

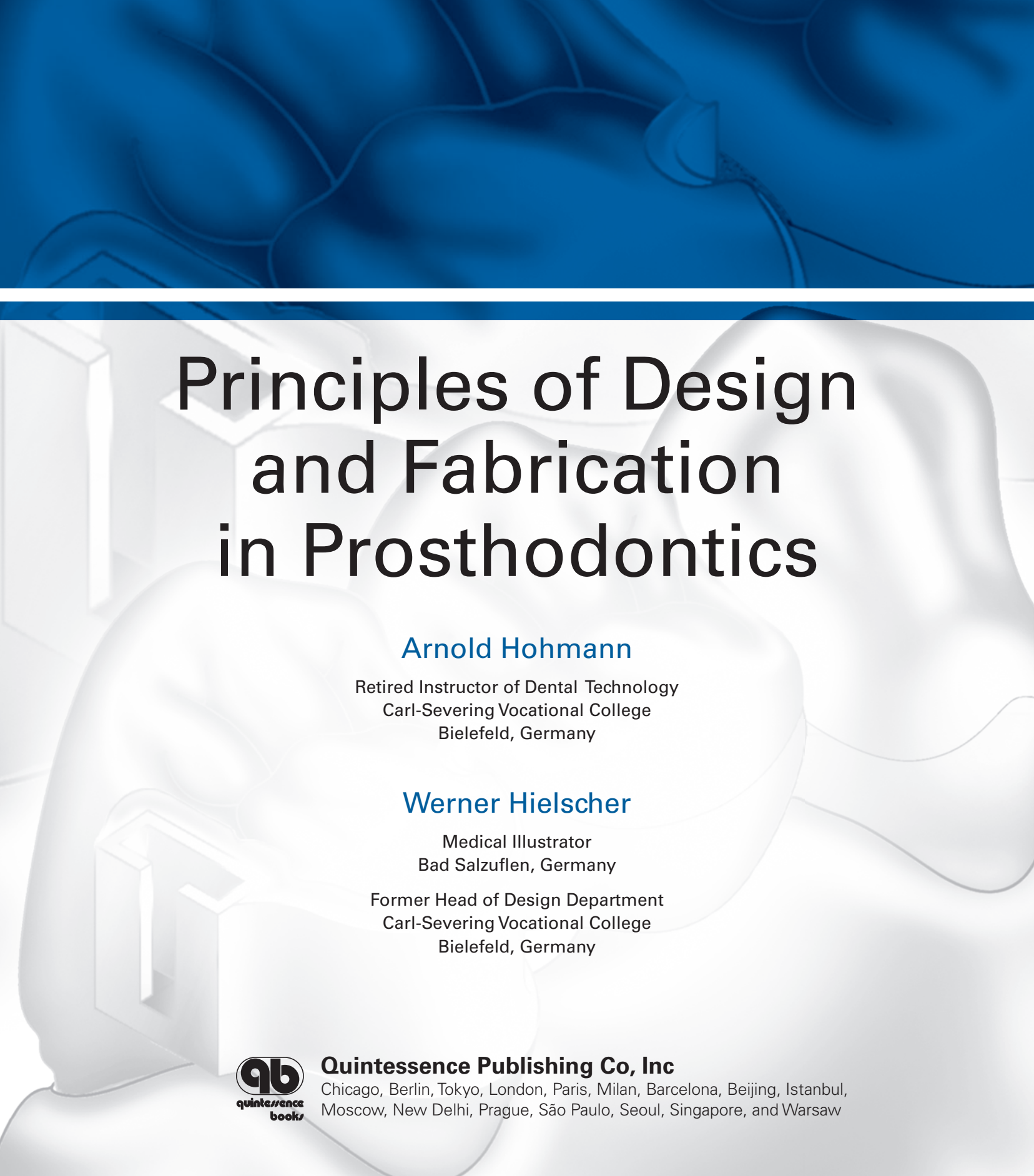


Principles of **DESIGN**
and **FABRICATION**

in **Prosthodontics**

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Principles of Design and Fabrication in Prosthodontics



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Introduction

This textbook is designed for the specialized teaching of advanced dental students and technicians. It is written and illustrated by people who have a passion for their craft and take joy in passing on their knowledge. The text describes the philosophy behind prosthodontic design and systematically details all of the working steps in designing and fabricating restorations and dentures. Unlike other prosthodontic texts, this one is written from a design perspective first and foremost, explaining the rationale behind the most minute of design considerations, such as different extension arms in removable partial denture clasps. Because prosthodontists must possess the skills required to physically fabricate restorations, the book includes comprehensive instructions on fabrication, clearly delineating the clinical work from the laboratory work. It also presents each technique as an illustrated algorithm with detailed legends; these algorithms provide a quick orientation and visual aid for the reader. Multiple working methods for complete denture fabrication are presented, and the final chapter describes how to incorporate sound prosthodontic design into implant therapy. Armed with this book, the dental student will be well prepared to create esthetic, stable, and durable restorations.

Preprosthetics

Functional Disorders After Tooth Loss

The masticatory system is a unit made up of functionally oriented tissue parts, and it only functions properly if all parts of the system are present and working smoothly. If normal functioning of the masticatory system no longer exists—whether because of loss or because disease has changed one part of the system—this is referred to as a *functional disorder, malfunction, or dysfunction*. In relation to the position and size of an edentulous space between teeth or a shortened dental arch, changes in facial expression and articulation may be observed as well as effects on masticatory function, the muscles of mastication, and the temporomandibular joints (TMJs). Above all, however, there is an adverse effect on the remaining dentition.

If there is an edentulous space, the supporting function of the closed dental arch afforded by the approximal contact points is lost and the teeth migrate into the space (Fig 1-1). Under the pressure of tooth migration, the bony alveolar wall opposing the edentulous space is broken down. At the same time, the alveolar bone beneath the space is resorbed. The consequence is the formation of a periodontal pocket in the area bordering the edentulous space. In addition, the approximal contacts with adjacent teeth become loose. As a result, the interdental areas open up and are no longer protected against food particles, which can become trapped there. This is followed by the formation of approximal caries and inflammation, which will damage the marginal periodontium.

As a result of the tipping of teeth, the normal occlusal contacts with the opposing teeth are lost. The occlusal surface inclines toward the normal occlusal level, so that some occlusal points migrate beyond the normal level and others fall below what is normal. The antagonists then overerupt until they regain occlusal contact, giving rise to severe malocclusions.

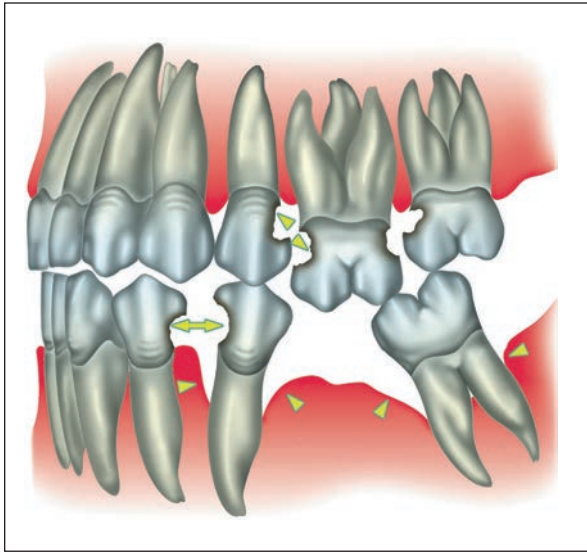


Fig 1-1 If a tooth is missing within an arch, the remaining teeth migrate into the edentulous space. As a result, the supporting function is lost, the interdental papillae are no longer protected, and caries develops in the approximal areas. In areas bordering the space, pocketing occurs at the marginal periodontium. In addition, the opposing tooth overerupts into the space, potentially causing tooth mobility, loss of support, and approximal caries in that arch as well.

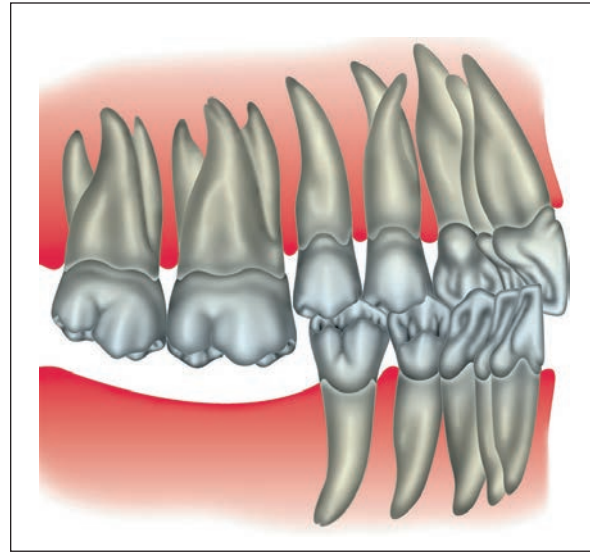


Fig 1-2 If the antagonists are missing, the teeth overerupt until they are stopped by the opposing jaw. This overeruption looks like lengthening of the tooth and is referred to as *elongation*. This exposes the cervical areas of the teeth so that cervical caries may develop. Prosthetic restoration becomes difficult under these conditions.

The elongation (lengthening) of teeth may be due to the reactive behavior of the periodontal tissues (Fig 1-2): If the tooth is not pressed into the socket by masticatory force, the pressure in the blood vessels lifts the tooth out of the socket. The gentle but continuous pull on the ligamentous apparatus acts as a stimulus on the alveolar bone, which grows in the direction of the pull until the tooth is held by antagonist contact or the opposing jaw.

The overeruption of an antagonist has two repercussions. First, in the dental arch from which the tooth is overerupting, all of the teeth become more mobile, bringing consequences such as loss of sagittal support, opening of the interdental spaces, approximal caries, and damage to the marginal periodontium. Second, the elongation gives rise to an occlusal disorder as the overerupting tooth interferes with gliding movements (Fig 1-3). Smooth occlusal gliding out of centric occlusion is no longer possible.

Enlargement of edentulous spaces means that the stresses on the residual teeth become greater and the periodontal damage more pronounced. Deterioration of the dentition progresses rapidly (Fig 1-4).

