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Complex single-tooth restorations

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The restoration of posterior teeth includes more restorative materials and techniques today than ever used in the past. Suspicious occlusal pits and fissures may require a sealant, a preventive resin restoration using a flowable or highly filled composite resin, or even an amalgam restoration. Inlays and onlays may be made from the traditional gold materials, but composite resin and ceramic are also options for the practicing dentist. Treatment should be based on aesthetic and functional considerations as well as caries risk. For patients at higher risk for caries, treatment with fluoride-releasing materials that decrease recurrent caries should be used when possible. This article in the *Dental Clinics of North America* describes the available materials and techniques used to restore large lesions in posterior teeth.

Materials used for direct restorations

Amalgam, glass ionomers, resin-modified glass ionomers, resin composites, and compomers are commonly used to restore proximal lesions in posterior teeth. Each material has specific advantages and disadvantages. Amalgam has a successful clinical history and is the most abuse-tolerant material to place.

Although it has limitations, amalgam may be placed in areas of contamination (especially blood and saliva) with good clinical results. Aesthetic materials such as compomers, glass ionomers, and composite resins have the following advantages: they bond to tooth structure; they have proven longevity in minimally invasive preparations; they have thermal insulators and aesthetic appeal; and some release fluoride, which may inhibit recurrent

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caries. Aesthetic restorative materials are not ideal, however. Compomers, modified resins, and conventional glass ionomers have poor wear resistance and cannot be used to restore occlusal surfaces. Composite resin restorations have clinical limitations [1] that restrict the use of resin as a posterior restorative material. Resin restorations are technically difficult and require more placement time than a similar-sized amalgam restoration. Interproximal contacts are difficult to obtain, and isolation from contamination, especially blood, is essential. Postoperative sensitivity with class II composite restorations has been reported and is primarily caused by polymerization shrinkage of the composite resin, which causes cracking and crazing at enamel margins and gap formation at the resin-tooth interface.

Posterior composite resin restorations

Preparations for posterior composite resin restorations are similar to amalgam preparations, but composite resin preparations can be more conservative, narrower, and shallower. Preparations for composite resin restorations are essentially preparations in which the caries are removed and the tooth restored. Because the composite restoration is more conservative than amalgam, ideally the initial cavity preparation in a tooth should be composite resin. The isthmus width for composite resin preparations should range from no isthmus to no greater than one half the intercuspal distance. The size restriction is not based on the poor wear performance of composite but instead on the amount of remaining tooth structure and the polymerization shrinkage of the composite. Retention has been advocated for slot-type composite preparations, but with larger preparations no auxiliary retention (such as grooves) is needed. One in-vivo study [2] has shown that placing an occlusal bevel on a posterior composite preparation enlarges the preparation width and increases wear of the composite resin restoration.

Bonding agent application

Phosphoric acid is currently used to etch enamel and dentin surfaces simultaneously. The etching step removes the smear layer, opens dentinal tubules, and exposes collagen fibers in dentin. In enamel, etching produces an etch pattern that provides mechanical retention to bond resin to tooth structure. Etchants have antimicrobial activity, and if proper isolation is maintained, it is redundant and unnecessary to apply a separate antimicrobial agent before etching. Etching is not passive, and the etchant should be stirred during application to ensure that fresh etchant is available at the surface being etched. Tooth structure contains hydroxide ions released during etching that inactive the etchant, so stirring keeps fresh, active etchant at the surface. If etchant is placed passively on a tooth, numerous unetched microscopic and some macroscopic areas occur because of air bubbles in the etchant. These air bubbles produce voids in the etch pattern. The unetched voids cannot be sealed and provide a pathway for leakage and recurrent decay.

Recommended etch times range from 15 to 20 seconds, but if no mat pattern appears on enamel after the etchant is rinsed and dried, the etch time [3] should be increased because enamel with high fluoride content is resistant to etching. The etchant should be rinsed until the etchant color is gone. [4] There is no added benefit to a longer rinse time. [5] After rinsing and drying to see the mat appearance of the enamel, the tooth is wetted with tap water until the dentin is glistening but no puddles are present [6–8]. A moist cotton pellet should be used to wet the dentin just before applying primer. Air drying dentin before placing the primer, for only 3 seconds, decreases bond strength. [9] When collagen fibers are supported by water they are easily surrounded by the bonding agent. During drying, the fibers collapse, preventing the bonding agent from surrounding and encasing the collagen fibers. The primer of fourth-generation adhesives or the combined primer and adhesive combination of fifth-generation adhesives must be applied and dried until the preparation has a shiny surface appearance. If the shiny appearance is not apparent, then another coat must be applied and dried. The primer or primer-adhesive combination should be air dried thoroughly to evaporate the acetone, ethanol, or water solvents within the adhesive.

