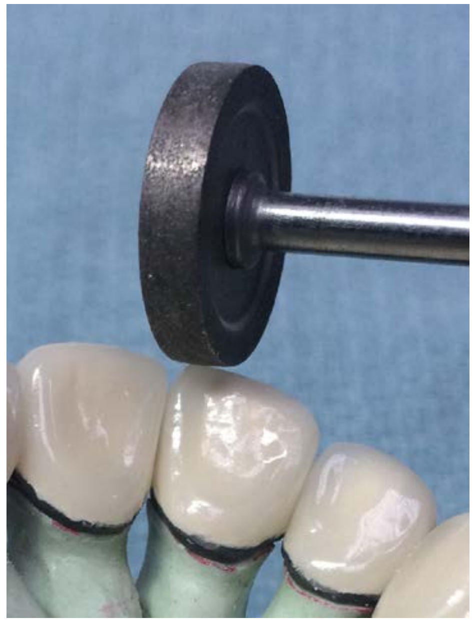


Figure 4–30. Adjusting the incisal edge.

Precision grinding the incisal edge and embrasure is an absolute must. Keep in mind that the eye is extremely sensitive to an object's outline. The incisal form is very noticeable because it is so prominently silhouetted against the oral cavity's dark shadow.

Frequently check the veneer thickness with a metal gauge, especially in the incisal third area. If the thickness measures less than 1.2 mm, chances are the opaque porcelain will be noticeable through the incisal porcelain. Do not reduce the facial to less than 1.2 mm to ensure minimum porcelain thickness for strength and appearance.

NOTE: The 1.2 mm rule of thumb applies only if the metal coping is at the maximum thickness of 0.3 mm.

This opaque porcelain show-through is hard to hide with extrinsic stains. You could also shape the restoration in a protruded fashion or labial version, but the restoration's appearance may be compromised. Be sure to consult with the dentist if a problem arises.

The crown's height of contour should correspond with the adjacent tooth. Shape the veneer's cervical third so the contour is continuous with the cervical collar. If the crown is collarless, this is the time you would refine the margins.

Do not impinge on the gingiva. Another way to ensure that this critical area is contoured correctly is to simulate soft tissue around the preparation. Commercial systems are available to simulate gingiva on fixed casts. Basically, the prepared dies and cast are placed in a polyvinyl impression, and a silicone material is injected around the dies. The impression is removed and the restorations are made.

With the cervical third established, smooth the entire facial surface while ensuring that all the line angles are correctly positioned. Inspect the labial surface shape by viewing it from several angles. You should be able to line up the restoration's facial surface with the matching tooth. This exact symmetry is not always your goal, but it is used as a guideline.

Once the overall facial contour has been defined, start shaping the lingual surfaces with a small diamond wheel or ball diamond (fig. 4–31). The restoration should have a definite lingual fossa with marginal and incisal ridges corresponding with the adjacent tooth. Check again to ensure that the restoration functions properly in excursive positions.

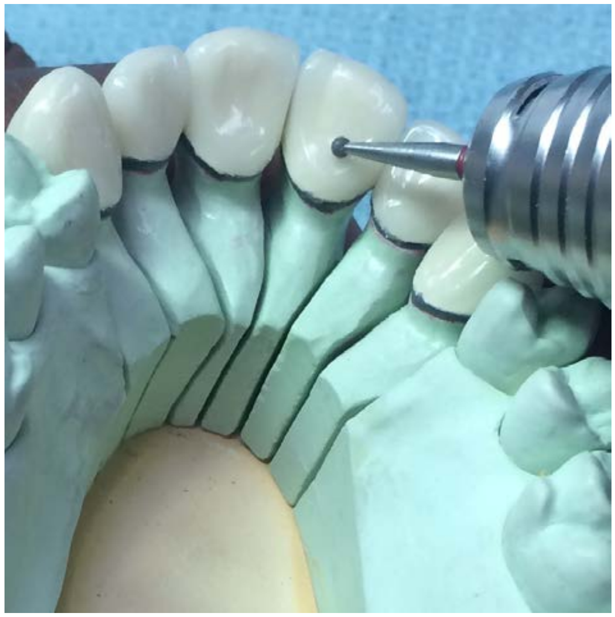


Figure 4–31. Carving lingual anatomy with a ball diamond.

Surface texture

Study the working cast or diagnostic aid for surface details. Most teeth have a satin finish, and only high spots such as ridge and point angles are shiny. Often, surface wear or abrasion may change the appearance of older teeth. These teeth may appear smoother, and some facial anatomy (e.g., horizontal grooves and developmental lobes) may be absent. By closely inspecting the diagnostic cast's adjacent teeth, you can determine the exact characterization method.

Finally, check the facial contour by marking the restoration with a sharp pencil. Trace out the ridge and point angles (fig. 4–32). Use a small diamond point or diamond wheel to make the developmental grooves. First scribe a fine groove, then widen and deepen it by gently moving the diamond from side to side. This procedure is shown in figure 4–33.

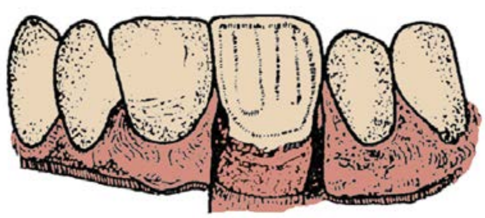


Figure 4–32. Outlining the ridge and point angles.

Numerous small transverse (horizontal) lines sometimes cover the teeth's facial surfaces. The surface can vary greatly from having deep irregular grooves to appearing almost smooth. You can use a small diamond ball to create the striations. Finer lines can be made with a diamond point held vertically and drawn across the surface. Often, the patient's tissue recedes, exposing the tooth's cervix. To shorten the tooth, this cervix must be reproduced on the veneer's surface or the restoration will look too long. Also, over-contouring a restoration in this area can lead to chronic gingivitis. Use a small round diamond to simulate the

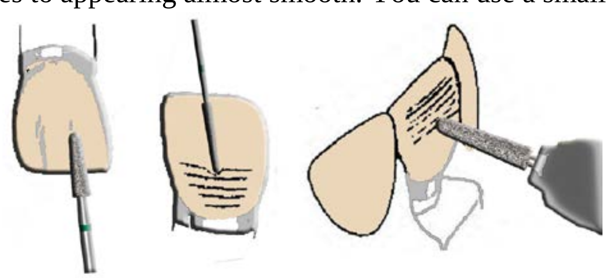


Figure 4–33. Carving various types of surface texture.

restoration's cervix (fig. 4–34). This critical area must match the original tooth. Lightly touch and polish all high spots with a rubber wheel to simulate natural wear in the mouth. The restoration should now be ready to glaze.

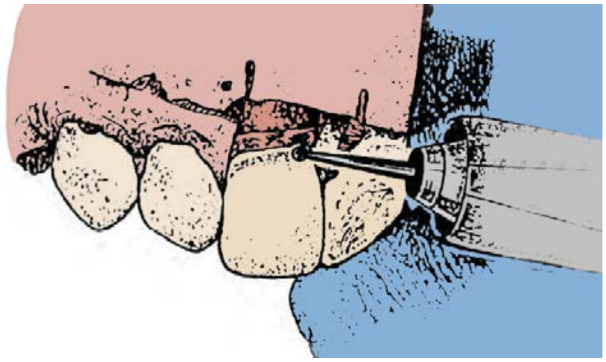


Figure 4–34. Carving a cervical line with a ball diamond.

You should have already built most of the occlusal anatomy in the raw (unfired) porcelain with the sable brush. This is the best time to contour and carve the anatomy. Now you only need to check the occlusal contacts and make sure there are no interferences during excursive movements. The finer carving of supplemental anatomy should already have been done with the brush or bladed instrument prior to firing.

Grinding posterior occlusal surfaces requires great skill. Your main objective is to highlight the detailed anatomy already present, not create it; therefore, the grinding stones and diamonds should be used with a very light action. Figure 4–35 illustrates some suggested finishing devices and their uses. Fissures should be finished with points, and supplemental grooves and fossae with small round diamonds. Make sure all the porcelain that overlaps the metal is removed before glazing. Any fired porcelain left on the metal can be very hard to remove when you polish the metal.

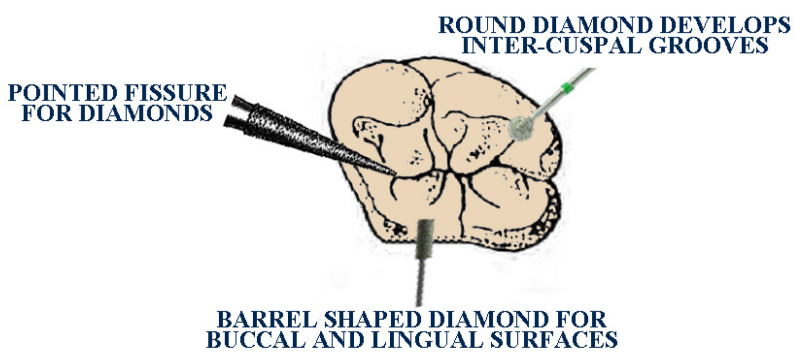


Figure 4–35. Types of diamonds used to carve occlusal surfaces.

Fixed dental prostheses

As the number of units increase, so does the level of difficulty. Finishing an FDP requires time and patience. Before you actually start, think about and plan your approach to contouring each restoration. It may even be helpful to scribe a pencil line showing each individual unit's boundaries. In the next few paragraphs, we present a few hints that may be helpful in shaping a fixed dental prosthesis.

The initial steps for seating the restoration and restoring the occlusion are basically the same as for a single unit. Adjusting the proximal contact areas is easier if the ridge areas are removed from the cast. Restore the centric occlusion, then the working and nonworking excursion, and finally the protrusive excursion.

A diagnostic cast is almost a necessity in determining the length of the anterior FDP. Without it, you must estimate length according to the remaining anterior teeth's anterior guidance and the proportional length.

One of the more difficult tasks involves shaping the interproximals. During the porcelain application step, many ceramists cut through the body porcelain just shy of the opaque porcelain (before firing the first build-up) that covers the metal connectors. When the restoration is processed, the porcelain shrinks away from these interproximal areas, and may leave sharp edges that must be adjusted (fig. 4–36). Shape the remaining porcelain until you are satisfied with the overall contour. Lightly sandblast the restoration and clean it in an ultrasonic cleaner. Steam-cleaners may also be used but be careful not to expose the porcelain to thermal shock. (Steam-cleaners have been known to fracture the porcelain veneer.) Add porcelain to the interproximals and other deficient areas the same way you first applied it. The interproximal must be precisely positioned and contoured to allow only minimal finishing.

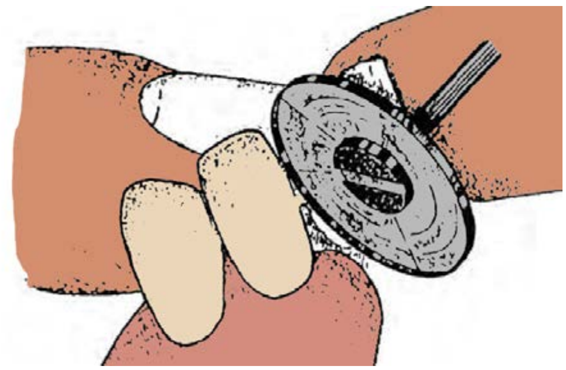


Figure 4–36. Shaping the interproximal area with a diamond disc.

Separation between the units must be finely divided and deep enough so that the teeth appear natural. This is demonstrated in figure 4–37. This division should appear V-shaped—not like a groove separating the individual units. It takes patience to shape teeth to look natural and not look like cutouts bonded to a new backing. Use a diamond-coated or ultrathin separating disc to divide the units. Do not expose the opaque layer or the underlying metal when shaping the porcelain.