Malocclusions in a partially edentulous dentition arise because the continuous masticatory field is interrupted and sagittal or occlusal support contacts are lost. As a result, centric stops no longer meet simultaneously in their contact areas: some have premature contact and others no contact at all. This brings about uneven distribution of forces in the masticatory field: some teeth are overloaded and others underloaded. Because the sagittal support is missing, tipping and migration of teeth will occur whereby the tipped and migrated teeth are loaded eccentrically and hence nonphysiologically.

In all lateral or protrusive movements, all the mandibular teeth glide downward and forward on the posterior sloping surfaces of their maxil-

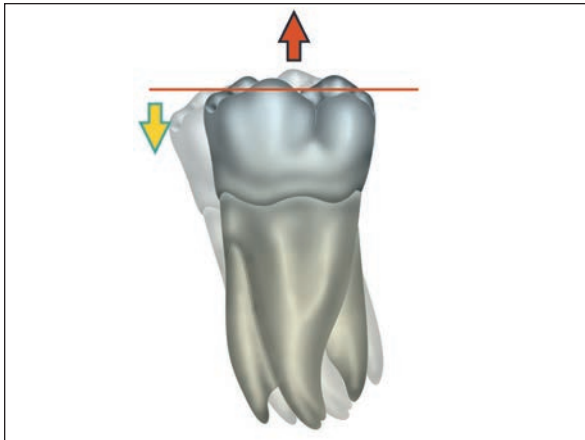


Fig 1-3 As a result of tipping, the distal occlusal points migrate beyond the occlusal line and the mesial points migrate below it. Consequently, the stress relationships for the affected teeth are also altered. Interference with gliding movements within the dental arch occurs during mandibular movements.

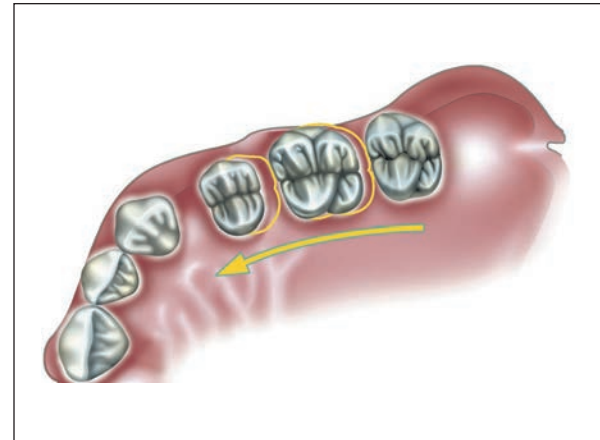
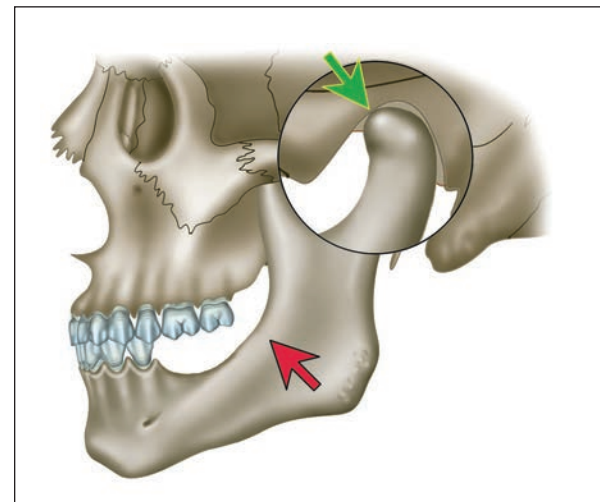


Fig 1-4 Early signs of destruction of a partially edentulous dentition can be seen from the migration of posterior teeth, which results in loss of interdental support. Tipping of teeth and hence a change in occlusal relationships are always associated with tooth migration.

Fig 1-5 In the fully dentate dentition, the condyle is in a neutral position in the fossa when in centric occlusion. If the supporting function of the teeth is lost because of shortening of the dental arch, there is inevitably abnormal loading of the TMJs. The condyle is pressed into the mandibular fossa by the activity of the masticatory muscles. This leads to traumatic changes to the TMJs.



lary antagonists because of condylar, neuromuscular, and tooth guidance. If the cuspal paths are no longer arranged in the right spatial inclination because of tipping of teeth, the centric stops lose their antagonist contact.

Condylar and neuromuscular guidance are therefore abnormally stressed, which may result in TMJ and muscle diseases (Fig 1-5). Joint damage is often evident as disc dislocation with acute

joint clicking when the disc pops out of its normal position beyond the edge of the mandibular fossa. This will result in pain of varying severity on loading.

Myopathies are diseases of the neuromuscular system that are evident initially as muscle tension and induration and later as disorders of metabolic breakdown and associated muscle pains.



Fig 1-6 In the face of an aged edentulous patient, the extreme wrinkling around the sunken mouth becomes pronounced, the nose appears to lengthen, the cranial fossae at the sides are also sunken, and the slack buccal muscles cause the cheeks to sag. The facial proportions are therefore shifted.

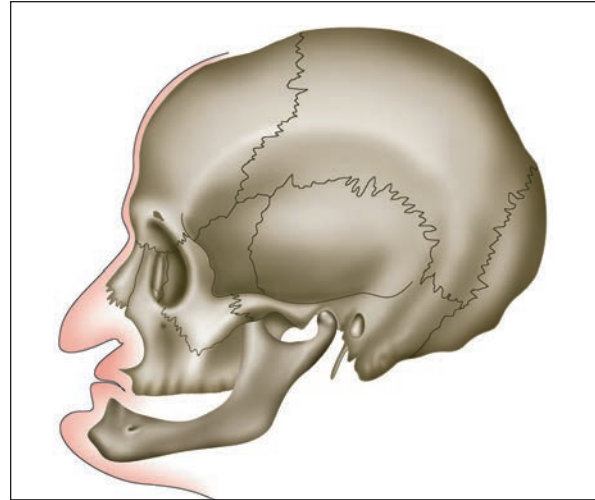


Fig 1-7 Changes to the masticatory system and face are most striking in complete edentulism: The alveolar ridges and bony tissue for the muscle attachments are resorbed, the mandible moves closer to the maxilla, lip support is lost, the vermilion of the lips disappears, and the face looks more aged.

Functional Disorders and Loading of Residual Dentition

Abnormal loading of the TMJs and the masticatory muscles appears when the supporting function of the posterior teeth is lost and the muscles of mastication press the condyle into the mandibular fossa. The abnormal loading of the masticatory muscles leads to displacement of the bite position; the mandible is shifted forward, which accelerates deleterious changes in the TMJ.

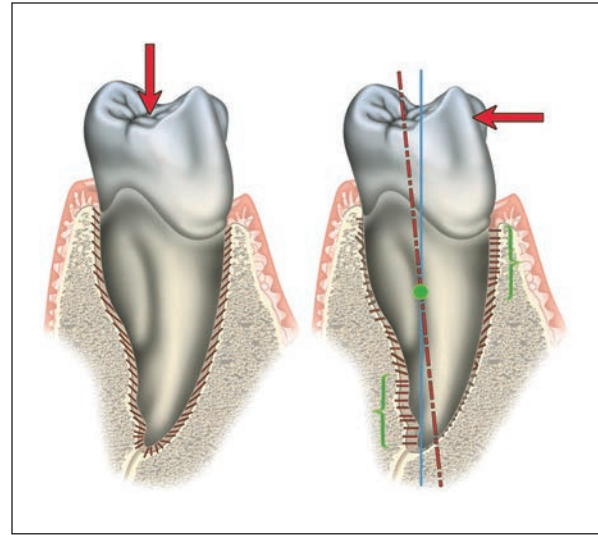
Displacement of the bite position influences the residual dentition. Either the remaining anterior teeth are moved labially by occlusal pressure, or an edge-to-edge bite arises with severe abrasion of the incisal edges. This results in severe mobility of teeth and even complete deterioration of the dentition.

The progressive destruction of a partially edentulous dentition may be delayed over prolonged

periods. For instance, given normal loading and a resistant periodontium, a dentition may even make up for the loss of several molars itself. In most cases, however, the described symptoms occur within a few years and quickly lead to loss of all the teeth if the deterioration is not halted by prosthetic treatment.

The changes are most striking in complete edentulism. As a result of complete tooth loss, the mandible or maxilla collapses, lip support is lost, and the vertical dimension of occlusion is reduced, which inevitably pushes the mandible forward. All of these changes cause the lips to cave in; in addition, the vermilion of the lips disappears, the mouth becomes thin, and the lower part of the face is shortened. This results in an aged facial appearance with pronounced wrinkles around the mouth area caused by general slackness of the muscles of mastication and the perioral musculature, because normal masticatory function no longer places any load on these tissue parts (Figs 1-6 and 1-7). The bony areas to which the masticatory muscles attach are also resorbed.

Fig 1-8 If a force hits the tooth centrally, the whole periodontium is physiologically under tension. On transverse loading and tooth tipping, only a third of the periodontal fibrous surface is physiologically under tensile stress (*green bracket*), a third remains neutral and unloaded, and a third is nonphysiologically compressed.



Impaired masticatory function affects the entire digestive process. The inability to crush food properly, together with insufficient insalivation and predigestion, will initially lengthen the time food stays in the stomach; the stomach muscles slacken, and diseases of the intestinal tract develop because of the abnormal decay and fermentation processes.

The consequences of tooth loss that impairs function suggest that prosthetic replacement of missing teeth is indispensable. The prosthetic replacement has to be anchored to the residual teeth that are still present or supported on the mucosa, which is unsuitable for absorbing masticatory forces.

Periodontal tissues are far better suited to absorbing masticatory forces than the mucosal and bony foundation for a denture base (Fig 1-8). The cells of the periodontal tissue have differentiated to absorb forces: Sharpey fibers convert pressure into tension, stabilizing the alveolar cortical bone, which can dissipate force effectively. Bone is known to grow in the direction of pull and is broken down under pressure—a functional relationship that is exploited to achieve orthodontic tooth movements.