In most direct applications, a fourth-generation adhesive (with a separate primer and adhesive) is a better choice. These materials form thicker layers than the one-bottle bonding agents. Adhesives containing acetone evaporate rapidly, producing lower bond strengths as the material becomes more viscous and more difficult to apply. [10] Any adhesive containing acetone should be dispensed from the bottle directly to a brush tip and applied immediately to the tooth. The bonding agent must be light cured before the composite resin is placed over it. When the adhesive step is not separately light cured, bond strengths are reduced. [11] There is a direct relationship between bond strength and the distance that the light is from the adhesive. [12] Light intensity decreases in air, and the decrease is dependent on the type of light guide being used. When the curing light guide cannot be brought close to the floor of the gingival box, for example, the adhesive is polymerized poorly, with resultant poor bond and seal. The light guide should be as close as possible to the surface being cured to produce the highest bonds to the tooth and the best seal.

Matrix systems provide the shape for the missing tooth. These matrices vary from plastic to metal and range from segmental to circumferential. Metal matrices are easiest to place because they pass more easily through contact areas. Toffelmire retainers and Dixieland bands (Teledyne-Getz; Fort Collins, CO) are recommended because they are thin and contoured to shape the composite resin being placed into the matrix. Interproximal wedges separate the teeth and compensate for the thickness of the matrix and the shrinkage of the composite resin when it is polymerized. Greater separation is required when a mesial-occlusal (MO) or distal-occlusal (DO) restoration is fabricated, and circumference matrices are used because the separation must compensate for two thicknesses of matrix. When segmental matrices are used, only one thickness of matrix must be regained to achieve an adequate separation because segmental matrices do not surround the tooth being restored and separate it from the adjacent tooth. Sectional matrices such as Palodent matrices (Dentsply/Caulk; Milford, DE, or Composi-Tight; Garrison Dental Solutions; Spring Lake, MI) are placed on the interproximal surface being restored, a wooden wedge is placed, and the separating ring is placed in the gingival area between the two teeth being restored. The separating ring is made of spring steel that attempts to close by pushing the teeth apart and separating them. These rings separate the teeth and help develop tighter proximal contacts. The Composi-Tight matrix system grasps teeth better, and those rings are retained better on shorter teeth such as bicuspids or mandibular molars. These matrix systems provide good contacts in most posterior restorations. Wooden wedges are needed with either system and are placed before positioning the separating ring.

Materials used

Wear-resistant, low-shrinkage composite resins should be selected for posterior use. Recommended materials are P-60 (3M ESPE; St. Paul, MN), Pyramid (Bisco; Schaumburg, IL), Z-100 (3M ESPE), Heliomolar HB (Ivoclar/Vivadent; Amherst, NY), or SureFil (Dentsply/Caulk). These materials have higher filler loading (P-60 has the highest filler loading of any composite resin), which reduces slumping during placement and allows the materials to be sculpted. This ability to be molded allows the composite resin to hold its shape and reduces its stickiness to placement instruments. These materials allow the restoration to be contoured much like an amalgam is carved, which reduces finishing time.

Composite resin placement

After the bonding agent is applied and cured, the composite resin is placed. There are four methods for placing the composite resin. Incremental placement [13–16] (Fig. 1) and curing is controversial and may not reduce marginal opening and microleakage resulting from polymerization shrinkage. Incremental placement and curing of each increment of composite resin with visible light is necessary, however, to polymerize each increment thoroughly. A review of the literature shows that no incremental placement technique is superior to any other incremental placement method. Increments no greater than 2 mm thick should be placed to ensure complete polymerization. Incremental placement of composite resin does not eliminate stress at the marginal areas of the resin restoration; however, it ensures complete polymerization of the composite. High-intensity curing units such as plasma arc curing lights (Virtuoso; DenMat, CA; and Wave Light; Schein Dental) shorten curing times but do not significantly increase curing depths. [17]

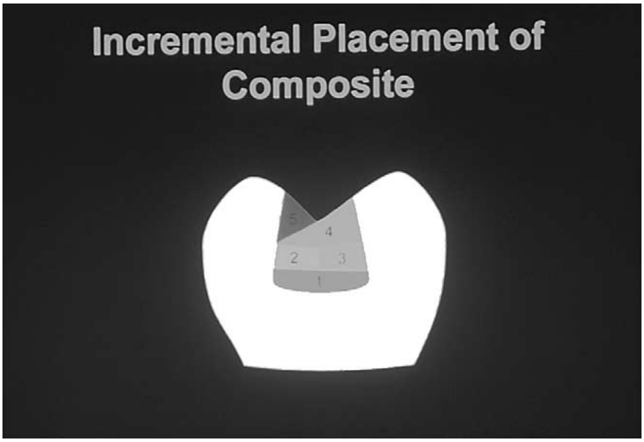

Fig. 1. The incremental method of placing the composite resin.