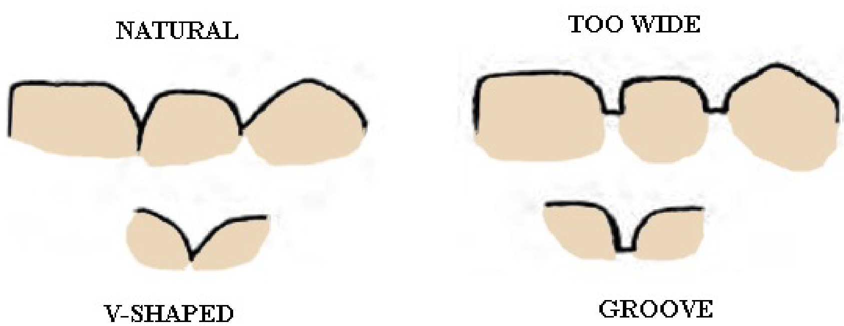


Figure 4–37. Examples of natural and unnatural separation between FDP units.

Before each subsequent porcelain application, you must remove the glaze, clean the restoration, and apply the same porcelain powder originally used during the application. To make the addition, process the porcelain using the vacuum cycle at a lower temperature (100° per firing). Sometimes you can use a correction powder such as air-fired porcelain instead to glaze the restoration at the same time. Be sure to add enough porcelain to the area to allow for contouring. The porcelain must be meticulously applied and well condensed. If it is not, the addition will be defined by a chalky-white border. Any visible addition will be hard to hide with extrinsic stains.

818. Glazing the restoration

During this construction phase, the metal-ceramic restoration receives its final touches. The overall form and surface texture are correct, but the surface must be sealed. In addition, any minor color corrections must be made. The surface of the porcelain is sealed during the staining and glazing sequences. While any shade alteration or characterization is better done within the porcelain body (intrinsic), some external (extrinsic) staining may be needed. The remaining metal surfaces are then finished and polished to complete the restoration. In this lesson, we will cover the following subjects:

- Extrinsic effects.
- Extrinsic characterization.
- Glazing.
- Polishing.
- Repairing porcelain restorations.

Extrinsic effects

Extrinsic staining involves applying porcelain stains to the restoration's surface and then processing the stains, usually during the glazing sequence. When the stains are fired, they actually fuse to the porcelain in a thin, transparent glaze layer. The advantage of extrinsic staining is that it lets the dentist or technician make corrective changes after the restoration is completed.

Surface stains are highly pigmented porcelains that absorb some light rays and reflect others. As such, when used in heavy concentrations, they tend to mask the porcelain surface, reducing the restoration's translucency and vitality. The stains should be mixed to a consistency that is neither too wet nor too dry. They should flow on easily, evenly, and smoothly—but stay in place and not run. The surface on which the stains are placed should be clean and dry and, of course, the glaze should be removed. For example, by sandblasting or steam cleaning the surface.

Any shade changes should be minor and, if possible, limited only to corrections between tabs. It would be better to remake the restoration rather than make a major correction to the shade. Obviously, the unglazed restoration won't resemble the final product in color or appearance due to the matte finish. A liquid glaze medium is used to apply the stains and to simulate the glaze surface. The liquid medium restores the surface luster and allows a good color appraisal.

NOTE: Do not use saliva or water for this purpose.

Apply liquid medium evenly over the surface. Compare the restoration and shade guide using the principles and shade selection process we have presented. Evaluate the restoration's color to determine where the change is needed. This involves three adjustment factors:

- Chroma adjustment.
- Hue adjustment.
- Value adjustments.

The lab technician must have knowledge and a general understanding of the color wheel. This is important prior to making color adjustments to the restoration.

Chroma adjustment

Increasing and decreasing the chroma can be a very simple matter—or it can be very difficult. To increase the chroma, simply add the stain of the same dominant hue to the restoration until the intensity is correct. Decreasing chroma is more difficult. To decrease chroma, add the dominant hue's complementary color. For example, if the shade is bright yellow, add violet to neutralize it. This also lowers the restoration's value. Usually, fired porcelain has a higher value due to the way the porcelain is applied. If the porcelain always appears darker, it is because the porcelain is not properly condensed.

Hue adjustment

To change a restoration's hue, refer to the color wheel. For example, add pink to a yellow hue to achieve an orange hue. Pink is used rather than red because a true red is almost impossible to make with dental porcelain. Pink stain can simulate gingiva colors and neutralize green. To reduce an orange chroma, add yellow, which reduces the red content. These are the only two hue modifications needed, since natural tooth color ranges from yellow−red to yellow−orange.

Value adjustment

You can lower a restoration's value by adding the dominant hue's complementary color. If the dominant hue is orange, add blue; if yellow, add violet. Since most teeth are yellow, violet stain is used most often, especially in the incisal third. Adding violet to the incisal third can simulate translucency. If the restoration is predominantly orange, add blue instead. If, at any time, the actual restoration's hue can be seen rather than the desired neutral gray, remove the stain and repeat the procedure.

Brown stain is another powerful modifier used to lower value. Brown is composed of low value red, orange, and yellow. A small amount of brown applied to the surface increases chroma and lowers value.

Raising a restoration's value is next to impossible. The only method to raise value is to add a higher value stain. Sometimes a small amount of white stain can increase the value, but it is very opaque and decreases translucency.

Extrinsic characterization

Extrinsic characterization shares some similarities with intrinsic characterization; however, intrinsic stains are more natural appearing since they can be seen in depth. The ceramist's basic goal is to produce a restoration that is so natural it defies detection in the patient's mouth. Therefore, the characterization shouldn't be a focal point but should blend with the restoration. In the following paragraphs we look at the following factors:

- Proximal stains.
- Cervical stains.
- Enamel crack line.
- Hypocalcified area.
- Composite restorations.
- Occlusal and lingual anatomy.

Proximal stains

Every tooth has proximal stains to some degree. The stain's intensity and color vary with the patient's age and lifestyle. A young patient may have very little proximal staining compared to an older patient. The same comparison can be made between a coffee drinker and a noncoffee drinker. The dentist specifies the amount of proximal staining for that patient.

Figure 4–38 shows the area where the proximal stain should be applied. Apply an orange-brown stain—that complements the patient's characteristics—beyond the contact area, without covering the facial surface. For a fairly young patient, you may want to use a gray stain instead of the orange-brown stain. FDP proximal staining is done the same as for individual units.

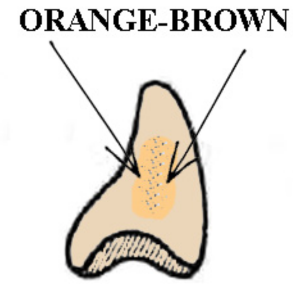


Figure 4–38. Proximal stain location.

Cervical stains

Tooth cervical areas reflect the gingival's pink color and may also be stained. This effect may vary from a light pink-orange color to an orange-brown color. Cervical staining is used on most shade guides. This staining influences the restoration's overall shade and should be included. Some dentists use a second shade guide with the necks removed to select the body shade. Ask the dentist if you should include cervical staining.

Cervical staining is often used to simulate the tooth's root portion. This is especially true with periodontally involved teeth and exceptionally long pontics. Apply an orange-brown mixture to the prepared area to accentuate the cementoenamel junction and make the restoration look shorter (fig. 4–39).

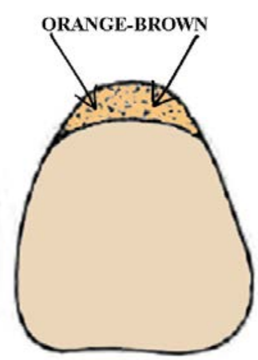


Figure 4–39. Defining the cementoenamel junction with stain.

Enamel crack line

The enamel crack line is hard to simulate with surface (extrinsic) stains. To give the line depth, the enamel crack simulation should have both a highlight and shadow. This can be done by applying a white and yellow stain (mixed in a 4:1 ratio) in a thin line. The excess stain is removed by a method called painting off. Use a clean brush to narrow the line's width, and then apply a second gray stain line distal to the first line, simulating the shadow (fig. 4–40).

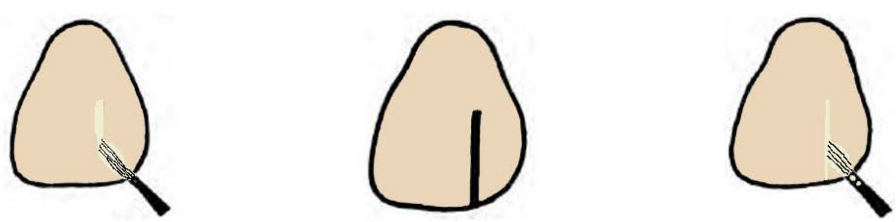


Figure 4–40. The paint off technique.

Narrow this second line until just a hint of a shadow remains (fig. 4–41).

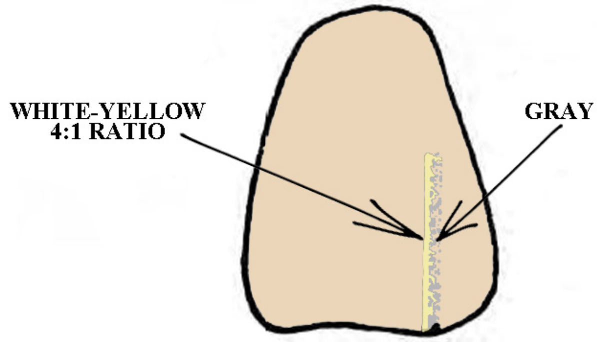


Figure 4–41. Close-up view of the enamel check line.

Sometimes enamel crack lines are discolored by food, tobacco, or other stains. If this happens, replace the white-yellow mixture with orange-brown, and apply a small amount of orange stain on either side of the first line to create the shadow.

Hypocalcified area

Hypocalcification areas result from calcium loss from the enamel and appear as white blotches or even white lines. Mix the white stain with liquid medium to a fairly heavy consistency. Although this white stain is quite opaque, it is sometimes difficult to apply in the desired degree of opacity. Do not use so much stain that it actually creates lumps on the surface. Figure 4–42 represents a hypocalcified area on a restoration. The desired effect should appear much the same after firing as it does when the stain is applied.

Composite restorations

Sometimes it's necessary to place a metal-ceramic restoration in a patient's mouth with many anterior composite restorations. A flawless restoration would stand out in such an environment. Select the proper color of an orange-brown mixture (with white, if needed) and apply it to the desired area. Then, outline the first application with a little brown stain. The outline should be narrowed to a thin marginal line. The desired effect is shown in figure 4–43.

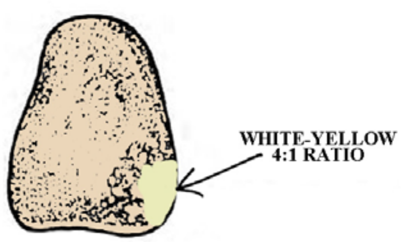


Figure 4–42. Hypocalcification.

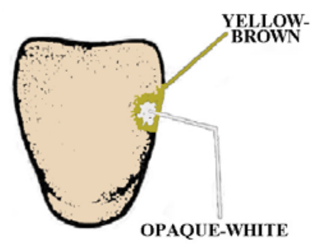


Figure 4–43. Discolored filling.

Occlusal and lingual anatomy

Posterior teeth occlusal anatomy and anterior teeth lingual anatomy should also be characterized to define surface detail and break up the basic shade. Your concern; however, is to avoid overusing stains. Different ratios of orange and brown are used, depending on the anatomy. A darker stain is normally applied to a defect such as a pit rather than to a groove or fissure. On occlusal surfaces, apply the stain randomly with a fine-tipped brush. Figure 4–44 shows the procedure. The lines should appear as merely suggestions of grooves, rather than being heavily accented. You can make the marginal ridges seem more translucent by adding violet stain, and you can highlight the cusp tips with a blue-white stain. In addition to occlusal anatomy, lingual anatomy may also be accentuated in much the same way (fig. 4–45).

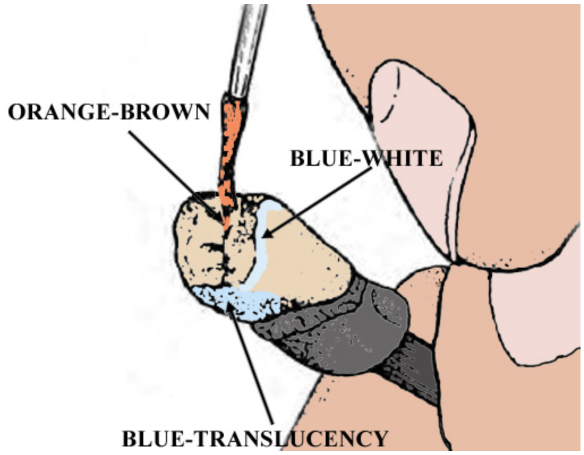


Figure 4–44. Occlusal staining.