The mucosal and bony base can absorb moderate masticatory force because of shifts of fluid in the soft tissue. The mucosa transfers masticatory

force to the bone, for which a moderate masticatory force is favorable because the periosteum here is stimulated by fibrous anchorage of the attached mucosa. The bone will atrophy if there is complete inactivity. However, even at masticatory forces that are normal for the periodontium, the bone is subject to compressive loading to such an extent that it is resorbed; this has to be corrected by constant rebasing.

If the loading of the residual dentition is greater than normal because of the prosthetic replacement, there is a pronounced increase in the Sharpey fiber bundles, and hence periodontal loading capacity is higher. It is important that the higher load contacts the periodontium centrally and does not tip the tooth, causing nonphysiologic loading of the fibrous tissue.

In a fully dentate dentition, tipping of the teeth is compensated for by the sagittal support from approximal contacts, tissue interlinking, double interlocking with antagonists, and the neuromuscular reflex arc. In a partially edentulous dentition, sagittal support, tissue interlinking, and antagonist contacts are largely lost; only the reflex arc remains. However, the arc only works when there is overloading and not with below-threshold continuous loads. This can give rise to and explain specific denture requirements.

Function of Dental Prostheses

The term *prostheses* refers to all mechanical devices that serve as a functional or cosmetic replacement for lost anatomical tissue. Hence every tooth replacement—whether a crown or a partial denture—is a prosthesis. The term *partial prosthesis* is actually a tautology because any prosthesis is essentially a partial replacement. The following grouping of teeth replacements is useful in distinguishing the different types of prostheses, and their names emphasize the design features of the specific replacements (Fig 1-9):

- A *crown* replaces hard dental tissue in a wide variety of fixed designs; in the broadest sense, this also includes restorative treatment.
- A *fixed partial denture* replaces teeth, dental hard substance, and alveolar bone; this fixed prosthetic replacement is firmly spanned between abutments, which is why they are also called *bridges*.
- A *removable partial denture* is a removable tooth replacement that replaces single teeth and alveolar bone in a partially edentulous dentition.
- A *complete denture* is a removable full denture that replaces all the teeth and missing alveolar bone.

Depending on the amount of time a prosthesis is used, a distinction is made between interim/provisional or immediate prostheses and definitive prostheses. The terms *immediate prosthesis* and *interim prosthesis* denote the instant prostheses used for a specific indication.

An immediate prosthesis is fabricated according to a model prepared before extraction of the teeth that are going to be replaced. The teeth are ground on the model and replaced by a prosthesis construction. An immediate denture is inserted directly after extraction of the teeth.

An interim prosthesis is a provisional removable tooth replacement that is fabricated and inserted immediately after tooth extraction as a form of wound closure and is used until the definitive replacement is inserted. After tooth extraction, an impression is taken, models are made, and the prosthesis is fabricated with the same design features and functions as an immediate prosthesis.

Interim prostheses offer good wound closure and better adaptation of the alveolar ridge tissue to loading. Researchers have observed that patients who are fitted with interim prostheses experience less shrinkage of the alveolar ridge than those who are not. Interim prostheses offer an esthetic replacement until the definitive restoration is inserted; they maintain the vertical dimension of occlusion, allow natural chewing movements, and as spacers prevent any displacement of teeth bordering edentulous spaces. Another advantage of these interim prostheses lies in the recording of the maxillomandibular relationship for the definitive prosthesis, especially in the case of complete dentures. Furthermore, speech function is preserved for the patient. Definitive prostheses are the form of tooth replacement that is intended to be in place in the long term.

The aim of prosthetic treatment is to replace lost tissue and avoid, or at least reduce, all the functional disorders that occur because of tooth loss. The specific functions of a tooth replacement can thus be identified as follows (Fig 1-10):

- *Biomechanical function* involves restoring the closed dental arch by replacing the missing tissue parts. The aim is to secure the supporting function within the dental arch, create a normal occlusal situation, and enable physiologic loading of the available tissue.
- *Therapeutic function* involves halting any deterioration of the dentition that has already started. This also relates to delaying or preventing changes to other tissue parts of the masticatory system by means of correct prosthetic design.
- *Prophylactic function* means stopping secondary damage resulting from the prosthetic replacement and preventing future pathologic changes.
- *Regulating function* concerns prosthetic measures intended to improve or establish the functioning of a masticatory system. This includes esthetic aspects and unimpaired phonetics.

Design principles and the criteria of functional testing can be deduced from this general description of functions. Descriptions of specific prostheses in the following sections not only explain the constructional measures but also cover the functional references of the tooth replacement. Possible errors that may result are examined in detail.

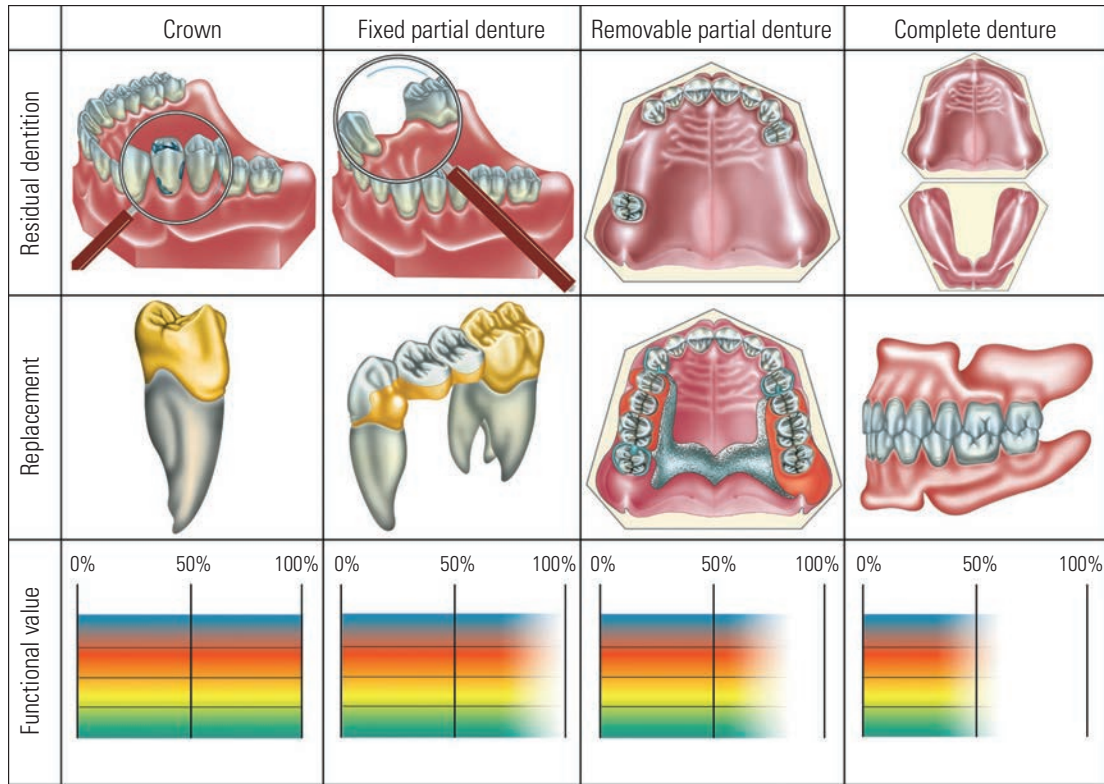


Fig 1-9 The possible functional value that can be achieved by a dental replacement in the ideal situation can be correlated with the different prosthesis and tooth replacement groups. A functional value of 100% in single-tooth rehabilitation can be achieved by dentistry and dental technology methods, whereas severe loss of masticatory function can be expected in the case of complete prostheses.

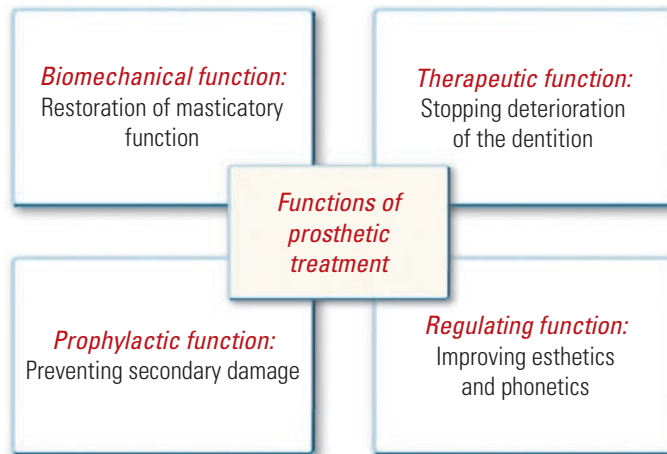


Fig 1-10 The functions of prosthetic treatment can be broken down into four functional areas for teaching purposes. No area has particular priority, and all functions need to be accomplished equally.

Restorative Treatment

Restorative treatment refers to a single-tooth restoration in which the diseased dental hard substance is replaced by tissue-compatible material. Restorative treatment becomes necessary for dental defects resulting from chipping of the teeth during trauma, caries lesions, or abrasive wear.

Restorations are intended to restore the original morphology of the tooth and to be resistant to conditions in the oral cavity, dimensionally stable, and tissue compatible. Their color should not differ from that of the natural tooth, and restorations should be cost-effective to produce. The margins of the restoration are placed in areas that are accessible to mechanical oral hygiene measures or subject to self-cleaning. The restoration must withstand masticatory loads and must not fall out. Restorations can be classified according to the following:

- The extent of dental destruction or the dimensions of the tooth surfaces to be replaced
- The nature of the restorative material (ie, plastic or metal)
- The nature of the fabrication process (ie, direct or indirect fabrication)

Cavity or tooth preparation refers to preparing the tooth to receive a restoration. The process involves removing the caries or preparing the defect in the dental tissue and treating the wound in the dentin. To remove the soft carious tissue with a low-speed drill, the hard enamel layer is first removed at high speed under water cooling. Tooth preparation is intended to spare hard dental tissue, provide permanent retention for the restoration, and prevent new caries from developing. It is done with rotary instruments at low or normal speed (4,500 rpm and above) and under water cooling and is not extended to the gingival margin.