High-intensity curing lights speed curing of each increment and decrease the total time required to place a composite resin restoration. A small glass ionomer base may be placed on thin areas of dentin to decrease postoperative sensitivity. The incremental placement technique is indicated for patients with low or normal caries risk. A second technique for placing posterior composite resins is the bulk-filling technique, in which the preparation is filled completely, and composite resin is polymerized in one increment. This technique, often called *trans-tooth curing*, places the composite resin in bulk and cures the tooth from the facial and lingual and then from the occlusal surfaces. Bulk-filling techniques developed with the "packable" composite resins such as SureFil (Dentsply/Caulk), ALERT (Jeneric/Pentron; Wallingsford, CT), Solitaire (Heraeus Kulzer; Armonk, NY), and Pyramid (Bisco). A recent article [18] measuring the polymerization shrinkage of these materials has shown that they have no better wear resistance or less shrinkage than less viscous materials. Packable composite resin materials are less sticky, may achieve tighter contacts, and allow occlusal anatomy to be formed more easily because they hold their shape during sculpting. They cannot be carved but can be molded and once molded, they maintain that shape until polymerized. Although flowable composite resins have been advocated with condensable composite resins to improve marginal adaptation, little research has been found to support the use of flowables. Condensable composites, available in limited shades, often produce poor aesthetic restorations rather than an aesthetic restoration that blends with the surrounding tooth structure. Condensable composite resin dries out when stored and crumbles when used. P-60 and Pyramid are not true condensable composites but are easy to place, do not dry out during storage, and are recommended, even though they are available in limited shades. In the third technique, the open-sandwich technique, a fluoride-releasing material is applied at the gingival margin of the proximal box and extended to the gingival margin (Fig. 2). The fluoride-releasing material is extended to just below the contact point of the adjacent tooth and places a rechargeable fluoride-releasing material at the gingival surface. Fluoride released from the restorative material is absorbed by the adjacent tooth structure, especially the gingival margin. In this technique, the resin-modified glass ionomer is applied in the proximal box of the preparation from the gingival area to just below the proximal contact of the adjacent tooth, and a wear-resistant composite resin is applied over the fluoride-releasing material. A 5-year clinical study showing the success of this technique was published recently. [19] Typical results from this study are seen in Figs. 3 and 4. In-vitro studies also have demonstrated that

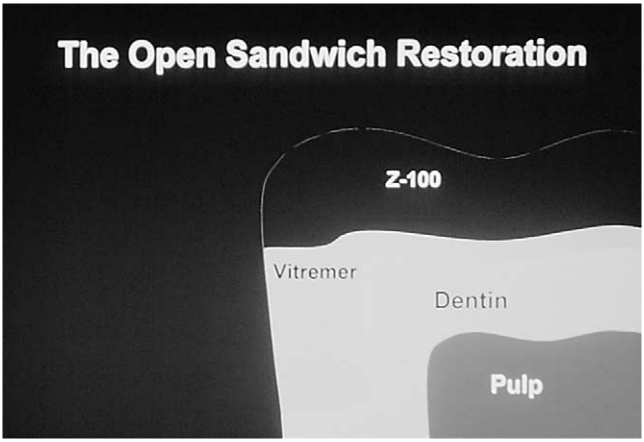

Fig. 2. The open sandwich technique. A fluoride releasing material is applied and extended to the gingival margin to improve fluoride release at this location.

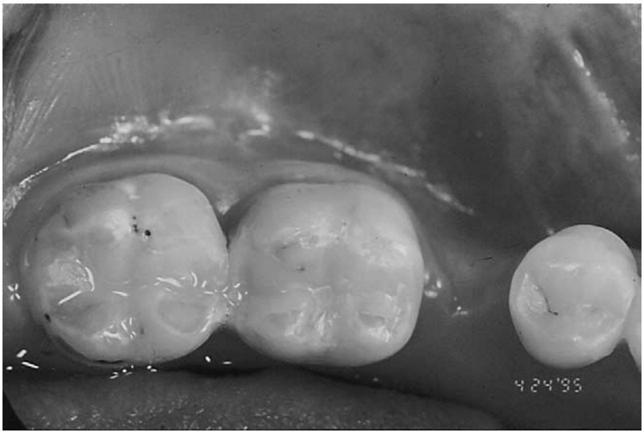

Fig. 3. Baseline view of a posterior composite resin.

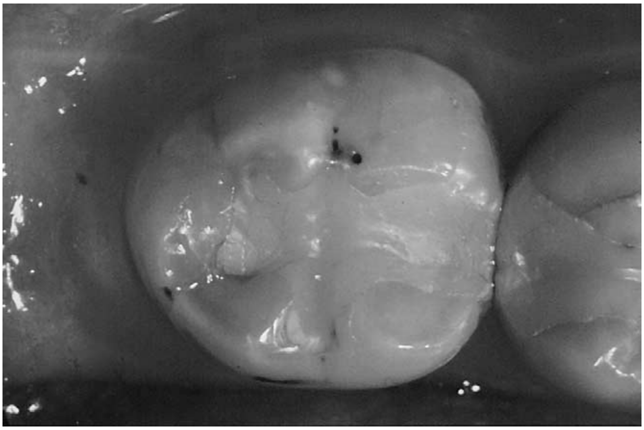

Fig. 4. A five-year follow-up of the same restoration seen in Fig. 3.

demineralization of dentin along the gingival wall of class V lesions is significantly reduced when the glass ionomer or fluoride-releasing resin liner was exposed at the cavosurface margin of the tooth. [20] Two in-vivo studies [21,22] also have reported decreased caries associated with glass ionomers in class V restorations. This technique is strongly recommended for patients at higher risk for caries.