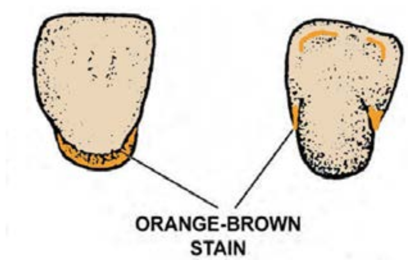


Figure 4–45. Highlighting cervical and lingual anatomy.

Glazing

A glazed porcelain surface has been described as being impervious to mouth fluids and biologically compatible with oral tissues. The glaze itself is a thin transparent glass. The amount of glaze on the surface determines its appearance. For example:

- A low glaze appears as a slight sheen with no surface detail loss.
- A medium glaze appears glossy with some rounding of fine detail. This type of glaze is usually preferred for beauty and long-lasting quality.
- A high glaze appears glossy (highly reflective, smooth) with greater surface detail loss and rounding.

The glazing technique can be either the autogenous (self-glazing) method or the overglaze (commercially prepared glaze powder) method. In the first method, the ceramic restoration is air-fired in a porcelain furnace until the desired amount of glaze is reached. The materials (glasses, fluxes) necessary to bring about this reaction are a part of the porcelain's original composition. In contrast, an overglaze is applied to the surface, air-fired to a preset temperature, and the glaze powder fuses to the surface, sealing the pores. Many dentists and technicians prefer an autogenous glaze for its durability, simplicity, and beauty. We briefly present both methods below.

Autogenous glazing

The autogenous glazing method is usually done in conjunction with extrinsic staining. After the restoration is processed; the stains fuse to the surface and become part of the thin transparent glass covering the restoration. Two factors are used to control the glass formation. They are time and temperature. Either variable can be increased or decreased to obtain the desired amount of glaze. For example, a restoration fired to 1,688 °F may require holding at that temperature for a 2- or 3-minute period. The same restoration fired to 1,724 °F may only require holding for 1 or 2 minutes. It is always easier and safer to increase the holding time than it is to increase the temperature. You might accidentally cause the restoration to coalesce (over fire) or devitrify. If the porcelain is overfired, it needs to be recharacterized. If the porcelain devitrifies, it may not take a glaze, in which case you must start from scratch.

After the extrinsic staining is complete, place the restoration on a firing tray; then place it on the firing table to dry. Set the firing temperature at the lowest manufacturer's recommendation, or 45 °F below the last known firing temperature for that restoration. A typical setting is 1,688 °F for 2 to 3 minutes. Air-fire the restoration using the proper time and temperature controls. Remove the restoration and visually inspect the glaze. If the restoration is underfired, immediately return it to the furnace and raise the temperature another 38 °F. If it is still underfired, raise the temperature yet another 38 °F, and hold the restoration at that temperature for 30 seconds to 1 minute. When you get the glaze you want, remove the restoration immediately and let it cool completely.

Overglaze glazing

Using an overglaze is much like regular glazing. You mix the overglaze powder with the liquid medium into a slurry that "strings" from the spatula when you lift it from the mix. Apply the mixture in one direction, using a small clean brush. Keep the mix even and remove any excess or puddling. Dry the overglaze in front of an open furnace as if it were a stain. Correctly applied glaze material appears as an even white layer after drying. Air-fire the restoration to approximately 1,580 °F. Immediately remove the restoration and let it cool. Some uses for this technique are to glaze denture teeth, glaze a ceramic restoration that has been adjusted, and to ensure a glazed surface covers a ceramic restoration that may have been difficult to glaze.

NOTE: An autogenous glaze is superior to an overglaze; therefore, avoid routinely using an overglaze.

Finishing and polishing are fairly standardized procedures. Remember the basic principles involving abrasives, and be alert at all times while you are finishing.

You will grow proficient in these procedures with practice. Let us look at some specific problems in finishing and polishing metal-ceramic restoration.

Polishing

By now, you have made almost all adjustments (seating, contacts, and occlusion). In addition, you have finalized the porcelain veneer by glazing. All that remains for you to do is to finish the visible metal surfaces. You should have removed all porcelain particles from the nonporcelain-bearing areas before glazing. It is frustrating to try to remove porcelain particles fused to the metal without disturbing the glaze surface. These fused particles are best removed by light grinding with a mounted stone or sandpaper disc. Any glazed porcelain area that was unavoidably removed should be rubbered smooth and polished or mechanically glazed.

Due to a difficult to remove oxide layer, the metal surface of most restorations will require stoning following the glaze cycle. It is a good idea to rubber from the metal surface onto the porcelain surface. Rubbering the other way makes the harder porcelain particles scratch the metal. When rubbered correctly, the restoration should be very easy to polish.

A polishing agent, such as tripoli or silicone abrasive, is used to provide a low shine on the metal's surface. Again, polish the porcelain-to-metal junction from metal to porcelain. Since metal-ceramic alloys are much harder, you will have a hard time getting a superior shine if you did not rubber the restoration completely. Patiently apply the abrasive to metal using a bristle brush or felt wheel. Let the abrasive do the polishing. Do not move to the next finer abrasive until the first one has done its job. You get the final high shine by applying rouge or polishing paste.

Special abrasive wheels and pastes are manufactured to mechanically glaze porcelain surfaces. You or the dentist can use them to make minor corrections to the porcelain's surface. Rough porcelain abrades enamel very quickly. Do not leave the porcelain in a rough condition, without a luster, or sheen.

Repairing porcelain restorations

Some of the more common failures are porcelain fractures. Normally, these problems can be traced to either faulty construction techniques such as procedures or design or accidental breakage caused by an occlusal interference. Regardless, the restoration must either be repaired or replaced. It depends largely upon the restoration type and the extent of the damage.

If the porcelain is chipped, you may be able to smooth the area and simply reglaze the restoration. If appearance is a factor and replacing the broken piece would be better, use special low-fusing porcelain. These air-fired porcelains come in a variety of shades and fuse at a temperature of approximately 1,598 °F or according to the manufacturer’s directions. Lightly grind the area to remove any surface roughness. Apply the appropriate shade porcelain to the defective area and process it. Make the necessary corrections to contour and then glaze the restoration. If you do not need to contour, you can process and glaze the restoration in one step.

The uses for low-fusing porcelains are too numerous to mention in this text. The possibilities range from adding colored porcelains on an existing surface to making metal and porcelain repairs during the same firing sequence. The usual way to gain this knowledge is through trial and error testing. What may work for one technician may not work for you. When all else fails, start at the beginning.

When you receive the repair, the decision to repair or replace should have already been made. If a large porcelain piece is missing or separated from the framework, remove the veneer. If this is the case, the dentist normally provides an impression with the restoration seated in the patient’s mouth and an opposing arch impression. Pour the final impression to serve as a diagnostic aid during the construction process. Remove most of the porcelain’s veneer by grinding with a large bulk-reducing wheel. You can sandblast or strip away the remaining porcelain from the framework using hydrofluoric acid or a substitute like No-San, Triodent Inc. You should then refinish and treat the substructure as a new framework.

Often, there are clinical factors that the requesting dentist has control over and you do not, but that does not mean that you should not know about these clinical problems. The better prepared you are, the better qualified you are to support the dentist. The following table lists common problems with the clinical side of metal-ceramic restorations:

Clinical Problems with Metal-Ceramic Restorations		
Problem	**Probable Cause(s)**	**Solution**
Porcelain flaking	Fine edges of porcelain in occlusal contact.	Porcelain-metal junctions must be at 90°.
	Porcelain too thick—over 1.5 mm.	Porcelain must be supported by metal.
Premature contact in occlusion	Wax-up or porcelain overbuilt; incisal guidance incorrect.	Posterior teeth mustn’t touch nonworking contacts; anterior teeth should be formed with custom incisal guide table.
No occlusal contacts	Wax-up or porcelain out of occlusion.	Remake restoration and confirm occlusion using indicator.
	Metal occlusal over polished.	Check occlusal contacts frequently—use the proper abrasive.
	Casting or die not seated completely during fabrication.	Periodically confirm seating of die and casting.
Shadow at porcelain metal junction	Porcelain overlapped porcelain metal junction.	Remove excess and polish junction.
	Glaze or stain over porcelain metal junction.	

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

817. Contouring the restoration

1. Why is precision grinding the incisal edge so important?

2. When establishing contour, why should you *not* reduce the porcelain less than 1.2 mm?

3. What distinguishes an older tooth from a younger tooth?

4. How can you prevent a restoration from appearing too long?

5. When is the best time to contour and carve the occlusal anatomy?

6. How should the separations between units of an FDP appear?

818. Glazing the restoration

1. What is the color range of natural teeth?

2. What color stain would you apply to a predominately yellow restoration to simulate a translucent incisal edge?

3. What color stain would you use to raise a restoration’s value? What is the downside to this?

4. What is the ceramist’s basic goal when using extrinsic staining?

5. When staining, what is used to simulate the tooth’s root portion?

6. What is the preferred glazing method? Why?

7. Why should you polish from the metal onto the porcelain instead of the porcelain onto the metal?

8. What type of porcelain is usually used for repairs?

Answers to Self-Test Questions

814

1. Undesirable color influences.
2. By rounding the labial line angles (the junction of two tooth surfaces) and softening the teeth's arrangement.
3. Surface texturing.
4. Flatten the facial surface and move the contacts facioincisally.
5. Adjust the incisal edges to the correct length, which is established by mandibular movements and indicated by visible wear.
6. Teeth with extra long clinical crowns can be made to appear shorter by carving a very definite cervical line.
7. Subtle axial rotation.

815

1. Mask or hide the underlying metal's color, simulate the dentine of a natural tooth and complement the body shade porcelain, and combine with the metal surface oxide to form a strong chemical bond.
2. About 0.2 mm.
3. Gentle vibration.
4. Apply a thin second opaque layer, covering all areas.
5. Overfired opaque, poor handling, incorrect finishing, surface contamination, and gases escaping from the casting.
6. Cracks and surface defects.

816

1. Condensing and slightly overbuilding the porcelain.
2. Vibration.
3. Seal the surface contact areas with clear fingernail polish or cyanoacrylate glue.
4. A dry buildup can trap large air bubbles and cause blotchy opacity.
5. A 90° shoulder preparation on the facial that extends from one proximal surface to the other.
6. To prevent cracks in the veneer because of steam releasing during the firing cycle.
7. By firing the mamelons in position, then stacking the rest of the crown.
8. By using opacious dentine porcelain.
9. Place a small amount of colorless porcelain in each groove.
10. Build the porcelain to full contour and hollow out the area to be filled. Lightly coat the cavity walls with yellow-brown stain. Then fill the cavity with opacious dentin, followed by clear porcelain.
11. The wedge technique.

817

1. The incisal form is readily noticed because it is so prominently silhouetted against the oral cavity's dark shadow.
2. To ensure minimum porcelain thickness for strength and appearance.
3. Loss of facial anatomy and surface wear.

4. Carve a cervical collar into the restoration.
5. When building the restoration in raw porcelain with the brush.
6. A deep V-shaped finely divided separation looks most natural.

818

1. Yellow-red to yellow-orange.
2. Violet.
3. White. It is very opaque and decreases translucency.
4. The characterization should appear normal. The characterization should not be a focal point, but blend with the restoration.
5. Cervical staining.
6. The autogenous method because of its durability, simplicity, and beauty.
7. If done the other way, the porcelain particles can scratch the metal.
8. Low-fusing air-fired porcelain.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter.

44. (814) You are attempting to attain a shade match of a patient's tooth when fabricating a metal-ceramic restoration. Covering or blocking all colors outside the gray or light-blue range during this process will prevent you from misperceiving the
    a. actual color.
    b. actual value.
    c. complimentary color.
    d. complimentary value.