The cavity to receive a restoration has the following basic features (Fig 1-11):

- The cavity floor is the interface directed toward the pulp, which must be a minimum of 1.5 mm from the tooth surface in order to create high enough walls for the restoration.
- The cavity walls are the lateral borders to the enamel and dentin. The transitions between the

floor and wall are rounded. For plastic restorative materials, the cavity walls are slightly undercut. For metal restorative materials, the floor and wall form a nearly 90-degree angle.

- The cavity margin, or the border between the cavity wall and the tooth surface, forms the subsequent restorative margin. For cast restorations and adhesive restorations made of composite, the cavity margin is beveled in the enamel.
- Extension surfaces are the cavity walls that border the vertical pulpoaxial cavity floor on the approximal surfaces.

Caries lesions are subdivided into five classes according to Black's classification (Fig 1-12):

- *Class I caries* refers to occlusal lesions in the area of the pits and fissures in molars and premolars. The term is used for fissure caries that starts in spots in the fissures and runs along the dentinoenamel junction. Any overhanging enamel areas that arise will break off under masticatory pressure.
- *Class II caries* describes approximal lesions in premolars and molars. An approximal defect in posterior teeth in a closed dental arch can only be prepared occlusally so that a multisurface cavity is formed. A box-shaped preparation with rounded transitions is required to restore an approximal caries lesion. The approximal-cervical shoulder lies perpendicular to the crown axis or slopes slightly from the outside inward.
- *Class III caries* refers to approximal cavities in anterior teeth without involvement of the incisal edge. The small, round cavity opening in the area of the anterior teeth is prepared from the lingual, and the cavity margins are extensively beveled to achieve a wide retentive surface on the dental enamel.
- *Class IV caries* relates to approximal defects in anterior teeth involving damage to the incisal edge. Loss of the incisal edge necessitates extensive beveling of the enamel (1 to 2 mm), which is mainly restored with a tooth-colored restoration retentively fixed to the dental enamel by the enamel etching technique.
- *Class V caries* denotes defects close to the gingiva on the labial and buccal tooth surfaces. Cervical cavities are surrounded by enamel on all sides.

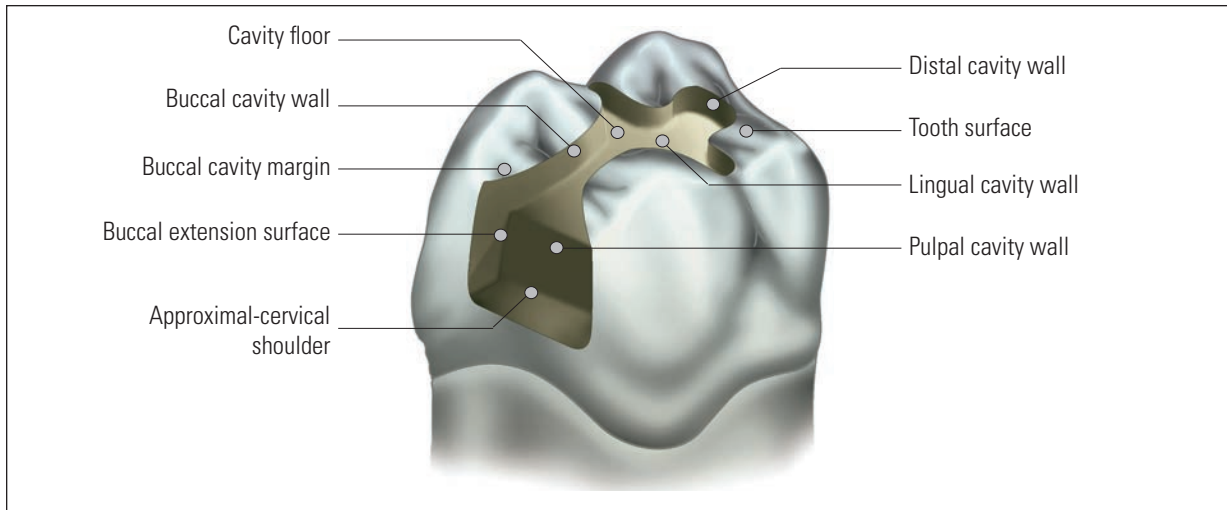


Fig 1-11 Tooth preparation removes carious dental hard substance and shapes a cavity to receive a restoration.

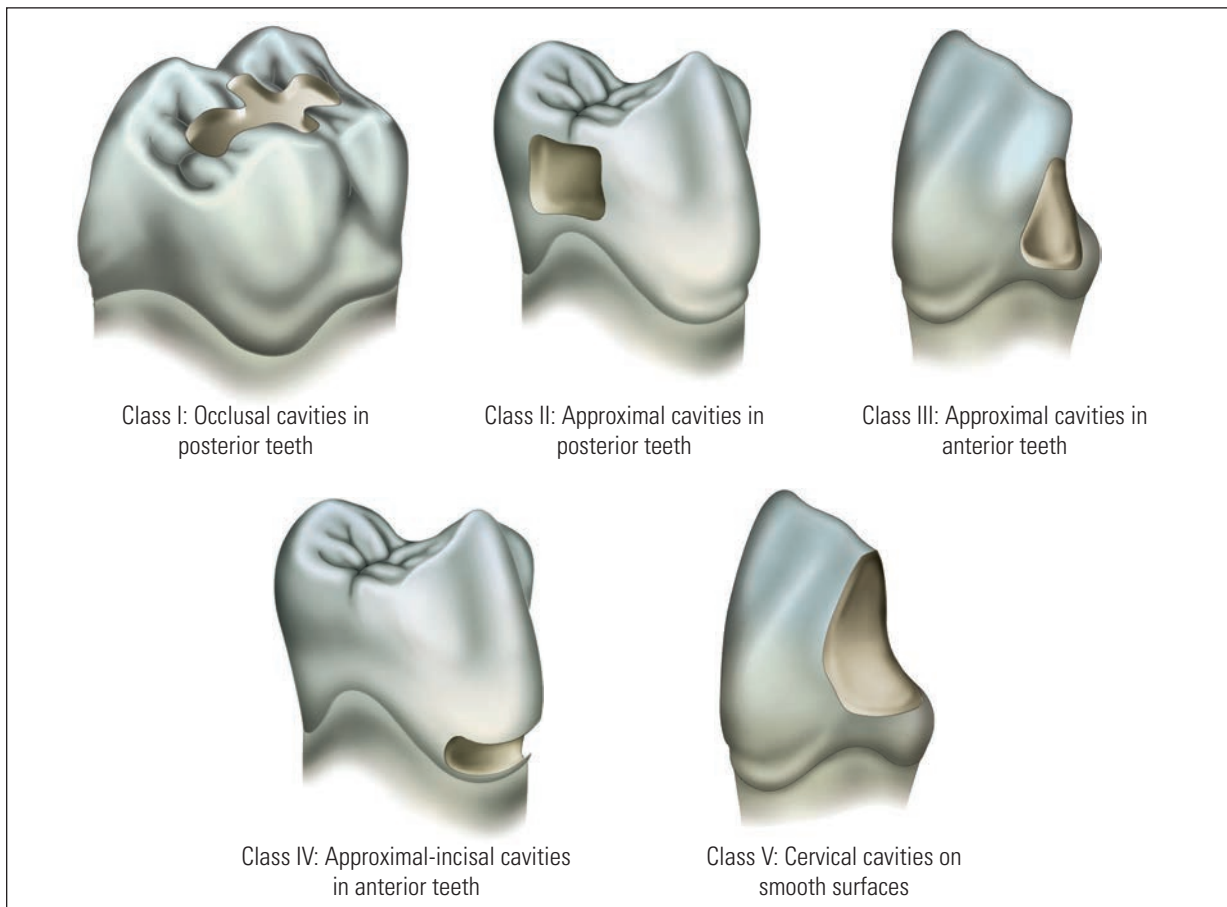


Fig 1-12 Caries classes I through V can be distinguished based on Black's systematic classification.

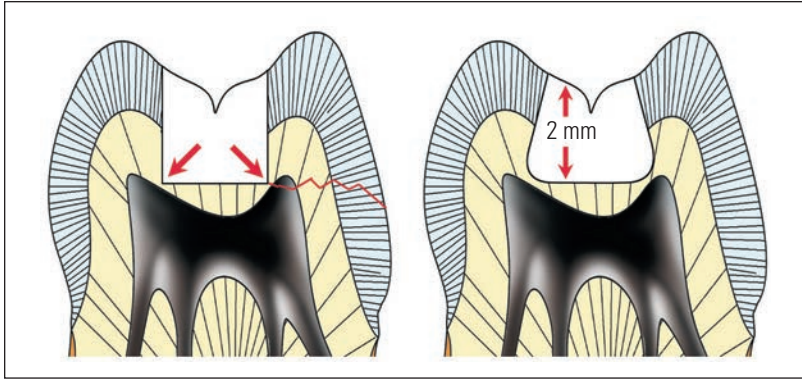


Fig 1-13 The buccal and lingual cavity walls for an amalgam restoration are prepared slightly undercut. The minimum cavity depth is 2 mm. The transitions are rounded at the cavity floor to prevent a notching effect with the dental tissue.

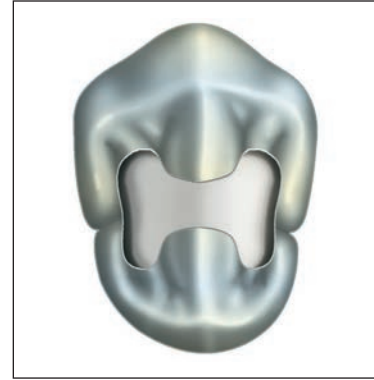


Fig 1-14 The approximal cavity walls for an amalgam restoration are prepared slightly divergent, in an occlusal direction, so that the marginal ridge areas cannot break. The buccal and lingual walls are slightly undercut to give the restoration material sufficient retention.

Restorative Materials

Restorations made from plastic restorative material are fabricated by the dentist in the patient's mouth using the direct method. A distinction is made between a provisional restoration as a temporary seal and the definitive restoration for the long-term restoration. Hardening substances in the form of ready-to-use mixtures of zinc and calcium sulfate from tubes, zinc oxide–clove oil with additives, and heat-deformable gutta-percha are used as temporary restorative materials.