A fourth method used to place posterior composites is the directed-shrinkage technique. In this technique, a chemically cured composite resin is placed into the gingival box of the preparation after the adhesive has been placed. Heat and moisture cause the composite resin to shrink toward the center of the tooth, reducing stress at the marginal interface and reducing leakage. After the chemically cured resin polymerized, a light-cured composite resin was placed on the occlusal surface and light cured. No clinical study was located to validate the effectiveness of this technique. In view of the poor support for this method, it is not recommended.

Forming the contact area

Perhaps the most difficult area to develop with posterior composite resins is the contact area. The Contact Pro (C.E.J.; San Juan Capistrano, CA) is placed into unpolymerized composite resin, pushes the resin against the adjacent tooth, and forms a curved contact area. This instrument is useful when the contact is stretched to the adjacent tooth. It provides a snug contact and forms a nice occlusal embrasure.

Flowable composite resins are sometimes recommended as an initial increment for posterior composite resin restorations. These materials shrink more than composite resin, have greater water uptake and staining, and have lower mechanical properties than composite resin. Flowable resins, when used as a liner, may be acceptable but no clinical studies have documented that these materials produce better restorations than those achieved without them.

Finishing posterior composite resin restorations requires carbide burs (7901 and 7404) (Brasseler; Savannah, GA) and Sof-Lex disks (3M); a series of four disks is recommended in the snap-on size and large size. A number 12 B blade on a bard parker handle is a must for removing flash at the gingival margin. The AstroPol polishing kit from Ivoclar is highly recommended to form occlusal embrasures and to develop occlusal anatomy and proper contours. Aluminum oxide polishing paste (Dentsply/Caulk) is recommended as a final polishing agent for the restoration.

Rebonding

After the composite resin is inserted and finished, the margins are etched with phosphoric acid for 10 seconds, rinsed, and a surface-penetrating resin (Fortify, Bisco) is painted onto the margin and the composite resin and cured. One clinical study [23] has shown 17% less occlusal wear after a single application of Fortify at 5-year recall. In addition to less wear, Fortify penetrates and improves the marginal seal. After rebonding, the restoration is complete.

Amalgam restorations

When larger restorations are needed or when isolation from saliva and blood cannot be prevented, amalgam restorations provide durable, clinically successful restorations. Amalgam has been used to restore teeth for more than 150 years and has been a dependable restorative material in restorations with sizes ranging from small occlusals to total cuspal coverage. [24,25] Complex amalgams are posterior amalgam restorations that replace one or more cusps. [26] Complex posterior amalgam restorations protect cusps from fracture when tooth structure has been lost to disease, trauma, or endodontic treatment. [27]

Complex amalgam preparation

Complex amalgam preparations are similar to other amalgam preparations: unsupported enamel is removed; 90° cavosurface margins are made to provide strength to the amalgam and the tooth; adequate resistance and retention form are developed to prevent restoration displacement during function; and the cusp height is reduced enough to provide 2 mm of cuspal amalgam coverage. Retention form provides retention for the restorative material, and resistance form provides resistance to stress applied to the restoration and to the remaining tooth structure. Retention form prevents displacement of the restoration by tensile forces. Resistance form prevents dislodgment of the restoration or fracture of the restoration or remaining tooth structure by vertical, oblique, or horizontal forces. The walls of the preparation, pins, amalgapins, slots, boxes, or bonding agents may provide retention for the restoration. These features must be distributed around the preparation to resist forces encountered during function. The restoration must be designed to resist forces applied from any direction to any surface. The preparation should remove unsupported enamel and reduce weakened or cracked cusps 2 to 4 mm to provide good resistance form. Cusp reduction should be 2.5 to 3 mm to provide adequate bulk of amalgam to resist fracture during function and to cover the pin with amalgam. Depth cuts should be made to standardize the reduction. Strong tooth structure should not be reduced. The preparation should not be extended to an intact tooth simply to increase retention or resistance form. If the mesial cusps of a maxillary molar are reduced and the oblique ridge is intact, it should not be prepared because it strengthens the tooth.

Retention and resistance features for complex amalgam preparations include self-threading pins, amalgapins, grooves, remaining walls, and proximal boxes. There are advantages and disadvantages for each feature, and several features may be used in the same preparation. Self-threading pins are frequently used retentive devices. Pinholes are prepared, and self-threading pins are threaded into the channel. The Max pin (Fig. 5) from Coltene/Whaledent (Mahwah, NJ) has the best combination of features (lower stress to the tooth, good retention, a collar that limits penetration to prevent perforation and rapid insertion) and is inserted by using a slow-speed handpiece. [28] This pin is recommended for clinical use. Before a site is selected for a pin, radiographs of the tooth should be examined to estimate the size of the pulp chamber. One should visualize the root anatomy in the area where the pin channel is about to be placed. Bifurcations and trifurcations, root depressions, and large pulp chambers may be present and should be avoided. Pins should be placed in dentin and within the dentoenamel junction (DEJ). If pins are close to the DEJ or the external surface of the tooth, cracks in dentin may appear and extend to the external tooth surface. Pins are supplied in varying diameters, and pin size should be determined