45. (814) When fabricating metal-ceramic restorations, you can make periodontally involved teeth that have been restored with long clinical crowns to appear *shorter* by
    a. carving a definite cervical line.
    b. placing the cervical margin above the margin.
    c. placing the cervical margin below the margin.
    d. carving several horizontal lines across the facial surface.

46. (815) Opaque porcelain *does not*
    a. form a bond with the metal.
    b. mask the underlying metal's color.
    c. simulate the dentine of natural teeth.
    d. simulate the enamel of natural teeth.

47. (815) What is one solution for when the opaque layer blisters or bubbles?
    a. Finish in one direction.
    b. Dry opaque slowly before firing.
    c. Allow opaque to reach a viscous state.
    d. Cover opaque when not applying porcelain.

48. (816) On average, porcelain's shrinkage by volume is between
    a. 10 and 20 percent.
    b. 20 and 30 percent.
    c. 30 and 40 percent.
    d. 40 and 50 percent.

49. (816) When processing porcelain veneer, incomplete condensation of porcelain causes the buildup to shrink and
    a. crack.
    b. appear darker.
    c. appear lighter.
    d. compress the porcelain.

50. (816) What method of condensing porcelain is used to dry and shape the surface of the porcelain build-up?
    a. Whipping.
    b. Vibration.
    c. Capillary action.
    d. Pressure packing.

51. (816) When processing the porcelain margin on a metal-ceramic restoration, what can you use as a *release* agent when applying porcelain to the preparation's shoulder?
   a. Petrolatum.
   b. Mineral oil.
   c. Platinum foil.
   d. Cyanoacrylate.

52. (816) What *common* problem associated with applying veneer porcelain to the framework causes sub-surface porosity?
   a. Over condensing.
   b. Glazing under vacuum.
   c. Improperly condensed porcelain.
   d. Failure to moisten dentine porcelain.

53. (816) When you want to include special effects in a metal-ceramic restoration, you intrinsically stain the fired opaque to
   a. mask the opaque.
   b. simulate a decalcified area.
   c. provide a color background.
   d. reduce the restoration's value.

54. (816) What color stain can help simulate the natural tooth appearance of translucency at the mesial and distal incisal edges?
   a. Pink.
   b. Blue.
   c. White.
   d. Violet.

55. (817) When establishing contour, what must you inspect for fired porcelain particles or other interferences that might keep the restoration from seating on the die?
   a. Exterior.
   b. Interior.
   c. Lingual.
   d. Buccal.

56. (818) When glazing a restoration, you can *decrease* the restoration's chroma with extrinsic stain by
   a. lowering the restoration's value.
   b. covering the veneer with white stain.
   c. adding green stain to the cervical area.
   d. adding the dominant hue's complementary color.

57. (818) How can you lower a porcelain restoration's value?
   a. Intrinsic staining.
   b. Extrinsic staining.
   c. Decrease the chroma of the primary color.
   d. Add the dominant hue's complementary color.

58. (818) What is cervical staining used to simulate?
   a. Decalcified area.
   b. Enamel crack line.
   c. Hypocalcified area.
   d. Tooth's root portion.

59. (818) Routinely using what type of glaze is discouraged?
    a. Autogenous glaze.
    b. Overglaze.
    c. Medium glaze.
    d. Low glaze.

Please read the unit menu for unit 5 and continue ➔

Student Notes

Unit 5. Fixed Restoration Applications

THERE ARE TIMES when "traditional" approaches to fixed prosthesis fabrication must be modified or supplemented by using additional techniques and procedures. In this unit, we present information on posts and cores, surveyed crowns, porcelain laminate veneers, all-ceramic restorations, computer-aided design (CAD)/computer-aided manufacturing (CAM) technology, and three-dimensional (3D) medical modeling.

5–1. Metal Restorations

Sometimes, a patient requires more than a simple fixed restoration. Occasionally, a "component" restoration must be fabricated before the final restoration can be inserted. In this section, we discuss how to fabricate posts and cores and surveyed crowns.

819. Fabricating posts and cores

Post and core fabrication is a significant treatment step for endodontically involved teeth. By definition, these teeth have a disease that affects the dental pulp and periapical tissue. When dentists decide that endodontic treatment is appropriate, they will usually remove the dental pulp of the diseased tooth and replace it with an endodontic implant or post and core. The post and core can be fabricated using either the direct or the indirect technique. The dentist performs the direct technique, while the laboratory technician does the indirect technique. In this lesson, we discuss the following topics:

- Post and core applications.
- Post and core design considerations.
- Post and core design principles.
- Indirect fabrication procedures.
- Post and core systems.

Post and core applications

Most endodontically treated teeth have been so destroyed by cavities or previous restorations that there is very little clinical crown left. Often, only the root is left to retain the crown. When this happens, you must make a device that anchors in the root and replaces the supragingival (above the gingiva) axial walls of the standard crown preparation.

Posterior teeth normally can be reconstructed using a pin-retained amalgam or composite restoration. On occasion, a post and core can be constructed for use on posterior teeth. Illustrations are shown on figure 5–1. Anterior teeth that have been endodontically treated should always be reinforced with a post and core, or simply a core alone. The post and core are usually made separate from the crown and cemented in the canal. The crown is then made and cemented over the core, as shown in figure 5–1.

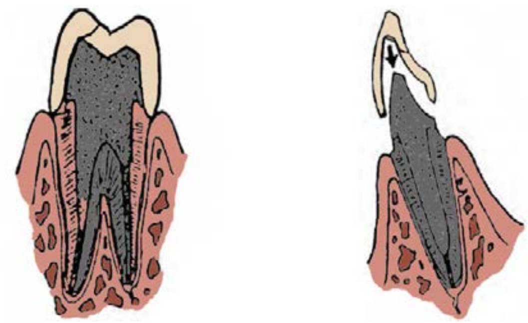


Figure 5–1. Posterior and anterior post and core.

Design considerations

To design a post and core preparation successfully, you must understand the six design requirements. The numbers on figure 5–2 correspond to the following criteria for the post and core preparation:

1. Complete apical seal.
2. Minimum canal diameter with no undercuts.
3. Sufficient post length.
4. Horizontal ledge.
5. Vertical wall to prevent rotation.
6. Final restoration margin on sound tooth structure.

You should keep these design requirements in mind as you produce and finish posts and cores.

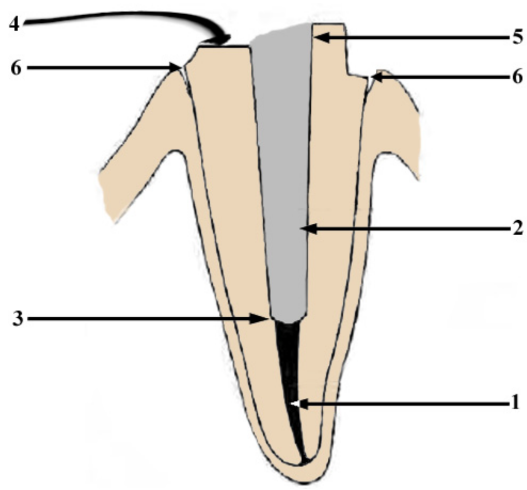


Figure 5–2. Post and core preparation design criteria.

A properly designed post and core is similar in function to a prepared abutment tooth. Each provides support for the final restoration; however, a post and core must meet even more criteria than an abutment tooth because the support structure is internal to the tooth (fig. 5–1).

Design principles

Since the post fits into the excavated pulp of the tooth, it is vitally important that the post meet design principles for these two factors:

- Resistance.
- Retention.

Resistance

Resistance is defined as a post and core's ability to resist occlusal loading. Resistance is further defined by two factors: (1) rotational resistance and (2) stress distribution, defined below.

Resistance Factors	
Factor	**Description**
Rotational resistance	Rotational resistance is defined as the post's ability, by design, to *resist rotating* during function.
Stress distribution	Stress distribution is the post's ability to resist lateral (side-to-side) motion.

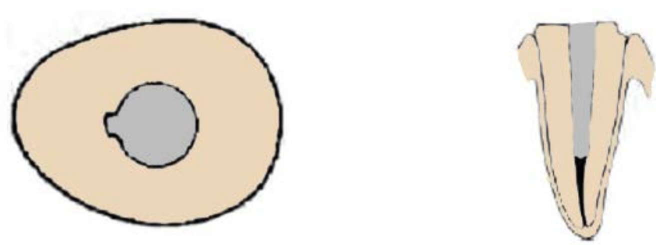
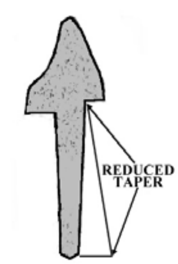
A post that fails to meet these design criteria can transfer disproportionate occlusal stress to the surrounding tooth structure, causing the supporting tooth to fracture.

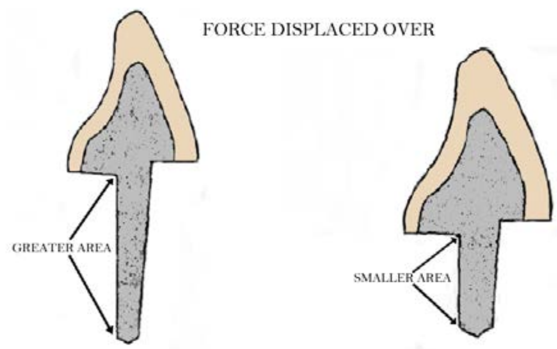
Retention

Retention is defined as the post and core's ability to oppose dislodgment. Post retention can be either increased or decreased based on these four design factors:

- Preparation geometry.
- Post length.
- Post diameter.
- Post surface texture.

The table below describes these factors further:

Retention Design Factors	
Factor	**Description**
Preparation geometry	Preparation geometry is the shape of the excavated canal (fig. 5–3). Some tooth canals, maxillary central incisors, in particular, have a circular cross-section. This circular shape makes it difficult to prevent rotation of the post.  **Figure 5–3. Preparation geometry for excavated tooth canal.** A parallel walled or reduced tapered (minimally tapered) post design is usually recommended to reduce this problem (fig. 5–4).  **Figure 5–4. Reduced taper post design.**
Post length	Post length and retention increase proportionately—as post length increases so does retention; however, a post that is too long can damage the seal of the root canal or perforate the apical portion of the canal. Conversely, a post that is too short is likely to fail and fracture

Retention Design Factors	
Factor	**Description**
	the surrounding tooth canal because of lateral force distribution (fig. 5–5).  **Figure 5–5. Short post and lateral force distribution.**
Post diameter	Increasing post diameter to improve retention is *not* recommended because surrounding tooth structure is thinned and weakened.
Post surface texture	Surface texture of the post should be serrated or roughened as opposed to smooth. This is particularly important if the post designed is tapered.

Indirect fabrication procedures

Regardless of whether the direct or indirect fabrication technique is used, three initial clinical procedures for endodontically treated teeth are used:

- Removing the pulp.
- Enlarging the canal.
- Preparing the coronal tooth structure where the final restoration will rest.

After these clinical procedures are completed, you can fabricate a custom post and core. To do this, follow the procedures below.

Fabricating a Custom Post and Core	
Step	**Action**
1	Disinfect and inspect the impression for accuracy.
2	Pour the impression.
3	Inspect the cast for voids or nodules.
4	Return the cast to the dentist to identify margins.
5	Apply separating medium to the interior of the preparation and the entire area that will be waxed.
6	Cut notches in the plastic sprue to aid in the retention of the wax.
7	Trim the tip of the plastic sprue to fit into the root canal and to extend to bottom of the preparation.
8	Fill the apical end of the canal with a soft wax such as margin wax.
9	Warm the sprue slightly and insert it completely.
10	Allow the wax to cool and then remove the wax post.
11	Rewax if the pattern has voids or breaks.
12	Replace the pattern in the previous position.
13	Build up the core of the pattern with inlay wax to simulate contours of an ideal crown preparation.
14	Refine the margins of the pattern using the preferred waxing instrument.
15	Sprue the post and core pattern on the incisal or occlusal surface.
16	Invest the pattern in accordance with (IAW) manufacturer’s instructions.
17	Cast the pattern with the requested metal.