Amalgam, composites, glass-ionomer cements, and gold leaf or crystalline gold (sponge gold) are used for definitive restorations. Tooth preparation is performed as described, depending on the restorative material used.

Amalgam restorations for caries treatment in conservative dentistry are made of a heterogeneous alloy of mercury with other metals. They are used in the occlusion-bearing posterior region and to build up cusps (Figs 1-13 and 1-14); amalgam restorations are not used for anterior restorations for esthetic reasons. The liquid mixture of mercury and other metals can be readily packed into the cavity before it hardens into its solid form. The ready-to-use amalgam alloy is

mechanically blended from two components at a 1:1 ratio of liquid mercury and powdered amalgam particles. Correctly prepared amalgam restorations are extremely durable and leak only small amounts of mercury. However, because of this leakage, amalgams are suspected of being deleterious to health. Measurements of mercury in saliva, blood, and urine show a correlation between the concentration of inorganic mercury compounds and the number of teeth filled with amalgam. Therefore, amalgam restorations are unsuitable for children younger than 6 years, pregnant women, and patients with kidney disease. Owing to the hazard posed by mercury vapors and their chemical affinity for precious metals, amalgams are rarely used. Similarly, amalgam in direct contact with metallic crowns will release mercury because of electrogalvanic corrosion.

Composite restorations are made of tooth-colored acrylic resin reinforced with inorganic fillers. The composite is packed into the cavity in its liquid state and sets chemically or under ultraviolet light. Composite is not as mechanically durable as amalgam because it shrinks during curing and has high thermal expansion. Composites are not as suitable for posterior restorations as they are for the anterior region. They can be

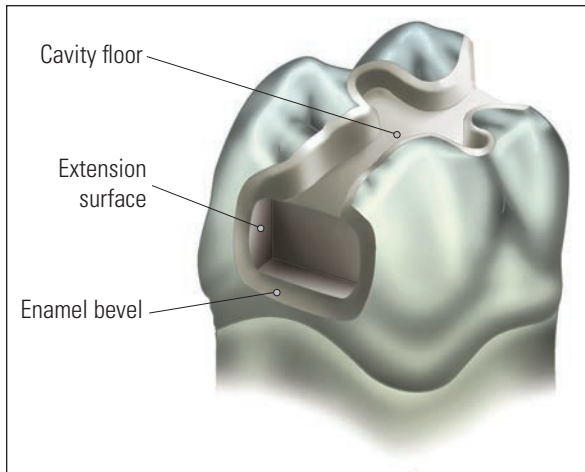


Fig 1-15 In a multisurface cavity for a composite restoration, the cavity floor is at least 2 mm deep. The approximal extension surfaces are clearly directed in a lingual and buccal direction. The cavity margin is encircled by an enamel bevel. Conditioning with an etchant gel is performed in this enamel area.

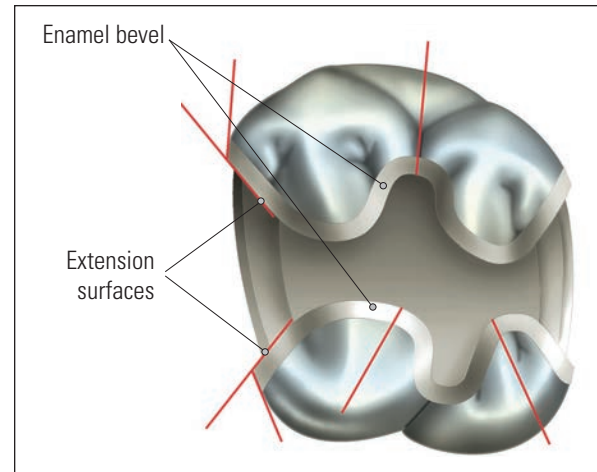


Fig 1-16 For a multisurface cavity, a gold inlay restoration is generally made; the same design is chosen as in Fig 1-15, with a depth of 2 mm, the extension surfaces, and the enamel bevel. The occlusal antagonist contacts must always lie outside the cavity margin.

used for small occlusal cavities if the antagonist contacts lie on the natural dental hard substance. Composite restorations are adhesively and retentively bonded to the dental enamel by the enamel etching technique, for which an absolutely dry cavity must be maintained (rubber dam).

The marginal integrity of composite restorations is ensured by the preparation of mechanical retentions (grooves, adhesive points) and with dentin bonding agents. In addition, a tight, acid-resistant cavity lining is placed to protect the pulp against the acrylic resin monomer or phosphoric acid (etching gel). The composite material is applied layer by layer, finished, and polished and thus provides esthetically superior restorations with a tight marginal seal (Fig 1-15).

Glass-ionomer cement restorations may be used for small caries lesions. Glass-ionomer cements bond well to dentin and enamel so that a restoration with marginal integrity is produced. Cements cannot be polished, are light impermeable, and are not abrasion resistant. Their use is confined to

cervical caries lesions bordered by enamel as well as caries lesions in the cementum. Glass-ionomer cement is mainly used as a tooth preparation lining material and for buildups on crown stumps.

Gold compaction restorations are very rarely fabricated for small occlusal and approximal caries lesions. Tooth preparation must be box shaped with sharp edges. The cavity walls are parallel or undercut to provide sufficient retention (Fig 1-16). The restorative material consists of a special gold foil (gold leaf) or crystalline gold. The core of the restoration is built up with the crystalline gold, which is coated on the outside with gold leaf. The gold is packed in portions into the cavity and cold-welded with hammer blows so that it wedges into the cavity with a tight marginal seal. Fabrication is time-consuming and costly but does produce long-lasting, dimensionally stable inlay restorations that are appropriate when a patient is allergic to other restorative materials and their ingredients.

Inlay Restorations

Inlay restorations made from metal, ceramic, or composite can be used to restore occlusal, approximal, or approximal-incisal cavities caused by carious defects, fracture, or other damage after they have been prepared. Inlay restorations are only indicated for patients who have good oral hygiene, minimal susceptibility to caries, and healthy periodontal conditions. Inlay restorations can be placed over several surfaces and may be retained by shoulders and pins (Fig 1-17). They differ depending on the amount of tooth structure to be replaced (Fig 1-18). The term *inlay restorations* encompasses inlays, onlays, overlays, and onlay partial crowns.

While an inlay is fixed entirely intracorona-ly without covering the occlusal surface of a tooth, an onlay covers the entire occlusal surface, and an overlay encompasses the occlusion-bearing cusps and includes both approximal surfaces. There is a smooth transition from overlay to partial crown when the cervical area of the tooth and the occlusal and approximal defects need to be restored.

The design for inlay restorations is extended and demands plenty of dental hard tissue, especially if a metal and porcelain restoration covering the occlusal surface is to be placed. The cavity walls are not undercut occlusally, in contrast to the preparation for plastic restorative materials (Fig 1-19). Cavity walls close to the pulp are coated with a lining so that even undercut areas are blocked out. The cavity walls and the liner should be smoothed, and then an impression is taken. The prepared teeth are fitted with a temporary acrylic resin restoration until an inlay restoration has been made in the dental laboratory.

Inlay restorations are fabricated using dental technology measures. First an impression is taken of the cavity, and the restoration is made indirectly on a model by the following methods:

- Cast in metal using the lost wax technique
- Milled out of a ceramic block using computer numeric controlled (CNC) technology
- Compressed in ceramic by the extrusion technique
- Ceramic fired onto galvanic carrier layers
- Cured in composite using the layering technique

After fabrication, inlay restorations are inserted with cement or special bonding agents. They adhere to the cavity walls by a gripping effect and static friction.

Metal inlay restorations are made from gold alloys; other metal alloys (non-precious metal and palladium alloys) are rarely used. A working model and opposing jaw model are first fabricated from artificial stone and placed in the articulator. By the traditional method, the inlay restoration is carved in wax, sprued, invested, and cast. Metal inlay restorations can also be milled out of a full metal block using CNC technology.

Composite and ceramic inlay restorations can be fabricated by the indirect technique using an impression and plaster cast and adhesively fixed in the cavity by the acid-etching technique.

Various methods are used for fabricating ceramic inlay restorations. In the sintering method, a split model made of plaster and a duplicate model made of castable material are prepared, onto which the restoration is sintered. If the ceramic inlay restoration is made of castable ceramic (eg, glass-ceramic) or pressed ceramic, the restoration must be carved out of wax on the working model and invested. For fabrication by computer-controlled techniques, an optical impression of the prepared cavity must be made using special imaging methods. On the basis of this impression, the inlay restoration is ground out of a compact ceramic block using CNC techniques. In the copy-grinding method, a restorative block made of acrylic resin is mechanically scanned, and a ceramic duplicate is milled out of a ceramic block.

Composite inlay restorations are made of composite with a high proportion of inorganic fillers. They can be fabricated directly in the mouth or by indirect fabrication on a working model in the dental laboratory.

In the case of electroformed inlays, tooth-colored ceramic is fired onto a thin carrier layer of electroformed gold. A thin gold layer is electrogalvanically deposited on the model die in order to fire on a ceramic layer. These inlay restorations have very good accuracy of fit and are inserted using phosphate cement. A thin gold margin remains visible, which is esthetically unsightly.

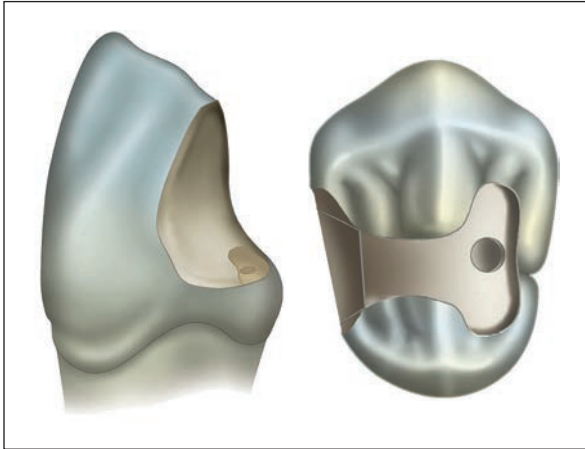


Fig 1-17 An extensive cavity restoration can be created with additional retentions in the form of pinholes. Short pins engage in these holes to secure the restoration. The term *pinlays* is used for restorations that mainly gain their retention in the dental tissue by means of pinholes or pins.