Fig. 5. A close-up photograph of the Max pin. Note the tapered end, reverse buttress thread, and self-limiting collar.

based on the remaining dentin thickness and the retention needed. Large-diameter pins provide more resistance and retention than smaller pins, so that in a molar tooth, fewer larger pins may be used to support the restoration. Smaller pins should be used where there is inadequate dentin for larger pins. Coltene/Whaledent TMSpins are supplied in four diameters, varying from 0.0145 inch to 0.031 inch. The Regular pin diameter is 0.031 inch and has the greatest pin-pinhole mismatch of all the pins (0.004 inch). The Minim and the Max pins are the most popular and have a 0.023-inch diameter. Minikin pins are 0.019 inch in diameter, and Minuta pins are the smallest, with a 0.0145-inch diameter. Pins ideally should be placed at the line angles, where the greatest bulk of dentin is present. In addition, placing pins at the line angles reduces stress and provides proper distribution for the restoration. The legs of a chair are placed at its four corners to provide the best balance. Likewise, a pin-retained restoration should have pins placed at each line angle to distribute the stress created from inserting the pins and to provide the best resistance to the forces of mastication. Pins should be placed so that amalgam can be condensed completely around the pin to allow the pins to retain the amalgam restoration. To measure the clearance, a condenser or explorer should be placed between the pin and any dentin wall, adjacent pin, or matrix. The instrument should pass freely to allow thorough condensation of the amalgam around the pin. If the condenser cannot pass between the pin and any adjacent structure, then additional tooth structure is removed or the pin is bent. The starting point for the pin is a dimple made with a no. 0.25 bur at least 0.5 mm inside the DEJ. Before cutting a pinhole, parallel the pin drill with the external tooth surface in the area where the pin will be placed, examine the radiographs once again, and drill the pinhole from 1.5 to 2 mm deep depending on the diameter of the pin. Depth-limiting drills are available for each pin diameter and provide the optimal depth for each pin. The channel is prepared with the twist drill in a pumping action to clear the debris from the drill and to cool the drill. Although pins may be inserted with a hand driver or a low-speed handpiece, the most efficient insertion method is the slow-speed handpiece. If the pin strips the dentin during insertion and loses its retention, a larger-size pin may be used in the same position. Do not place the next larger size in the old pinhole, because this size mismatch will increase the stress to the surrounding dentin. Re-drill the pinhole, with the drill corresponding to the larger pin, and insert the pin. Pins have been redesigned to reduce stress to the dentin and yet provide effective retention. The Max pin (Coltene/Whaledent) has a collar, which limits the insertion of the pin and promotes shearing of the pin (Fig. 6). The Max pin is slightly shorter than the twist drill to reduce stress to the apical dentin. Stress is further reduced with the reverse-buttress thread design. The Max pin has an ideal 2-mm head length and rarely needs to be reduced. For these reasons, the Max pin is recommended. Pins may be shortened with a 169L bur using a brushing motion and adequate water or air coolant to prevent heat build-up. Gen-

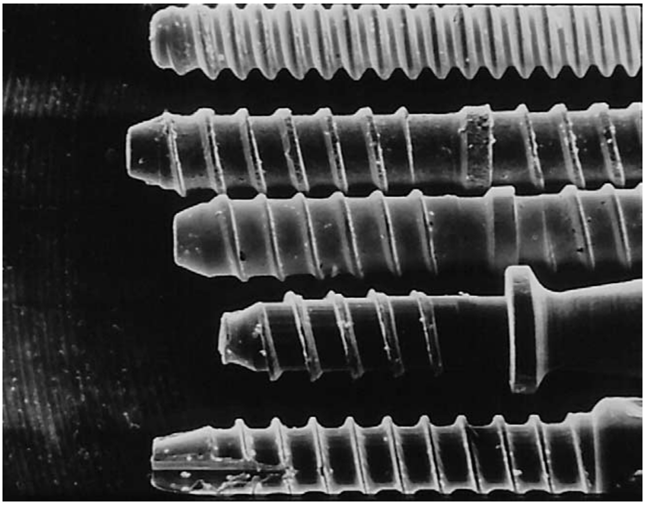

Fig. 6. A scanning electron micrograph of four pins. From the top Minim pin, Link Pin, Link Plus pin, Max pin and Brasseler pin.

erally speaking, the pin should extend 2 mm above the prepared tooth surface to provide retention for the amalgam, but 1 mm of amalgam occlusal to the pin may be adequate to prevent amalgam fracture during function if the pins are distributed around the tooth. [29] Pins should be bent with a pin-bending tool (Coltene/Whaledent) to ensure amalgam bulk between the pin and the external surface of the restoration. After the amalgam is inserted and the matrix removed, the restoration is carved using an interproximal carver, cleodiscoid, and other carvers.