Fabricating a Custom Post and Core	
Step	**Action**
18	Divest and deoxidize the casting.
19	Remove any nodules using burs or stones.
20	Check the casting fit using a disclosing medium and gently seat the casting into the preparation.
21	Relieve any spots that are disclosed by the medium using a second pour cast if possible, repeat until the casting seats into the preparation and the margins are closed.
22	Desprue the casting.
23	Recontour the sprue attachment area.
24	Finish the core area using stones and rubber wheel.
25	Air-abrade the entire casting.
26	Place the casting in the ultrasonic cleaner for 2–3 minutes.
27	Disinfect the restoration.

Post and core systems

The following table presents a variety of available post and core systems. As you can see, the table presents the type, recommended use, advantages, and disadvantages:

Post and Core Systems			
Type	**Recommended Use**	**Advantages**	**Disadvantages**
Prefabricated			
Tapered.	Small circular canals.	Minimum canal excavation. High strength and stiffness.	Less retentive than parallel or threaded systems.
Parallel-sided.	Small circular canals.	High strength. Good retention.	Larger canal required. Corrosion of stainless steel core. Expense of precious-metal post.
Threaded.	Maximum retention.	Only when maximum retention required.	Stresses tooth canal. Larger canal required.
Direct Fabrication			
Amalgam.	Molars with adequate tooth structure.	Minimum canal excavation. Simple technique.	Low tensile strength. Corrosive with base metals.
Glass ionomer.	Use on teeth with minimal tooth structure missing.	Minimum canal excavation.	Low strength. Difficult to condense.
Composite resin.	Use on teeth with minimal tooth structure missing.	Minimum canal excavation.	Low strength. Micro-leakage.
Indirect Fabrication			
Cast post and core.	Elliptical or flared canals.	High strength. Improved fit over prefabricated.	Time consuming procedure. Expense.
Combination			
Wire post cast core.	Small circular canals.	High strength.	Corrosion of base metals.

820. Fabricating surveyed crowns

Occasionally a patient with an existing RDP may require a fixed restoration on a supporting abutment tooth—a surveyed crown. In addition to meeting all the prescribed requirements of a “typical” fixed restoration, a surveyed crown must also support the RDP. Constructing a surveyed crown that meets this support prerequisite requires that you understand the design principles of surveyed crowns. In this lesson, we present two important subjects:

- Surveyed crown design principles.
- Fabrication procedures for a surveyed crown.

Design principles

You have three primary concerns when you are designing surveyed crowns:

- Path of insertion (of the proposed RDP).
- Axial contours.
- Rest seats.

Path of insertion

The path of insertion is vitally important to the health and longevity of the underlying abutment tooth. This path is determined by the relative alignment of the long axis of the teeth that will support the RDP. The inclination of the long axis will also determine the optimum path of RDP insertion and removal. Careful planning is necessary when selecting this “path” for surveyed crown preparations.

Axial contours

Axial contours of surveyed crowns are influenced by the path of insertion. Unlike conventional crowns whose axial contours usually parallel the long axis of an individual tooth, the axial contours of surveyed crowns must parallel the path of insertion of the RDP. This path will influence the shape and appearance of the axial surfaces of a surveyed crown.

The axial areas of a surveyed crown that provide retention and bracing—for the RDP—are the guide planes and reciprocal planes (fig. 5–6). Often these areas require greater tooth reduction than a typical fixed restoration.

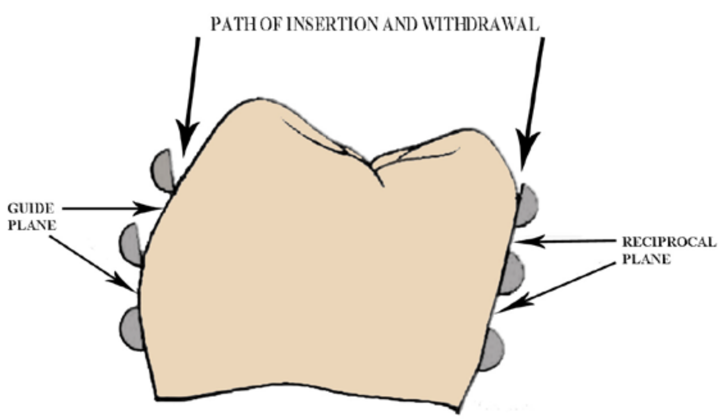


Figure 5–6. Guide and reciprocal planes of surveyed crown.

Additionally, surveyed crown axial surfaces adjacent to an edentulous ridge often require greater reduction. This is particularly evident if a surveyed crown must be contoured to accommodate the distal guide plane and allow the nonretentive part of an occlusal approach clasp to be positioned as far gingivally as possible (fig. 5–7). Once this path is determined, the appropriate anterior posterior and mediolateral cast tilt is determined.

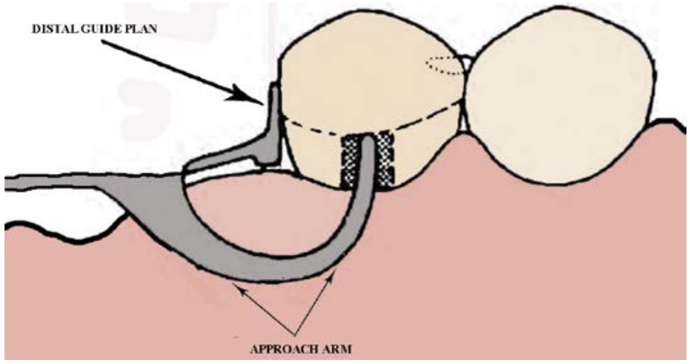


Figure 5–7. Distal guide plane adjacent to edentulous ridge.

Rest seats

Rest seats for surveyed crowns may require more than the minimum 1 mm occlusal reduction. To reduce lateral forces, rest seats should be spoon-shaped. The junction between the internal aspect of the rest seat and the proximal guide plane should be rounded to reduce framework stress and ultimately crown failure.

Each of these design principles will influence the dentist's surveyed crown design. After the design has been determined, there are three basic approaches to fabricating a surveyed crown—direct, indirect, and combination.

Direct

For the direct method, the dentist creates the pattern and has the technician cast and finish the restoration.

Indirect

When using the indirect method, the laboratory technician creates the pattern, casts, and finishes the restoration. The following procedures provide step-by-step guidance for the indirect method:

Indirect Method of Fabricating a Surveyed Crown	
Step	**Action**
1	Inspect the die preparation for undercuts or distorted areas.
2	Block out any undercuts, mark the margins, and apply die spacer/hardener.
3	Verify there is adequate occlusal reduction for rest thickness.
4	Apply the separating medium to the die and opposing teeth.
5	Form a coping on the die.
6	Remove the wax coping and inspect the internal surface for voids.
7	Replace the wax coping on the die and reseal with inlay wax.
8	Place the master cast on the articulator and reduce any occlusal interferences.
9	Apply wax to form the lower 2/3 of the tooth contour.
10	Wax all occlusal aspects of the pattern.
11	Allow wax coping to reach room temperature. Check occlusion.
12	Apply wax to any deficient contours, then smooth and refine the entire pattern.
13	Remove the master cast and position it on the surveyed table.
14	Reestablish the tilt to the prescribed anteroposterior and mediolateral markings using tripod marks.
15	Lock the table in place.
16	Use an undercut gauge to determine a desirable undercut depth for the clasp tip.
17	Carve the guide planes at the required locations.

Indirect Method of Fabricating a Surveyed Crown	
Step	**Action**
18	Adjust the contours to ensure the surveyed lines are compatible with the proposed clasp assemblies.
19	Carve the rests in the prescribed locations.
20	Smooth and refine the entire pattern.
21	Sprue in non-critical areas; invest, burnout, and cast.
22	Finish and polish the restoration. **NOTE:** Do not over finish the crown especially in undercut, guide plane, and rest seat areas.
23	Clean and disinfect the finished restoration.

Combination

As the name implies, the combination method is a hybrid of the direct and indirect method. When the combination method is used, the dentist provides a coping with predetermined axial contours and rest seats; the lab then completes the restoration.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

819. Fabricating posts and cores

1. When looking at the resistance factors for a post and core, what role does stress distribution play?

2. When considering design criteria for a post and core, define retention.

3. What are the four design factors that can either increase or decrease post retention?

4. When considering fabrication procedures for a post and core, what initial clinical procedures for endodontically treated teeth are used?

820. Fabricating surveyed crowns

1. When a surveyed crown is fabricated, what primary design concerns must be considered?

2. What design criteria is vital to maintaining the overall health of the abutment tooth?

3. Why do surveyed crown axial surfaces, adjacent to an edentulous ridge, require a greater reduction?

4. Why should a rest seat be spoon-shaped?

5. When a surveyed crown is fabricated, what method is a hybrid of the indirect and direct methods?

5–2. All-ceramic Restorations

Material development and improvement have expanded the use of porcelain laminates throughout dentistry. Today's all-ceramic materials can provide a functionally sound and esthetically pleasing restoration that is nearly indistinguishable from the surrounding natural teeth. Additionally, advances in the use and application of dental implants have permitted some patients to have "fixed" rather than "removable" prostheses. In this section, we present information about porcelain laminate veneers and other all-ceramic restorations.

821. Fabricating porcelain laminate veneers

In this lesson, we will discuss some important topics as they apply to the fabrication of porcelain laminate veneers. As we go through the lesson, we will cover these subjects:

- Fabrication methods.
- Advantages.
- Refractory cast technique.

Fabrication methods

There are three common methods to fabricate porcelain laminate veneers, as described in the following table:

Fabricating Methods for Porcelain Laminates	
Method	**Description**
CAD/CAM	The CAD/CAM method is a process that involves the use the technology. The CAD scanner, *along* with the milling unit, can produce an accurate laminate for the patient.
Refractory method	The refractory method uses a duplicated master die, which forms the foundation for fabricating the porcelain laminate. This technique is still used but *not* as often because of improvements in dental porcelains.
Lost-wax method	The lost-wax method utilizes an existing concept; however, instead of a metal alloy replacing the "lost-wax", an all-ceramic material is cast or injected into the wax-up mold.

Advantages

Porcelain laminate veneers are a conservative method for restoring the appearance of discolored, pitted, or fractured anterior teeth. Usually a laminate veneer requires only 0.5 mm facial reduction; consequently, this minimal tooth modification has some distinct advantages over conventional metal-ceramic crowns:

- Partial versus complete circumferential tooth reduction.
- Maintaining the existing natural lingual contours—patient cannot "feel" any change.
- Less treatment time for patient and dentist.

Refractory cast technique

All-ceramic systems that eliminate the use of platinum foil are now available. Depending on the system, the laminate is constructed in wax, invested, and "formed" using an all-ceramic system. Inlays and crowns can also be constructed in an all-ceramic material. These systems primarily use a refractory material to form the "working" model.

NOTE: In this case, refractory is defined as a heat-resistant ceramic material that does not deform or erode when exposed to high temperatures.

Porcelain laminates are constructed and fired directly on the working (refractory) cast. The procedures to fabricate a porcelain laminate veneer are as follows:

Refractory Cast Procedures for Porcelain Laminates	
Step	**Action**
1	Inspect the master cast for accuracy.
2	Block out undercuts and apply the die spacer to the veneer surfaces.
3	Duplicate the master cast using polyvinyl siloxane impression material.
4	Pour the refractory cast and trim to include one tooth on each side of the veneer area.
5	Mark the margins of the refractory cast using a wax pencil.
6	Degas the refractory cast.
7	Soak the refractory cast in distilled water to displace air.
8	Apply a wash coat of dentine porcelain and then fire according to manufacturer's directions.
9	Repeat the soaking procedure and build the dentine porcelain to full contour.
10	Cut back the dentine buildup and apply enamel porcelain, over-building slightly.
11	Fire the porcelain buildup according to the manufacturer's directions.
12	Contour the fired porcelain to duplicate the contours of the surrounding dentition.
13	Color-correct the veneer to the prescribed shade, and fire to a glaze.
14	Remove the bulk refractory material with a bur.
15	Air-abrade the residual refractory material with aluminum oxide or glass beads at a low psi.
16	Fit the veneer to the master cast using disclosing medium and a stereomicroscope.
17	Adjust the restoration with fine-grit diamond points.
18	Polish the restoration with diamond paste.
19	Clean and disinfect the veneer.