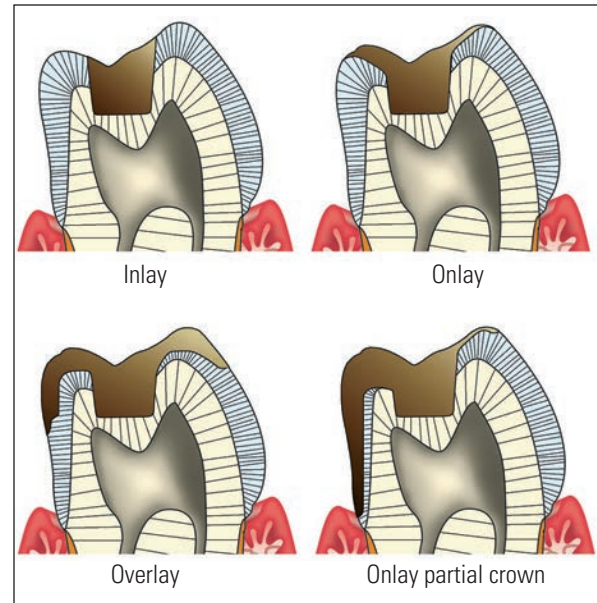


Fig 1-18 The term *inlay restoration* encompasses restorations made of metal in differing dimensions; they are classified according to the amount of dental substance to be replaced—inlays: intracoronal cavities; onlays: cavities on occlusal surfaces; overlays: cavities on occlusal surfaces and the occlusion-bearing cusps; onlay partial crowns: cavities involving the vertical smooth surfaces outside the portion visible from the vestibular view.

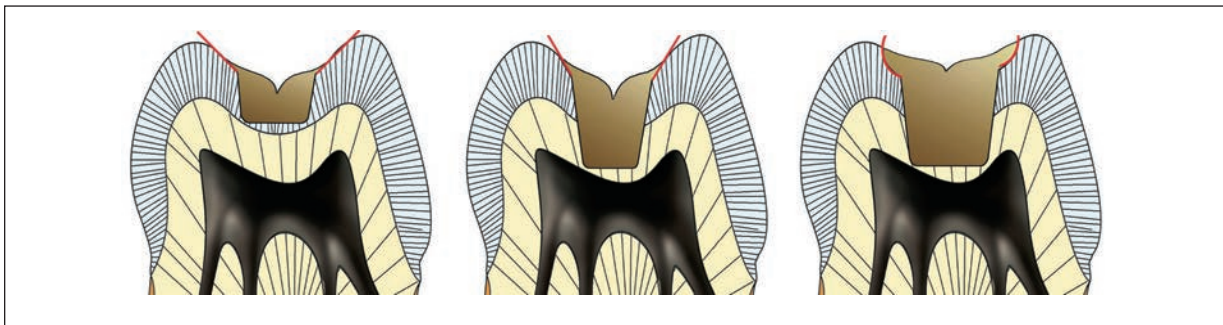


Fig 1-19 The bevel of the cavity margins for metal inlay restorations is designed differently, depending on the cavity volume: A flat cavity is given 45-degree bevels; a very deep cavity is given steeper bevels; and very deep and wide cavities are prepared with round bevels.

Occlusal inlays

For occlusal inlays, the width of the cavity is half the intercusp distance in order to maintain the stability of the dental substance and leave the

occlusal contacts on the natural dental tissue. An occlusal cavity is 1.5 mm wide and deep and includes the main fissures. The cavity walls have a common path of insertion without undercuts. The inner edges of the cavity are rounded, and

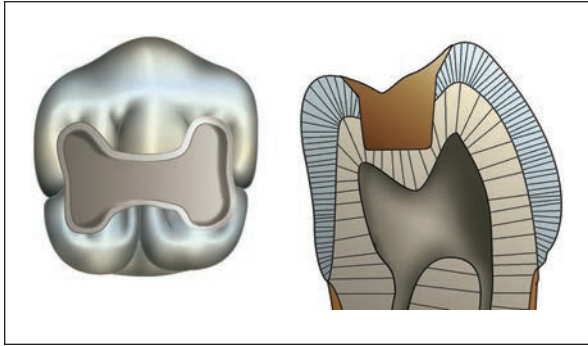


Fig 1-20 The cavity for a single-surface metal inlay has a minimum depth of 1.5 mm; preparation is slightly divergent, and there are no undercuts. The cavity margin does not lie in the area of occlusal contacts and is prepared with an enamel bevel.

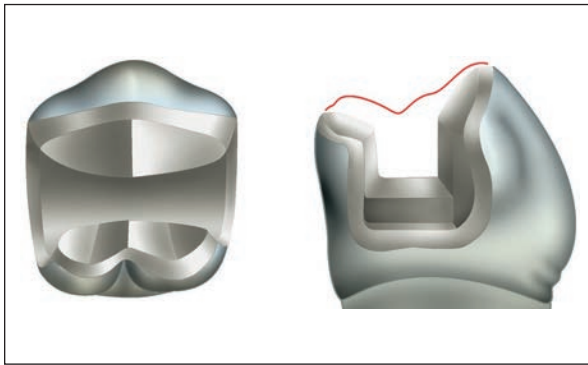


Fig 1-21 An onlay incorporates the whole occlusal surface and extends into the approximal surfaces. The approximal extensions run lingually or vestibularly; an approximal-cervical shoulder is usually prepared. An enamel bevel is prepared around the cavity margin.

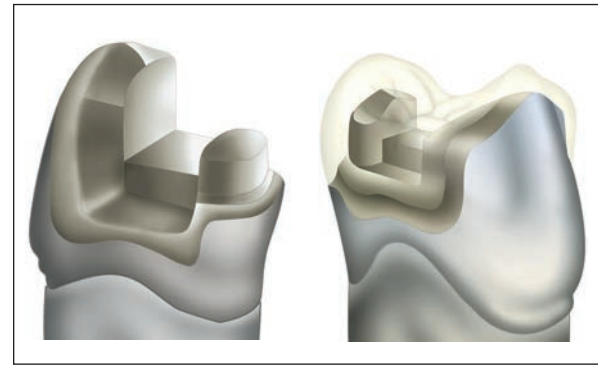


Fig 1-22 The overlay replaces the occlusal surface and fully encompasses the occlusion-bearing cusps. A shoulder is usually prepared around these cusps, while the nonsupporting cusp is surrounded by a simple enamel bevel.

the occlusal margin is beveled so that the margin of the metal restoration can be refined by reworking (Fig 1-20). Antagonist contacts lie either completely on the natural dental substance or on the surface of the restoration.

Inlay splints refer to cast restorations that are soldered together; they are used to fix mobile teeth to adjacent teeth and stabilize them. Inlays can be used to anchor partial dentures, but they offer less retention to abutment teeth than the use of crowns.

Onlays and overlays

Onlays or overlays are prepared when the dental hard tissue is weakened by large caries lesions and occlusal corrections are also necessary. For an onlay, preparation involves the occlusal sur-

face, including the cusp tips, and usually extends into both approximal surfaces (Fig 1-21). Overlay preparation incorporates the bearing cusps and ends in a shoulder preparation with bevel. The preparation margin runs level with the height of the contour and extends into both approximal surfaces. There is a smooth crossover between overlays and partial crowns (Fig 1-22).

A core buildup made of plastic restorative materials (glass-ionomer cement or composite) becomes necessary for badly damaged teeth before the onlay or overlay preparation can be started. All restorative margins must lie within healthy dental hard substance and not in the buildup material. Such core buildups are anchored with parapulpal pins in the form of root canal screws unless a cast post and core is being fabricated.

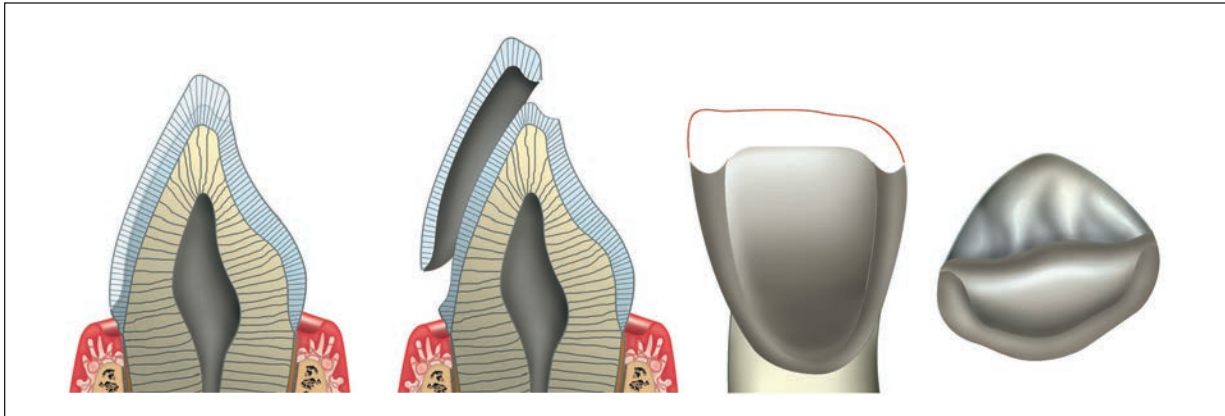


Fig 1-23 Veneers replace the labial facet of an anterior tooth. For this purpose, a consistent layer approximately 0.8 mm thick is ground out of the enamel into the approximal areas; the incisal edge is prepared into the lingual area. The approximal crown width is retained, and undercuts are avoided. The prepared surface is conditioned by acid etching to receive the ceramic veneer and therefore must lie solely within the enamel area. A composite bonding agent is used to achieve the adhesive bond.

Veneers

Veneers, also known as *laminates* or *facings*, are fabricated when circular preparation of dental crowns is to be avoided in order to preserve ample natural dental tissue as well as esthetics. Veneers can be made individually out of acrylic resin, composite, and ceramic directly in the mouth or in the dental laboratory, or they can be milled out of prefabricated ceramic blocks using CNC machining. Veneers are indicated for discolored facets or large anterior restorations, enamel cracks or chips, and morphologic or positional corrections.