Amalgapins may be used to provide retention and resistance for complex amalgam restorations. Amalgapins are simply amalgam-filled dentin holes. [30] Although originally drilled with a no. 1157 or 1156 bur to 3 mm, the technique was later modified to produce a 0.8-mm diameter channel 1.5 to 2 mm in depth with a no. 330 bur. Because little dentin stress is produced with amalgapins, these retentive devices may be placed closer to the DEJ than self-threading pins. Amalgam is condensed into the prepared channels using a condenser that fits into the channel. Careful condensation of the amalgam into the channel is essential for the success of this technique. One amalgapin provides about the same resistance form as one pin. [31] A significant disadvantage of using this retention device is that the amalgam restoration frequently fractures through the amalgapins when the matrix is being removed. To prevent this problem, use pins and amalgapins or delay the matrix removal until the amalgam strength is able to resist stresses generated during matrix removal.

The third retentive devices are boxes such as those used in proximal areas in traditional class II amalgam preparations. These retentive devices are effective methods to retain complex amalgam restorations. They may be used on facial and lingual surfaces and the proximal surfaces.

A fourth retentive method is adhesive. The bonded amalgam restoration is clinically proven if Amalgambond (Parkell; Farmingdale, NY) is the adhesive. Recently a 5-year clinical trial bonding Tytin amalgam with Amalgambond Plus was reported [45]. The 5-year report demonstrated that not one bonded restoration debonded, a remarkable testimony to the success of Amalgambond Plus.

Matrices for complex amalgam restorations

Forming a matrix for a complex amalgam is more complicated than fitting a matrix to a simple class II amalgam because the matrix must provide the shape of missing cusps that will be formed in amalgam. Toffelmire retainers use matrix material, which is often too narrow to provide the height needed if cusps are missing. A piece of matrix material may be cut and added to the inside of the matrix to provide additional cusp height. When a significant amount of tooth structure is missing, the matrix will have a space extending to the retainer. Amalgam is condensed into this space and must be removed after the matrix is removed. To reduce carving time, a piece of matrix material may be cut and placed on the side of the Tofflemire matrix where the Tofflemire matrix retainer attaches to the matrix. To properly position cut pieces of matrix band, a spot weld is sometimes made with an orthodontic spot welder. An advantage of spot-welded matrices is the absence of a large opening in which the two ends of the matrix come together. Spot-welded matrices should be stabilized and shaped using modeling compound when necessary. This practice occludes the split, and the amalgam is now condensed against the matrix and held in place with a wooden wedge placed from the occlusal aspect of the retainer. A Tofflemire matrix is the most frequently used matrix for most complex amalgam restorations, but it must be supported during amalgam condensation to provide proper shape for the final restoration. To do this, the matrix should be contoured to form the missing tooth structure anatomically, and it should be supported to maintain that form. Modeling compound will stabilize and maintain the matrix shape. First the matrix is placed, wedged, and shaped, then compound is heated over a flame, withdrawn when the stick sags, and compressed against the matrix with a gloved finger wet with water. The compound is cooled with air from an air syringe. The compound-supported matrix shape may be refined with a warm burnisher or the back of a spoon excavator. The warm instrument is placed on the internal surface of the matrix and is applied until the compound melts. The matrix is then pushed into the desired form, especially in the contact area, and the compound is cooled.

Copper-band matrices also are useful for providing contour and shape to large, complex amalgam restorations, especially when additional height is needed. Copper bands used to form these matrices may be purchased in a variety of sizes. These bands are too thick to be used out of the box. The areas that will form the proximal contacts must be thinned with a sandpaper disk. Because of the thickness of copper bands, they can be used intact only on teeth in which both mesial and distal contacts are to be restored. These bands, as supplied, are difficult to contour, but can be contoured if they are annealed. To anneal a copper band, it is heated in a flame to a dull red color, allowed to cool to a point at which no red color is evident, and quenched in water. This quenching process allows bands to be molded to the desired contour by shaping the annealed band with contouring pliers and stretching the band to fit the gingival margin of the prepared tooth. A copper band that fits the gingival area of the preparation snugly may be trimmed with scissors to the appropriate height and shaped to provide the desired restoration contours. In contact areas, copper bands must be thinned to develop contact of the restoration to the adjacent teeth after removal of the matrix.

Finishing the amalgam restoration

After the amalgam is condensed properly, the matrix is removed, and the restoration is carved first in the interproximal areas and then on the occlusal. After the shape of the restoration is produced, the occlusal anatomy is formed and the rubber dam is removed. At this point, a nonwebbed prophylactic cup is used to apply flour of pumice or Nupro Gold (LD Caulk; Milford, DE) directly to all surfaces of the restoration. This action will smooth the preparation and develop the mat appearance (Fig. 7). This restoration is easily polished (Figs. 8 and 9) with a Brownie and Greenie (Shofu; Menlo Park, CA).

Material selection for indirect restorations

The choice of a material depends on the functional and aesthetic demands placed on it. In the posterior, the aesthetic demands are not as stringent as in

Fig. 7. Complex amalgam restorations are smoothed with Nupro prophylaxis paste.