822. Fabricating all-ceramic restorations

The advent of improved ceramic material has changed how dental porcelains can be fabricated and used in prosthodontic dentistry. All-ceramic restorations may now be fabricated using two methods:

- Compression-molded method (pressable porcelains).
- Computer-designed and milled systems.

Pressable porcelains

Though the lost-wax technique is quite common for all-metal fabrication procedures, it was not until the early 1980s that this technique could be used with pressable (injection-molded) porcelains. Using the conventional lost-wax process, a mold is created to receive the material, in this case pressable porcelain. Pressable porcelain uses glass or other porcelain material to form a porcelain core, inlay, veneer, or crown. The porcelain is "pressed" by heating and compressing a heated porcelain ingot into the mold under pressure. This porcelain can be very esthetic because the restoration picks up the surrounding dentition's color. The two primary advantages of this material are its low abrasive quality and its resistance to plaque accumulation. An example of a pressable porcelain is IPS e.max Press.

Fabricating pressable all-ceramic restorations

The following steps describe the fabrication of the pressable, all-ceramic restoration:

Fabricating a Pressable, All-Ceramic Restoration	
Step	**Action**
1	Apply separator.
2	Wax the crown to full contour.
3	Attach a single 8-gauge sprue, 6–8 mm long. Attach the sprue to the incisal area of anterior teeth, or non-critical cusp of posterior teeth.
4	Use the silicone/plastic investment ring to form the investment cylinder. Place the sprued pattern in the thermal zone. Place the ring base on one end of the ring and seat the ring stabilizer on the other end.
5	Measure the pressable ceramic investment and liquid per the manufacturer's instructions and vacuum mix for the specified time according to manufacturer's directions. Carefully fill the cylinder just below the ring stabilizer. Remove the ring stabilizer and slowly position the investment gauge.
6	After the investment has set, remove the gauge, ring base, and investment ring. Scrape only the rough dimple created by the investment gauge. *DO NOT* alter the 90° angle of the mold.
7	Place the mold and support tray into the furnace for burnout. Follow manufacturer's instructions for heat rate and temperature settings. The settings are dependent upon the material being used. For example, with e.max Press and the IPS PressVest investment, the temperature of the preheating furnace when placing the investment ring is room temperature. When using the IPS PressVest Speed investment, the preheating temperature should be 850 °C/1562 °F. With some investment material it is desirable to scrape the top and outside area of the rings. The burnout times are also dependent upon the investment material and ring size.
8	Next, remove the mold from the furnace with opening up and immediately place the ingot(s) from the support tray into the hot mold.
9	Place the plunger on top of the ingot ensuring it's fully seated in the mold. Position the loaded mold in the center of the pressing furnace, manually close the muffle, and press the start button. The program will proceed automatically and alert when complete. Remove the mold and allow it to cool.
10	Recover the crown by first measuring the depth the first plunger traveled during the pressing. Mark this depth around the outside of the cooled mold. Cut along the line with a large separating disc, and pry at the line with a plaster knife.
11	Remove the remaining portion of the investment using glass beads. Desprue the crown with a diamond disc and recontour the sprue attachment point. Be careful near the margin areas.
12	Gently seat the ceramic unit on the die. A dentine-shaded die is used to evaluate restoration color during the staining procedures.
13	Reduce the enamel portion with diamonds or abrasives, leaving a dentine core of at least 8 mm. Slight reduction of all axial surfaces is also necessary to allow for the application of a neutral material layer. **NOTE:** Reducing the enamel portion is not always necessary because enamel stain effects are manufactured.
14	When contouring is completed, gently bead blast and steam-clean the dentine core.
15	Apply incisal layering material over the entire surface and fire in a porcelain oven at the appropriate temperature or cycle specific to the material being used.
16	Characterize the dentin by applying and firing stains or modifiers.

Fabricating a Pressable, All-Ceramic Restoration	
Step	**Action**
17	Apply incisal material to full contour. Slightly overbuild the incisal layer and add to the proximal contacts to compensate for shrinkage during firing.
18	Make final corrections to the shape of the restoration and apply one thin coat of glaze.

Fabricating pressable ceramic post and core

Procedures for ceramic post and core fabrication are the same as above, except this impression is generated after a tapered zirconium ceramic post insertion. This laboratory procedure begins when the technician waxes a core to the post. The post and attached wax core are then sprued, invested, burned out, and pressed using the same procedures as stated above. The material that forms the core is a prefabricated ceramic ingot made of silicon dioxide and zirconium dioxide.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

821. Fabricating porcelain laminate veneers

1. What benefits do porcelain laminate veneers offer?

2. What are the characteristics of a refractory cast?

3. Porcelain laminates are constructed and fired on what surface?

822. Fabricating all-ceramic restorations

1. List two benefits provided by pressable porcelains.

2. How long is the sprue attachment on a pressable, all-ceramic restoration?

5–3. Computer-Aided Technology

Technology plays an important role in all aspects of our daily life as well as in dentistry. CAD/CAM of dental appliances and prostheses is now widely used across the globe. The evolution of dental materials and advances in computer science has led to a rapid development in CAD/CAM technology. In this section, we will discuss CAD/CAM and 3D medical modeling.

823. Computer-aided design/computer-aided manufacturing

Digital dental capabilities vary according to your location. You may use several different brands of this system across the Air Force throughout your career. It is imperative you follow the manufacturer's instructions while utilizing this equipment for best results.

The CAD/CAM system consists of three components:

- A digitization tool/scanner.
- Software for processing data.
- Technology that manufactures the desired product from scanned data.

The main benefit of using computer-aided technology is that conventional ways to fabricate appliances, prostheses, and even impressions is not needed as much anymore. CAD/CAM systems can save the dentist chair time and eliminate time-consuming steps for the laboratory technician.

WARNING: The laboratory scanning and milling units must not be installed or operated in the vicinity of the patient (within a radius of 6 feet or 1.8 meters [m]). The unit complies with the definition of a class 1 laser product. The scanner contains a class 2 laser source.

Before starting the unit for the first time, you must calibrate it. To calibrate the unit, use only the calibration pins and the associated calibration specimen supplied with the unit. Remember to follow manufacturer's recommendations when operating the unit; ensure proper safety and warning signs are on display.

Computer-aided design

You will design your restoration using CAD software and scanner. You will need to carefully follow manufacturer's instructions for your base's specific unit.

The CAD scanner is the starting point of fabricating a prosthesis using the computer. To begin a new case you will open the design software and follow program prompts to set up a file. You will create a case by entering the information from the DD Form 2322. You must select case specifics such as the tooth number, type of restoration, and the material you will be using. You must verify all information is correct to move to the next screen.

Scan models

You will scan the models IAW the manufacturer's instructions. Start with the working cast and the opposing casts. Once you have scanned the casts, you will need to scan the buccal bite to transfer the occlusion from the casts to the system.

Procedures for Scanning a Dental Cast

Step	Action
1	If required, spray scanning medium on cast and prepped dies.
2	Choose materials and type of restoration (varies per CAD/CAM system and is sometimes the final step before milling).
3	Lock cast into scanning table, ensure dies are fully seated.
4	Complete preliminary scans per manufacturer's instructions.
5	Scan Antagonist matrix and opposing arch and/or scan "bite" of upper and lower casts.
6	Set locally established parameters.
7	Design restoration(s) according to traditional crown and bridge requirements and DD Form 2322.
8	Digitally place restoration into block puck, sometimes referred to as "nesting". When possible, ensure maximum use of resources by placing multiple restorations in one block/puck.
9	Prepare system for milling by following manufacturer's instructions (usually includes placing block/puck into system and transferring data to milling machine).

Design restoration

A dimensional image of the scanned model is displayed on screen, ready for quick and easy adjustments. Add cusps and shoulders. Automatically set coping thickness based upon doctor's choice of veneering porcelain, unless the final restoration is a full contour crown. Verify the occlusal and proximal contact strength and thickness. A local parameter sheet should be created to standardize milling results.

Send CAD/CAM e-file

After scans have been taken or once restoration is completely designed the systems allow you to export the case. To export only model scans, open up the top menu and click on “Export”. To export a fully designed restoration you must be at the final milling section and click on “Export Selection”. Select the type of file you wish to export (e.g., *.dxd, or *.stl) then use the standard Windows file dialog box to select the location of the file (e.g., hard disks/network drives, authorized universal serial bus [USB] devices, and compact discs [CD]/digital versatile discs [DVD]/Blu-rays). Follow the manufacturer’s recommendation for file set up of multiple scanners to milling unit machines.

Computer aided manufacturing

Once you have completed the design and have assessed the restoration in the milling simulation, you can mill the restoration. The system will state the smallest block for milling. The sizes and names of each block varies per manufacturer (e.g., I 12, C 14, YZ-14, YZ-20/15, etc.). Depending on the choice of material to be used, the restorations may be milled with an oversize of approximately 20–25 percent that subsequently shrinks to the exact fitting final contour during a sintering process. The exact shrinkage data of the respective blocks are stored in a “QR code” or barcode on the block itself, which is automatically read prior to the milling process.

Sinter CAD/CAM unit

Select material type on the sintering oven display screen. Place all the same items on the tray and start the sintering oven. Note the manufacturer’s operating guide for troubleshooting.

Build up porcelain on CAD/CAM unit

Use the same technique the manufacturer recommends for used material.

Finish and adjust CAD/CAM unit

Follow the porcelain manufacturer’s recommendations for finishing and polishing of materials used.

824. Three-dimensional medical modeling

The dental community is embracing the cutting-edge production of 3D printing. It is now possible to print models and some appliances. This technology is helping to improve patient care by making the fabrication process faster and more accurate. Printers enable the providers and technicians to go from patient scans to 3D prints to ready for use dental products. What once took days to weeks can now be done in a matter of hours.

Digital modeling

When utilizing a 3D printer, it is important to read and understand the manufacturer’s instructions. All 3D printed dental products follow the same basic steps.

- Scan.
- Plan.
- Print.
- Prepare.

Scan

The first step in 3D medical modeling is the scan. This can be done two ways. The provider can capture the patient’s anatomy digitally by using an intraoral scanner or the dental lab technician can capture impressions or stone models using a desktop optical scanner.

Plan

The planning phase begins by using the digital scan of the patient’s anatomy. The technician will design the prescribed appliance using CAD software. Most printers are compatible with any dental CAD software that allows open export of digital design files. The design step ends with the export of the digital model as .stl file.

Print

To print the file you must import the .stl file into the printer’s software and orient the object IAW the manufacturer’s instructions. After orienting the object, place supports. You must ensure printability of the object by verifying there are no cups or minima.

When referencing 3D modeling, a cup is defined as hollow models and concave surfaces that risk creating a suction cup during printing. A minima is defined as the lowest point of a surface.

Upload the object to the 3D printer. Ensure you don the proper personal protective equipment (PPE). Load the resin into the printer. Commence printing IAW the manufacturer’s instructions and allow the object to completely print.

Prepare

When the object you have printed is finished, remove it from the printer and wipe down any uncured resin using isopropyl alcohol (IPA). Place the object in the washing unit and wash the object IAW the manufacturer’s instructions. Once complete, remove the object from the washing unit and place the object into the curing unit. Cure the object IAW the manufacturer’s instructions. Remove the object from the curing unit; remove supports from the object. You must finish and polish supports/object as needed.

Figure 5–8. Printed model.

	Steps for Printing a 3D Object
Step	**Action**
1	Open CAD software.
2	Open .stl file in CAD software.
3	Orient object IAW manufacturer’s instructions.
4	Place supports on object.
5	Ensure printability of object (no cups or minima).
6	Upload object into 3D printer.
7	Don PPE.
8	Load resin into 3D printer.
9	Commence printing IAW manufacturer’s instructions.
10	Allow object to print completely.
11	Remove object from 3D printer.
12	Wipe down any uncured resin using IPA.
13	Place object in washing unit.

	Steps for Printing a 3D Object
Step	**Action**
14	Wash object IAW manufacturer's instructions.
15	Remove object from washing unit.
16	Place object in curing unit.
17	Cure object IAW manufacturer's instructions.
18	Remove object from curing unit.
19	Remove supports from the object.
20	Finish/polish supports and object as needed.