To prepare a veneer stump, the labial enamel and the incisal edge into the approximal surfaces are removed to a thickness of about 0.5 mm without exposing the dentin. The preparation surface is slightly curved in the horizontal and vertical direction and should be smooth without undercuts. The approximal surfaces can be incorporated as far as halfway; if the approximal areas are intact and not discolored, the approximal contact made of natural dental tissue can remain unchanged.

The veneers are retained on the dental enamel by micromechanical adhesive means. For the purposes of micromechanical retention, the enamel is conditioned at the cavity margin using the acid-etching technique, which enlarges the

surface of this enamel area and renders it wettable (Fig 1-23). The inside of the veneer is also conditioned (porcelain veneers are etched with hydrofluoric acid) and prepared with adhesive silane as a bonding agent to the composite. Adhesive cementation can be done with self-curing dual cement or light-curing composite cement.

The acid-etching technique is used to condition the surface of the enamel for adhesive cementation of ceramic or composite inlay restorations. The enamel surfaces intended for adhesive bonding are cleaned and treated with orthophosphoric acid (H_3PO_4) or phosphoric acid gel so that the apatites of the enamel prism cores partially dissolve. After 30 to 60 seconds, the etchant and dissolved enamel constituents are rinsed off. This leaves surface roughness between 5 and 8 μm deep, creating an enlarged surface with pores for micromechanical retention of the cementing acrylic resin. The roughened cavity margins and the restoration etched on the underside are silanized and cemented in place with a composite bonding agent. During acid etching and insertion with the composite bonding agent, irritation of the pulp and prolonged hypersensitivity of the restored tooth can arise if dentin areas are touched. Therefore, the cavity margins for adhesively cemented inlay restorations must lie within the area of etchable enamel.

Coronal Restoration

Definition and Classification

Single-tooth rehabilitation is a significant area of dental technology work. When an individual tooth is so damaged by caries, fractures, or other harmful factors that other dentistry measures are no longer able to preserve the tooth, an artificial crown may be placed on the prepared tooth like a cap. With this type of prosthetic single-tooth restoration, the masticatory function and health of the existing teeth can be maintained and restored.

An artificial dental crown must take on the functions of a natural crown and must accurately reproduce the ideal functional form of the natural tooth shape. Accurate knowledge of tooth morphology is therefore an essential requirement for dental technicians when fabricating a coronal restoration. Every tooth has specific functional shape characteristics that must be addressed by coronal restoration. Artificial crowns have many important functions, as outlined below. Figure 2-1 provides an overview of the various types of artificial crowns.

The occlusal surfaces of artificial crowns adapted to the antagonists should do the following:

- Achieve full functional contact
- Stop jaw movement
- Allow transfer of forces to the periodontium during mandibular movements with tooth contact (Fig 2-2)
- Allow interference-free gliding without overloading the periodontium

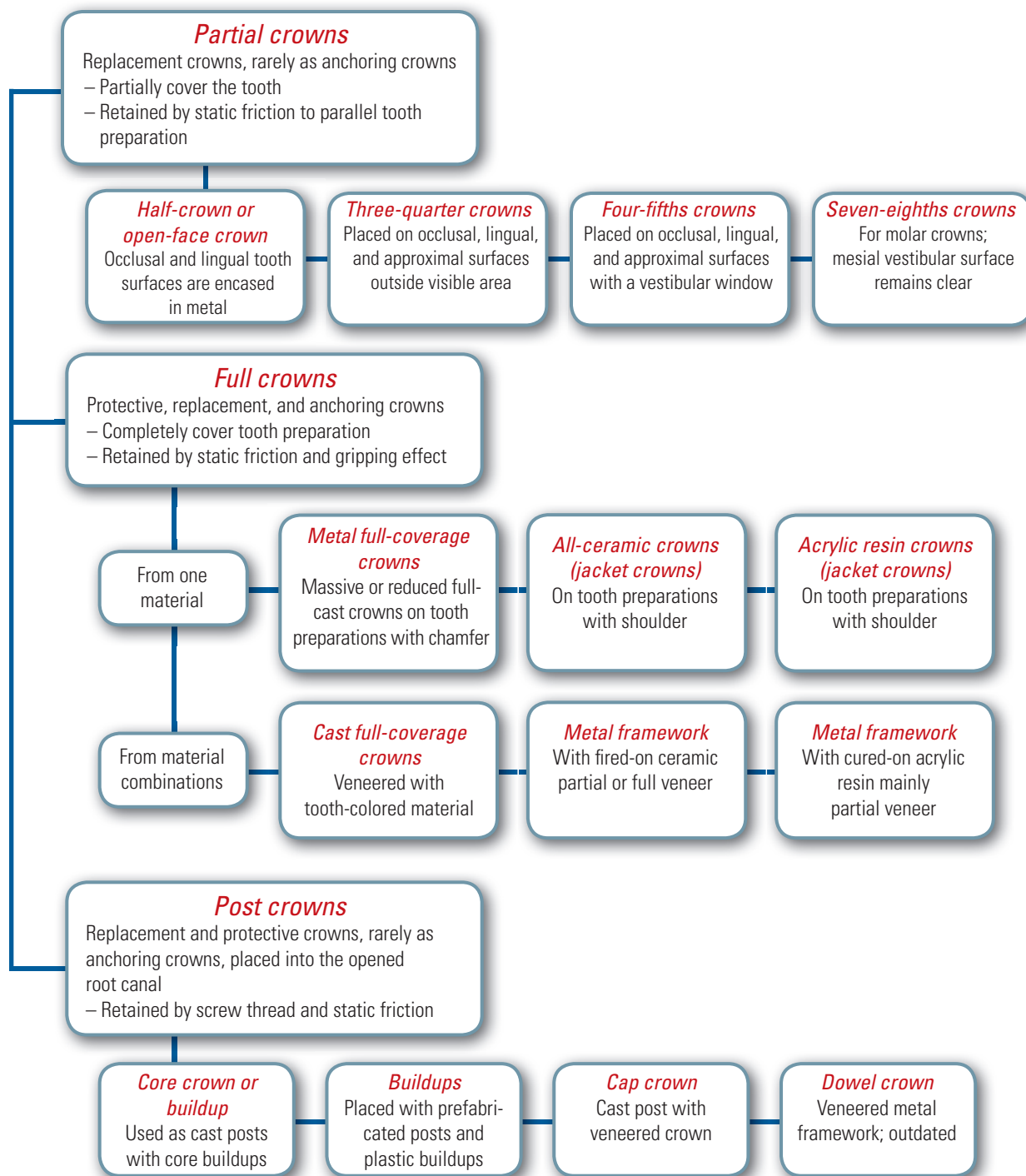


Fig 2-1 Diagram of crown types.

Fig 2-2 When fabricating an artificial occlusal relief, the functional surfaces must be adapted to the antagonists to ensure precise transfer of forces. Incorrect contouring of occlusal surfaces leads to faulty contacts and harmful transverse thrust. A lack of occlusal contacts can result in displacement of teeth.

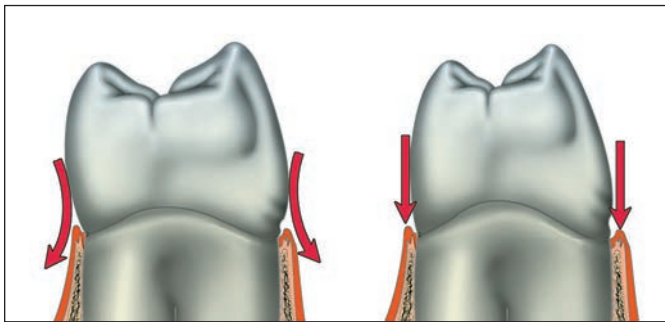
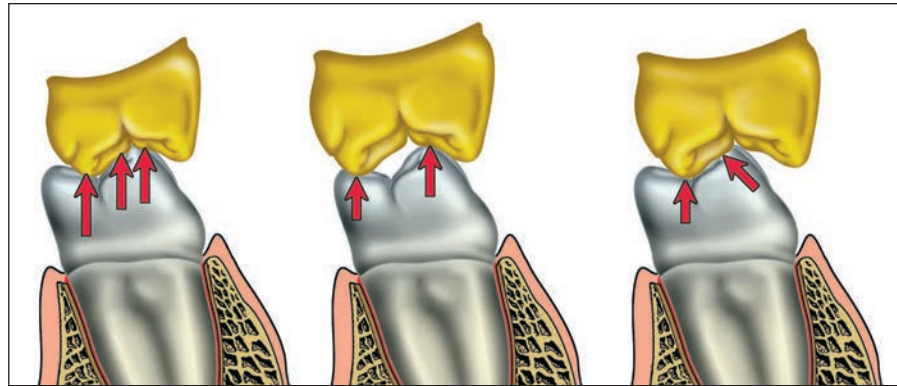


Fig 2-3 The anatomical surface bulges are functional shape characteristics that must be reproduced in artificial crowns. The so-called vertical curvature characteristics serve to protect the marginal periodontium; excessive curvatures produce undercuts that inhibit self-cleaning of the teeth. The horizontal curvatures of the vestibular surfaces also have to be reproduced to ensure that no niches are formed where contaminants may accumulate.

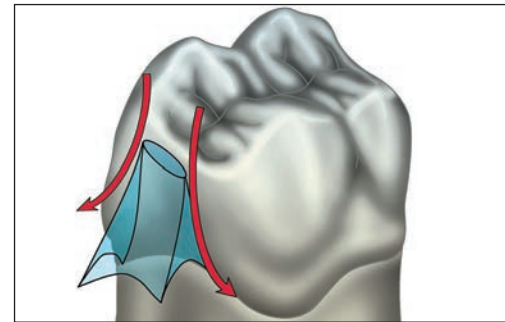


Fig 2-4 The approximal surfaces form the approximal contact point that covers and protects the interdental papilla. When this contact is reproduced in artificial crowns, space must be created for the interdental papilla.