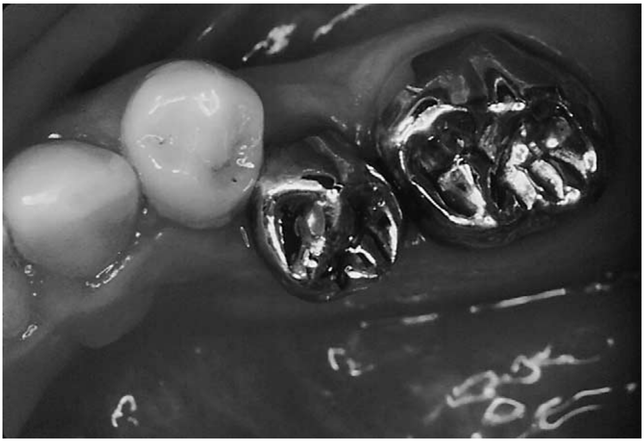

Fig. 8. The restoration of Fig. 7 polished with a Brownie and Greenie.

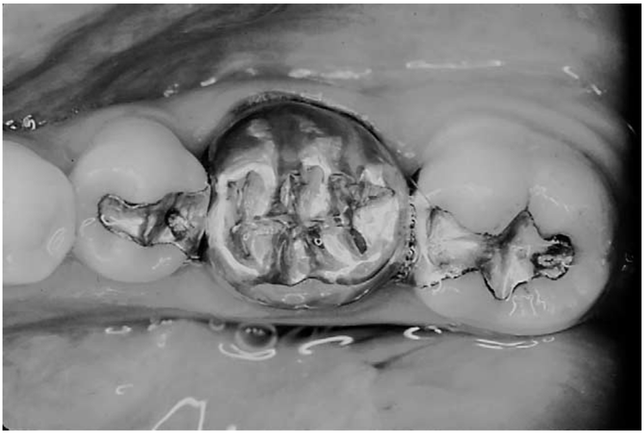

Fig. 9. A final polished restoration.

the anterior. A variety of materials can be used alone or in combination: gold, resin, porcelain, glass, and a combination of gold and resin or metal and porcelain, metal and resin, and glass and porcelain. Consideration also should be given to reducing wear on the opposing arch. The choice of material is also dependent on the desires and needs of the patient. [32] Ceramic materials can be divided into four main groups: conventional ceramics, strengthened ceramics, glass ceramics, and core-strengthened ceramics. [33]

Conventional ceramics are used to fabricate inlays and onlays even though they are the weakest ceramic, abrasive to the opposing dentition, and harder to polish after intraoral adjustment. They are aesthetically appealing and available in many shades, however.

Strengthened ceramics are stronger than conventional ceramics, with good aesthetics and similar fabrication techniques compared with conventional ceramics. This increased strength is achieved in several ways: they consist of conventional feldspathic porcelain with aluminous oxide, leucite crystals, or ceramic fibers (Cerinate; DenMat, Santa Maria, CA; Optec, Jeneric Pentron; and Mirage II, Mirage Dental Systems, Kansas City, KS). There are fewer shades available for strengthened ceramics than conventional ceramics, and they are just as abrasive to the opposing dentition and difficult to polish intraorally.

Glass ceramics consist of injection-molded glass ceramics (IPS Empress, Ivoclar; OPC, Jeneric Pentron; Finesse All-Ceramic, Dentsply/Caulk), and copy-milled materials (Celay, Mikrona Technologie Ag; Spreitenbach, Switzerland, and CAD-CAM, Sirona Dental Systems; Charlotte, NC). Injection-molded glass ceramics use a lost-wax technique. The ingots are precerammed, available in a range of colors, stronger than conventional ceramics, produce less wear on the opposing dentition, and can provide excellent aesthetics. Color modification requires extrinsic staining or veneering with conventional ceramic, and special equipment is required.

For CAD-CAM, the tooth is prepared, and the preparation is scanned electronically. The image is then manipulated, and the output is sent to a milling machine in which the restoration is milled from a ceramic blank. Copy-milling systems use a resin or wax pattern of the preparation. The external surface is traced mechanically, and the information is transferred to a milling device. CAD-CAM and copy milling use a ceramic material that is premanufactured (Dicor MGC, Dentsply/Caulk; Vita Mark II, Vident, Brea, CA; and ProCad, Ivoclar). This reduces many laboratory variables and provides increased physical properties. The shade range is limited, however, and expensive devices are required to fabricate the restorations. Only one appointment is necessary if the equipment is available in the office.

Core-strengthened ceramic restorations use cores of aluminous oxide (ProCera, NoblePharma; Inceram or Inceram Spinell, Vident) magnesium oxide, zirconium oxide, or dilithium silicate (Empress II, Ivoclar). The core provides added strength to the overlying conventional ceramic material. Core materials may be opaque, which is good for masking discolorations but is less aesthetically pleasing than other materials. Core materials may not be capable of being etched, but their increased strength allows conventional cementation. Because the crown is cemented, the preparation must meet retentive and resistance requirements of any conventional crown. This is important in areas in which proper isolation for bonding is not available. The additional space for core materials may not allow their use for inlays or onlays, and additional steps are required for fabrication.