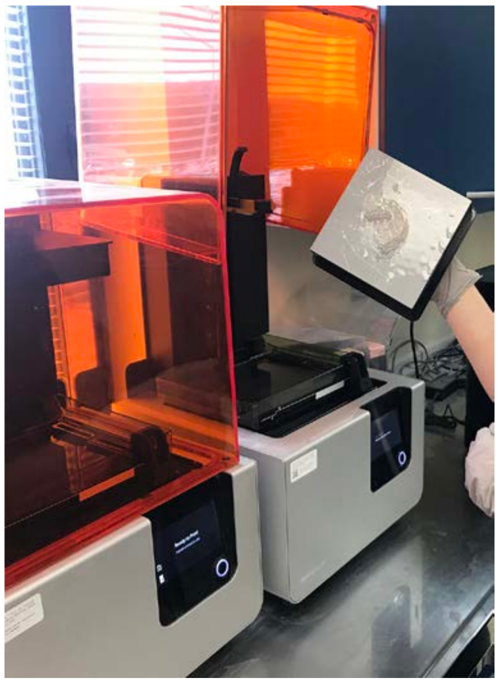


Figure 5–9. 3D printing.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

823. Computer-aided design/computer-aided manufacturing

1. The CAD/CAM system consists of what three components?

2. What is one of the main benefits for using CAD/CAM technology?

3. What is the starting point of fabricating a prosthesis using the computer?

4. What percent of restoration shrinkage occurs after sintering?

824. Three-dimensional medical modeling

1. What basic steps do all 3D printed dental products follow?

2. The first step in 3D medical modeling is the scan. What are the two ways it can be accomplished?

3. What phase begins by using the digital scan of the patient’s anatomy?

4. What is defined as hollow models and concave surfaces that risk creating a suction cup during printing?

5. When the object you have printed is finished, remove it from the printer and wipe down any uncured resin using what substance?

Answers to Self-Test Questions

819

1. The post and core’s ability to resist lateral or side-to-side motion.
2. The post and core’s ability to oppose dislodgment.
3. (1) Preparation geometry.
   (2) Post length.
   (3) Post diameter.
   (4) Post surface texture.
4. (1) Removing the pulp, (2) enlarging the canal, and (3) preparing the coronal tooth structure where the final restoration will rest.

820

1. Path of insertion, axial contours, and rest seats.
2. Path of insertion.
3. Allows room for placement of the distal guide plane and the nonretentive part of the clasp.
4. To reduce lateral forces.
5. Combination method.

821

1. Partial versus complete circumferential tooth reduction, maintains existing lingual contours, and takes less treatment time for patient and dentist.
2. It is a heat resistant ceramic material that doesn’t deform or erode when exposed to high temperatures.
3. Directly on the working (refractory) cast.

822

1. Relatively low abrasives and low-plaque accumulation.
2. 6–8 mm long.

823

1. A digitization tool/scanner, software for processing data, and technology that manufactures the desired product from scanned data.
2. CAD/CAM systems can save the dentist chair time and eliminate time-consuming steps for the laboratory technician.
3. CAD scanner.
4. 20–25.

824

1. Scan, plan, print, prepare.
2. The provider can capture the patient’s anatomy digitally by using an intraoral scanner or the dental lab technician can capture impressions or stone models using a desktop optical scanner.
3. Planning.
4. A cup.
5. IPA.

Complete the unit review exercises.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter.

60. (819) A properly designed post and core is similar in function to a
    a. prepared abutment tooth.
    b. metal ceramic crown.
    c. full gold crown.
    d. missing tooth.

61. (819) What is defined as a post and core's ability to resist occlusal loading?
    a. Retention.
    b. Resistance.
    c. Rotation.
    d. Stress.

62. (819) Which is *not* a prefabricated post and core system?
    a. Tapered.
    b. Amalgam.
    c. Threaded.
    d. Parallel-sided.

63. (820) Which areas of a surveyed crown provide retention and bracing?
    a. Axial.
    b. Mesial.
    c. Marginal.
    d. Proximal.

64. (820) What technique is *not* an approach to *fabricating* a surveyed crown?
    a. Direct.
    b. Indirect.
    c. Prefabricated.
    d. Combination.

65. (821) What process uses a scanner *and* a milling unit to produce a laminate for the patient?
    a. Ingot.
    b. Lost-wax.
    c. Refractory.
    d. Computer-aided design (CAD) and computer-aided manufacturing (CAM).

66. (822) You can fabricate all-ceramic restorations by using the compression molded method and
    a. computer designed and milled systems.
    b. sintering technique.
    c. refractory materials.
    d. lost wax system.

67. (823) Before starting the computer-assisted design/computer-aided manufacturing (CAD/CAM) unit for the first time, what must you first do?
    a. Calibrate it.
    b. Wipe it down.
    c. Install software.
    d. Check power source.

68. (823) After scans have been taken, or once a restoration is completely designed, the systems allow you to
    a. import the case.
    b. export the case.
    c. activate the case.
    d. eliminate the case.

69. (824) What are the basic steps to follow when using a three-dimensional (3D) printer?
    a. Scan, plan, print, prepare.
    b. Scan, print, design, prepare.
    c. Digitize, plan, print, prepare.
    d. Digitize, print, design, prepare.

Glossary of Terms, Abbreviations, and Acronyms

Terms

abutment—1. On removable partial dentures, it is the tooth on which a clasp is placed to support and retain the removable partial denture. **2.** On fixed dental prostheses, it is the tooth to which the retainer is cemented. **3.** On implants, it is the part that supports and/or retains the prosthesis.

adjustment—A modification to a dental prosthesis to enhance fit, function or appearance.

align—To properly position in relation to another object or objects.

alloy—A substance consisting of a mixture of two or more pure metals.

anterior guidance—See *mutually protected articulation.*

anterior teeth—The central and lateral incisors and the cuspids of either arch.

anteroposterior—Extending from the front, backward.

anteroposterior curve—The anatomic curve established by the occlusal alignment of the teeth, from the cuspid through the buccal cusps of the posterior teeth, when viewed from the side.

arrangement —See *tooth arrangement.*

articulation—1. In the anatomic sense, the place of union or junction of two or more bones of the skeleton. **2.** In dentistry, the contact relationship between the occlusal surfaces of the teeth during function**.**

articulator—A mechanical device representing the temporomandibular joints and jaws to which maxillary and mandibular casts can be attached for performing prosthodontic procedures.

axis—An imaginary line passing through a body, around which the body may rotate, for example, transverse horizontal axis.

base metal—Any metal element that doesn't resist tarnish and corrosion. Any metal which is not noble.

buccal—Pertaining to the cheek. The surface of the tooth toward the cheek.

buccal groove—Landmark on the buccal surfaces of mandibular molars, extending vertically from the occlusal surface down toward the cemento-enamel junction.

bur—A small rotating instrument used in the dental handpiece for cutting acrylic resin or metal. Also used by the dentist to cut enamel or dentin.

burn out—The elimination by heat of wax or resin from a mold designed to receive molten alloys.

burnout temperature—The temperature which must be reached to properly eliminate a wax pattern from the mold and expand the mold.

burnish—The drawing or flattening out of a malleable metal through pressure. If a rounded instrument is repeatedly rubbed across the margin of a soft gold casting and the tooth, the gold will be thinned and spread over onto the enamel of the tooth.

butt joint—A type of joint in which the two pieces to be joined touch each other but do not overlap.

cast—1. The positive reproduction of the mouth in stone or similar material upon which a prosthetic appliance can be constructed. **2.** To produce a shape by thrusting a molten liquid into a mold possessing the desired shape.

casting—1. An object formed in a mold. **2.** The process of forming a casting in a mold.

centimeter—A hundredth of a meter; 2.54 centimeters equals 1 inch.

centric occlusion—The occlusion of teeth when the mandible is in maximum intercuspation, may or may not coincide with centric relation.

ceramic—Having to do with the use of porcelain.

ceramic crown—A ceramic restoration, restoring a clinical crown without a supporting metal substructure.

cervical—Pertaining to the neck of a tooth.

cervical line—The line where the cementum and enamel join. Also known as the cementoenamel junction.

cervix—The neck of a tooth.

clinical crown—That part of a crown visible in the mouth above the gum line.

concave—Curving inward; dished in.

contour—1. (noun) The shape of a surface. 2. (verb) To shape into a desired form.

convex—A surface curved outward toward the viewer.

coping—A thin covering or crown.

coronal—Pertaining to the crown portion of a tooth.

cross-section—A cut section of an object, made so the cut is perpendicular to the object's long axis.

crown—1: In anatomy, the part of the tooth covered by enamel. 2: In the laboratory, an artificial replacement that restores missing tooth structure with a metal or ceramic restoration.

cups—Hollow models and concave surfaces that that risk creating a suction cup during printing.

cusp—A cone-shaped elevation on the occlusal surface of a molar or bicuspid and on the incisal edge of the cuspid.

cuspid—A tooth having one cusp or point; the third tooth from the midline. So named because they correspond to the long teeth of a dog. Also called *canine*.

density—The mass of a substance per unit volume.

dental implant—A prosthetic device implanted within the bone to provide retention and support for a fixed or removable appliance

dental plaster—A gypsum that is refined by grinding and heating.

dentin—The tissue of the tooth underlying the enamel of the crown which makes up the bulk of the substance of the tooth.

dentition—The natural teeth as a unit.

dentulous—With teeth; as opposed to edentulous (without teeth).

deoxidizing—To remove oxides from the surface of a gold alloy by heating the alloy in an acid or other proprietary agent. Also called "pickling."

desirable undercut—The part of an abutment tooth below the survey line which can be engaged by the clasp tip to retain the removable partial denture.

developmental groove—A groove formed by the union of two lobes during the development of the crown of a tooth.

siagnostic cast—A reproduction of the mouth for the purpose of study and treatment planning.

diastema—A space between the teeth.

die—The positive reproduction of a prepared tooth in any suitable substance.

disc—A flat circular plate usually impregnated with an abrasive agent, used in the laboratory to smooth and polish. The abrasive agent may be silica, garnet, emery, or some other agent.

disclude—Separation of the maxillary and mandibular teeth.

distal—A surface facing away from the midline of the mouth; the distal surface of a tooth.

distortion—Changed from a normal shape or position.

dowel—A post, usually made of metal, fitted into the prepared root canal of a natural tooth. Also called post and core.

eccentric—Any position of the mandible other than its normal position.

edentulous—Without teeth; may be an area, an arch, or an entire mouth.

embrasure—The space defined by surfaces of two adjacent teeth. The space is divided into occlusal/incisal, facial, lingual, and gingival areas.

eminence—A prominence or projection, especially upon the surface of a bone.

enamel—The white, compact, very hard substance covering and protecting the dentin of the crown of teeth.

esthetics—Harmony of form, color, and arrangement. The quality of a pleasing appearance.

excursion—The movement occurring when the mandible moves away from maximum intercuspation.

external or lateral—Surfaces farther from the medial plane.

extrinsic—Outside, as opposed to intrinsic or inside.

facial—The surface of the tooth or appliance nearest the lips or cheeks. Used synonymously for the words *buccal* and *labial.*

fineness—The proportion of pure gold in a gold alloy; the parts per 1000 of gold.

finish line—1. On an artificial tooth: the raised line in the cervical region used as a guide to trim the wax on the denture base material. **2.** In removable partial dentures: the special preparation placed in the metal to form a definite sharp junction between the metal and acrylic resin.

finishing—1. The process of smoothing and trimming a prosthesis before its final polish **2.** The entire procedure of smoothing and polishing.

fissure, dental—A fault in the surface of a tooth caused by the imperfect joining of the enamel of the different lobes.

fixed dental prosthesis—A prosthesis, cemented to the prepared teeth or attached to implants, restoring one or more, but fewer than all of the missing natural teeth.

flexible—Capable of being bent without breaking.

flux—1: A substance used to increase fluidity and to prevent or reduce oxidization of a molten metal. **2:** Any substance applied to the surfaces to be joined by soldering to clean and free them from oxides and promote union.

foil—An extremely thin, pliable sheet of metal, usually of variable thickness.

fossa—An anatomical pit, groove, or depression.