The precise anatomical surface curvature of the artificial crown does the following:

- Protects the marginal periodontium (Fig 2-3)
- Creates approximal contacts
- Protects the interdental papilla (Figs 2-4 to 2-7)
- Guarantees support in the dental arch
- Aids self-cleaning of the masticatory system (Figs 2-8 and 2-9)

- Fulfills esthetic demands
- Supports phonetic functions

A precise and accurate fit enables the artificial crown to do the following:

- Form a unit with the prepared tooth
- Preserve the tactile sense (Fig 2-10)
- Prepare food for digestion

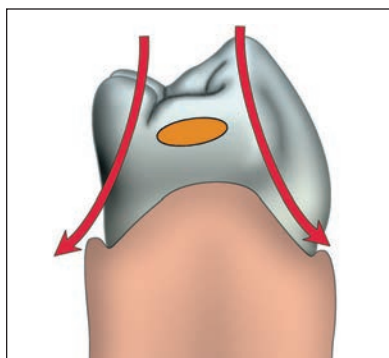


Fig 2-5 If the interdental papilla is well preserved, punctate shaping of the approximal contact is enough to maintain the protective function.

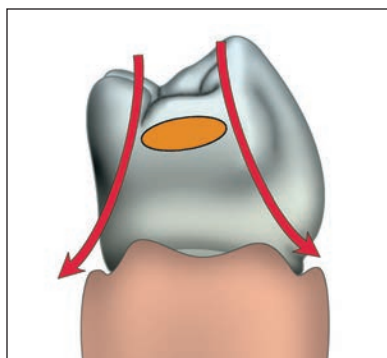


Fig 2-6 If the interdental papilla is reduced, the approximal contact must have a wider shape to secure the protective function.

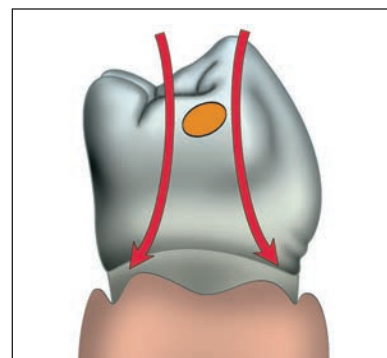


Fig 2-7 If the interdental papilla is reduced and shaping of the approximal contact is punctate, food is no longer deflected away from the interdental space.

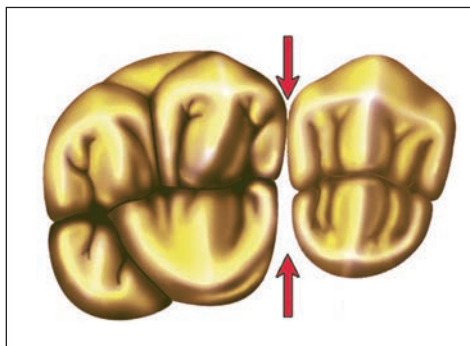


Fig 2-8 The approximal contact points viewed occlusally lie in the direction of the buccal cusps so that smaller niches are formed on the vestibular rather than the lingual side. The lingual areas of the teeth are easier to clean because of the action of the tongue.

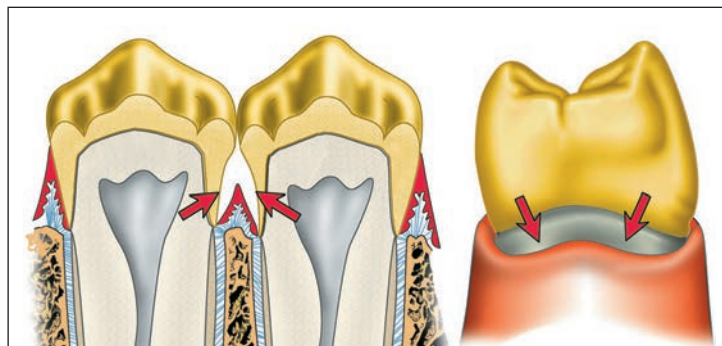


Fig 2-9 Contact points that overhang too much will create large interdental niches that are no longer filled with tissue. Deposits can accumulate because self-cleaning is prevented. This can result in chronic inflammation, and damage to the periodontal tissue cannot be ruled out.

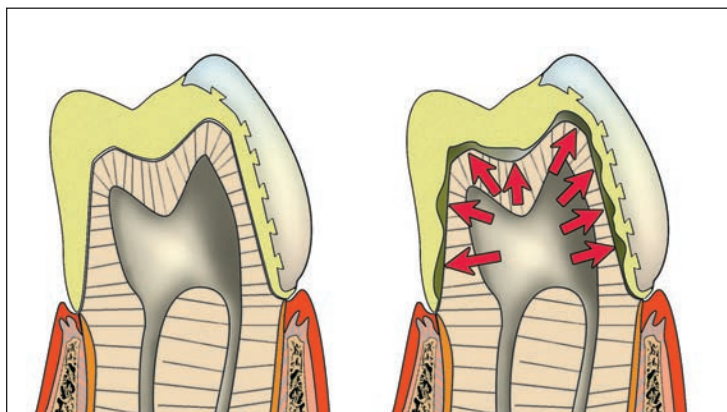


Fig 2-10 Accuracy of fit is not merely a requirement that sets the standard for technical expertise but also a functional necessity. Precise accuracy of fit allows the tooth to preserve a tactile sense and, as a mechanical unit, allows smooth transfer of forces. In the marginal area, accuracy of fit prevents damage to the marginal periodontium.

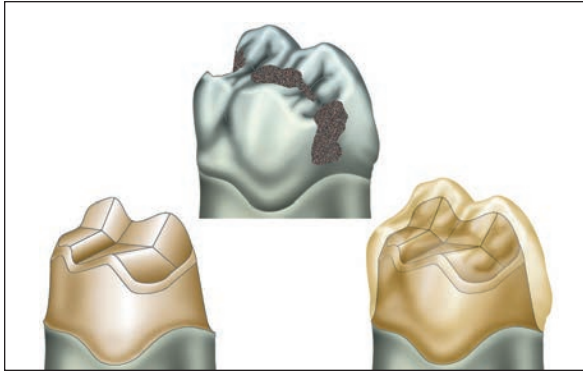


Fig 2-11 Artificial crowns replace lost hard tissue from teeth. If natural dental crowns are partly destroyed by caries and a tooth needs to be protected against further harmful influences, a protective crown should be fabricated that fully covers the natural dental crown.

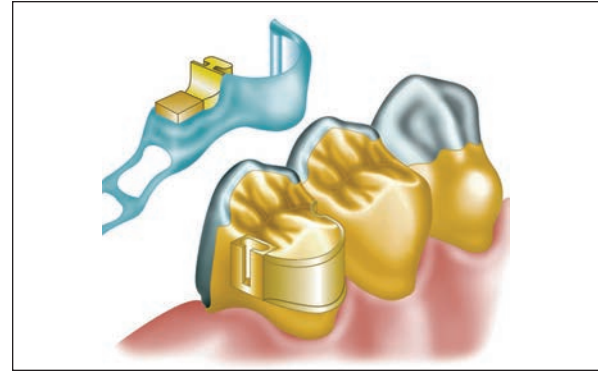


Fig 2-12 Artificial crowns can be used to bear retention parts. They are also used to protect teeth that will receive clamps. Generally speaking, anchoring crowns are associated with parallel fits, tapered designs, or prosthetic auxiliaries.

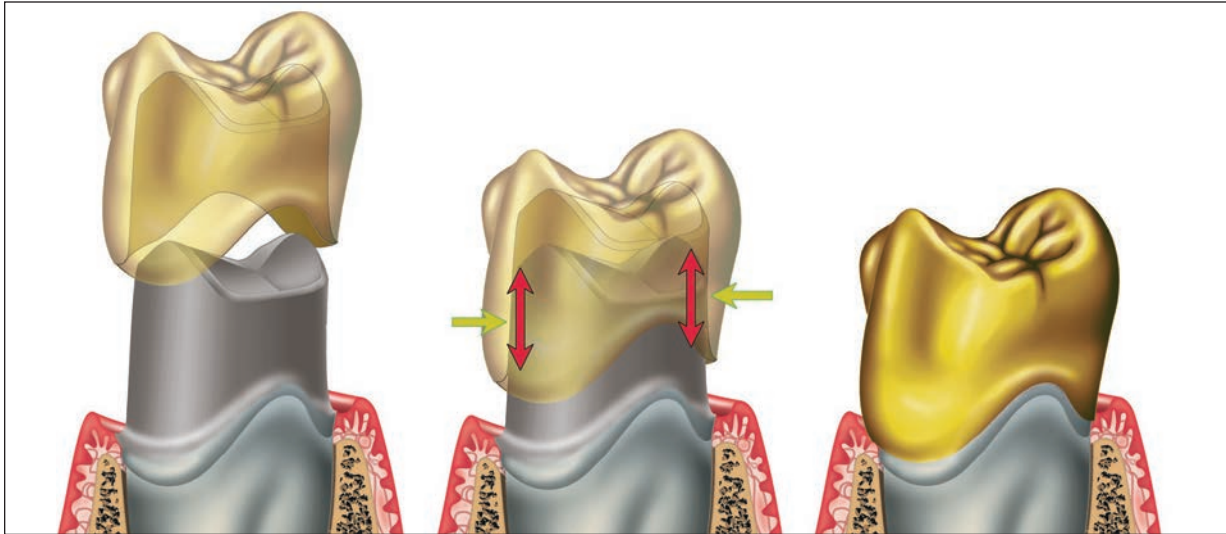


Fig 2-13 Retention of artificial crowns onto the tooth preparation can be achieved by two physical mechanisms: static friction and a gripping effect. Both are produced by the complete enclosure involved in a full crown and guarantee secure retention of the crown.

All of these functions are equally important and must be fulfilled within the broad range of applications for artificial crowns.

Classification of artificial crowns is based on their specific range of functions:

- *Replacement crowns* replace lost hard substance of the tooth, which can no longer be restored by other (conservative) dentistry measures.
- *Protective crowns* protect the tooth preparation against harmful influences (caries or defects

caused by clamps) by completely covering the organic dental substance (Fig 2-11).

- *Supportive or anchoring crowns* support and anchor fixed partial dentures and partial prostheses as abutments or carriers for attachments or prosthetic auxiliaries (Fig 2-12); they are fixed to the prepared tooth.
- *Full crowns* cover the clinical tooth preparation completely, while fixation (retention) is achieved by static friction resistance and a gripping effect (Fig 2-13).