fulcrum—The support upon which a lever rests when a force is applied. In removable partial dentures, an abutment tooth may act as a fulcrum for the appliance.

furnace—1. (burnout) The gas or electric oven used to eliminate the wax from a mold. 2. (porcelain) A specially constructed oven used to fuse dental porcelain.

fusion temperature—The highest temperature to which an alloy can safely be exposed in the soldering process; usually close to the lower limit of the melting range.

gauge—A measure of the thickness or diameter of an object.

gingiva—The gum tissue.

gingivitis—An inflammation of the gingiva.

gold—A noble metal used extensively in dentistry, most commonly in the form of an alloy.

gold alloy—An alloy consisting of gold mixed with other metals such as, silver, platinum, copper, and palladium.

gram—A unit of weight in the metric system, equal to approximately 15 grains in the apothecaries' system of weight.

groove—A long narrow depression on the surface of a tooth, such as the indentation between two cusps.

group function—Multiple contact relations between the maxillary and mandibular teeth in lateral movements on the working side; simultaneous contact of several teeth act as a group to distribute occlusal forces. Also called unilateral balance.

gypsum—The natural hydrated form of calcium sulfonate.

height of contour—The greatest circumference of the crown of a tooth.

horizontal overlap—The projection of teeth beyond their antagonists in a horizontal direction. Also called overjet.

hue—The basic color; white, black and grays possess no hue.

implant—See *dental implant.*

impression—A negative reproduction of a given area.

impression, final—An impression used to form the master cast.

incisal—Pertains to the cutting edge of the anterior teeth.

incisal edge—The biting edge of an anterior tooth.

incisor—A tooth with a cutting edge; the centrals and laterals.

inclination—Deviation of the long axis of a tooth with respect to a vertical line of reference. Four basic directions of inclination are described as facial, lingual, distal, and mesial.

index—A guide, usually of a rigid material, used to reposition teeth or other parts in some original position.

induction casting machine—A specially constructed casting machine which melts metal using an electric current to produce heat by electromagnetic induction.

ingot—Gold supplied in the form of one or two pennyweight (1.55 or 3.1 grams) pieces. Some of the base metal alloys are supplied in small cylinders and are also called ingots.

initial set—The first hardening of a gypsum product.

inlay—A restoration made to fit inside a prepared tooth cavity, and cemented into place.

insertion—A structure where a muscle attaches that has the greater movement during contraction.

intaglio surface—The portion of the denture or other restoration having its contour determined by the impression; the internal or reversal surface of an object. Also called internal surface or tissue surface.

intermediate abutment—A natural tooth located between terminal abutments serving to support a fixed or removable prosthesis.

internal—Surface closer to the medial plane.

interocclusal space—The difference between the vertical dimension at rest and the vertical dimension while in occlusion. Also called freeway space.

interproximal—Between adjoining tooth surfaces.

interproximal space—The space between two adjacent teeth.

intraoral—Within the mouth.

invest—To envelop or embed an object in an investment material.

investment—1. The gypsum material used to enclose a denture wax pattern in the flask, forming a mold. **2.** In fixed or removable prosthetics, a heat resistant material used to enclose a wax pattern before wax elimination.

labial—Pertaining to the lips. The surface of an anterior tooth opposite the lips.

lateral incisor—An anterior tooth located just distal to the central incisor. The second tooth from the midline.

line angle—The angle formed by the union of two surfaces of a tooth. The junction of the mesial surface with the labial surface of an incisor is called the mesiolabial line angle.

lingual—Pertaining to the tongue. The surface of a tooth or prosthesis next to the tongue is the lingual surface.

long axis—An imaginary line passing lengthwise through the center of a tooth.

malocclusion—Defective occlusion or deviation from normal occlusion.

mamelons—Small elevations of enamel present on incisors as they erupt; quickly worn down during mastication.

mandibular—Referring to the mandible or lower jaw.

mandibular movements—All natural, proper, or characteristic movements of the mandible made during speaking, chewing, yawning, swallowing, etc.

margin—1. The border or boundary, as between a tooth and a restoration. **2.** The outer edge of a crown, inlay, or onlay.

marginal ridge—The elevations of enamel forming the mesial and distal boundaries of the occlusal surfaces of the posterior teeth and the mesial and distal boundaries of the lingual surfaces of the anterior teeth.

master cast—The positive reproduction in stone made from the final impression.

mastication—The chewing of food.

matrix—1. The mold in which something is formed to use as a relationship record. See *index.* **2.** The portion of a dental attachment system that receives the patrix. Also called female attachment.

maxilla—The upper jaw.

maxillary—To refer to the maxilla or upper jaw.

melting range of an alloy—The interval between the temperature at which the alloy begins to melt, *solidus*, and the temperature at which it is completely molten, *liquidus*.

mesial—The surface of a tooth nearest the midline in a normal occlusion.

metal—A substance which is to some degree malleable and ductile and which conducts heat and electricity.

methyl-methacrylate—The chemical name for synthetic acrylic resin. One of its most common uses is as a denture base material for complete and removable partial dentures.

midline—The imaginary line through the middle of an object, dividing the object into equal parts.

millimeter—A unit of length in the metric system equal to 1000 microns or one thousandth part of a meter.

minima—The lowest point of a surface.

molars—The teeth situated in the posterior region of the mouth. The teeth behind the premolars.

morphology, tooth—The study of the form and structure of a tooth.

mucosa (mucous membrane)—The soft tissue lining the oral cavity.

nonprecious—A term used to describe metals or alloys that are not scarce, and do not possess a *high* intrinsic value. Examples are nickel and chromium. The term nonprecious is regarded by many as less technically correct than the preferred term *base metal.*

occlude—To bring together; to bring the upper and lower teeth together.

occlusal surface—The biting, grinding, or chewing surfaces of molars and premolar.

occlusion—1. The act or process of closure or of being closed or shut off. **2.** The static relationship between the incising or masticating surfaces of the maxillary or mandibular teeth.

oxidation—The process of heating a metal substructure in a porcelain furnace to cleanse the porcelain-bearing surfaces of contaminants and produce an oxide layer for porcelain bonding. Also called degassing.

oxidize—To combine with oxygen; for example, iron rust or brass tarnish.

path of insertion— The specific direction in which a prosthesis is placed on the abutment teeth.

periapical—The area around the apex or root tip of a tooth.

periodontium—Collectively**,** the tissues which surround and support the tooth.

physiology—The branch of biology dealing with the functions and activities of living organisms and their parts, including all physical and chemical processes.

placement—The process of directing a prosthesis to a desired location; the introduction of prosthesis into the patient’s mouth. Also called insertion.

plastic—1. Capable of being shaped or formed**. 2.** Pertaining to the alteration of living tissues**. 3.** Any of numerous organic synthetic or processed materials that generally are thermoplastic or thermosetting polymers. They can be cast, extruded, molded, drawn, or laminated into films, filaments, and objects.

pit—In dentistry, a depression usually found where several developmental lines intersect.

point angle—The angle made on a tooth by the convergence of three planes or surfaces.

polishing agent—Any material used to impart a luster to a surface.

pontic—A suspended artificial tooth on an FDP or an isolated tooth on an RDP.

porcelain—A ceramic material. In dentistry, most porcelains are glass and are used in the fabrication of teeth for dentures, pontics and facings, metal ceramic restorations, and other restorations.

porous—Pitted; not dense; containing voids and bubbles.

porosity—The presence of voids or pores within a structure.

posterior—Situated in back of or behind.

posterior tooth—All premolar and molars.

process—1. In anatomy, a prominence or projection of bone. **2.** In dentistry, any technical procedure that incorporates a number of steps; the procedure of polymerization of dental resins for prostheses or bases.

prosthesis—An artificial replacement for a lost part of the body. In dentistry, it is used in the more limited sense of a strictly dental replacement. Plural is *prostheses.*

prosthodontics—The branch of dentistry pertaining to the restoration and maintenance of oral function, comfort, appearance, and health of the patient by the restoration of natural teeth and/or the replacement of missing teeth and contiguous oral and maxillofacial tissues with artificial substitutes.

protrude—To project forward.

proximal—1. Situated close to. **2.** Next to or nearest the point of attachment or origin, a central point.

pulp—The connective tissue found in the pulp chamber and canals, made up of arteries, veins, nerves, and lymph tissue.

refractory cast—A heat-resistant duplicate of a blocked out and relieved master cast.

relief—1. The reduction or elimination of undesirable pressure or force from a specific region; e.g., The scraping of a working cast to better fit a facing to the ridge**. 2.** Material added to a cast to relieve the pressure over specific areas in the mouth. Also added to the master cast before duplicating it to create a raised area on the refractory cast

resin—1. A gummy substance obtained from various trees. It is used to make many dental materials. **2.** A broad term used to describe natural or synthetic materials that form plastic materials after polymerization.

resorption—The loss of tissue substance by physiologic or pathologic processes. The roots of the primary teeth are resorbed naturally.

ridge—1. An elevated body part; a long, narrow, raised crest. **2.** A linear elevation of enamel on the surface of a tooth; for example, a marginal ridge. **3.** The alveolar ridge: the area of the upper and lower jaws formerly occupied by the natural teeth.

ridge resorption—The resorption of the alveolar bone, once teeth are no longer present, resulting in a progressively flatter ridge.

root—The portion of the tooth covered with cementum.

root canal—The small channel running through the tooth’s root, connecting the pulp chamber and the root-end opening.

saturated calcium dihydrate solution (SDS)—A clear, true solution of water and a maximum amount of dissolved, dihydrate (set) gypsum product.

separating medium—An agent used between two surfaces to prevent them from sticking together.

setting expansion—The dimensional increase that occurs concurrent with the hardening of various materials, such as plaster of paris, dental stone, die stone, and dental casting investment.

setting time—The time necessary to harden or solidify.

shade—A term used to describe a particular hue, or variation of a primary hue, such as a greenish shade of yellow.

slurry—Suspension of gypsum particles in water.

solder—1. A fusible metal alloy used to unite the edges or surfaces of two pieces of metal. **2.** The act of uniting two pieces of metal by the proper alloy of metals.

solute—In a solution, the dissolved solution is called the solute. In salt water, the water is the solvent, and the salt is the solute.

specific gravity—The weight of a substance as compared to the weight of exactly the same volume of water. The standard formula used is: 1 cm3 of water at 4 °C = 1.

stability—The property of resistance to tipping and rocking of a prosthesis.

sulcus—1. A furrow, fissure, or groove. **2.** In dentistry, a linear depression in the surface of a tooth, the surfaces meet at an angle. A sulcus is always found along the surface of a developmental line.

superior—Above.

support—1. To hold up or serve as a foundation or prop for. **2.** The foundation area on which a dental prosthesis rests.

thermal expansion—The increase in size of a material when it is heated.

transverse horizontal axis—An imaginary line around which the mandible may rotate within the sagittal plane. Also called *hinge axis*.

trauma—A wound or injury, whether physical or psychic.

triangular ridge—The ridge of enamel which extends from the tip of the cusp down onto the occlusal surface of the premolar and molars.

try-in—A preliminary insertion of trial dentures, a partial denture casting, or a finished restoration to evaluate fit, appearance, maxillomandubular relations, etc.

veneer—A thin layer.

wax—There are many different types of waxes used in dentistry; each is compounded to produce certain physical properties for a specific purpose. They are manufactured in various forms, such as baseplate, boxing, inlay, and sticky.

wax pattern—Wax which has been formed into the size and shape desired in the finished prosthesis and used to form the mold in the investment.

working side—The side toward which the mandible moves in a lateral excursion.

Abbreviations and Acronyms

3D	three dimensional
°	degree
°C	degree Celsius
°F	degree Fahrenheit
CAD	computer-aided design
CAM	computer-aided manufacturing
CD	compact disc
CDC	career development course
cc	cubic centimeter
cm	centimeter
CRI	color-rendering index
DVD	digital versatile disc
FDP	fixed dental prosthesis
IAW	in accordance with
IPA	isopropyl alcohol
MI	maximum intercuspation
m	meter
mm	millimeter
PPE	personal protective equipment
psi	pounds per square inch
RDP	removable dental prosthesis
SDS	saturated calcium sulfate dihydrate solution
USB	universal serial bus

Student Notes

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