Composites

Indirect composite materials provide the ability to refine margins, achieve properly contoured contacts, develop a highly aesthetic restoration, and reduce wear compared with conventionally placed composites. Some of these new composites are processed under pressure, temperature, and nitrogen to reduce air pockets in the resin and increase polymerization when light cured. [34] Examples of these systems include Targis 99 (Ivoclar); belleGlass (Kerr Corporation, Orange, CA); Sinfony (3M ESPE); Crystobal (Ceramco/Dentsply, Burlington, NJ); and Sculpture (Jeneric Pentron). These materials can be used for inlays and onlays, full crowns, and sometimes for bridges with or without metal or fiber support. They also possess a shock-absorption capability because they absorb masticatory energy, unlike ceramic materials that are more brittle. They are gentler to the opposing dentition compared with ceramics but may wear more. They also are more easily repaired intraorally. [34]

Ceramic or composite inlays and onlays

Indications for the use of ceramic or composite inlays and onlays include the following:

- Small to moderate damage to vital molars or premolars in which a patient desires an aesthetic restoration.
- Inlays and onlays ideally should be prepared so as to leave an outer enamel margin to provide a more reliable seal.
- Large carious lesions that normally would require cast-metal coverage or a full crown. Adhesively luted restorations will strengthen the remaining tooth structure; however, occlusal contact of the inlay or onlay should never be on a margin, because this may result in failure of the restoration. Centric contact should be evaluated before preparation, and a change in cavity design may be necessary to avoid these contacts. An onlay may be needed to eliminate contacts at the interface between the restoration and tooth structure.
- An etched onlay restoration can sometimes be used as a conservative alternative to a post, core, and crown (Figs. 10 and 11).
- Teeth that would normally require pins, crown lengthening, or intentional endodontic treatment can sometimes be restored with adhesive restorations in conjunction with modification of resistance form (Figs. 12 and 13).
- Patients with metal allergies.
- Extensive overhang should be avoided because it may result in fracture as a consequence of the poor flexural strength of the ceramic material. [20,35–38]

Contraindications for the use of ceramic or composite inlays and onlays include the following:

- Patients with parafunctional habits, especially bruxism, are not ideal candidates for inlays or onlays. Night guard fabrication may allow their placement in selective cases.

Fig. 10. Tooth #30 prepared for a belleGlass onlay.

Fig. 11. belleGlass onlay luted into position provides excellent esthetics and cusp protection.

- Poor oral hygiene. Recurrent decay around these restorations would necessitate full coverage.
- Appropriate access must be obtainable so that proper preparation, impression, and adhesive luting with rubber dam can be achieved.
- Short teeth may present a problem because adequate depth of the preparation cannot be achieved.
- Patients with gold or composite restorations in the opposing arch may exhibit excessive wear with ceramic onlays.
- Technical difficulty of placement.
- Subgingival margins may preclude adequate isolation. [20,35–38]

Fig. 12. A tooth that would have required intentional endodontics or crown lengthening to fabricate a crown is prepared for a ceramic onlay.

Fig. 13. OPC onlay conserves natural tooth structure and promotes gingival health.

Preparation

Preparation for the placement of inlays should include the following:

- Axial walls with approximately 10° angle of taper (Fig. 14), which allows for easier placement and removal during try-in. Excess tooth structure removal should be avoided.
- The occlusal isthmus should be at least 2 mm wide.
- Rounded internal line angles, which facilitate laboratory fabrication and reduce stress, both of which can result in fracture of the restoration.
- A resin-modified glass ionomer can be used to establish the ideal depth and shape of the pulpal floor. The pulpal floor in the central fossa area

Fig. 14. Preparation must have proper flare for ease of insertion of the final restoration.

should be indented so that the thickness of the porcelain in this area is similar to the lateral aspects of the preparation (1.5–2.5 mm). This also provides adequate room for the opposing cusp.

- Occlusal margins should be a 90° cavosurface angle to avoid the thin layer of porcelain/composite. A hollow-ground chamfer can be used if not at the occlusal contact area to create a more aesthetic transition between restoration and tooth structure. If this is confined to the enamel, it will expose the enamel rods at right angles and aid in developing a more effective seal. Placement of translucent porcelain/composite at this interface allows the underlying dentin to show through and create a more natural transition of shade (Fig. 15). [20,35–38]

The main advantage of resin composite is that it is less likely to fracture during placement, and contacts can be added readily. Porcelain is more fragile and may fracture during placement. A furnace is needed to add a contact; however, the bond to composite inlays is not as strong as the bond to ceramic inlays. The stronger bond transfers forces from the restoration through the cement to be absorbed by the tooth.

Onlay modifications

Traditional inlays were converted to onlays to protect unsupported cusps. The bonded restoration reduces the risk of fracture. It is preferable to avoid onlaying the cusps, because this would result in a porcelain cusp (porcelain restoration) in contact with the opposing central fossa, possibly leading to increased wear on the opposing tooth. If this is required, ideally the cusp should disengage in excursions to minimize wear. If the margin of the restoration may be subject to occlusal forces, an onlay may be indicated to minimize fracture and avoid ditching of the margin. Failure with aesthetic inlays and onlays can be of two types: bulk fracture and marginal ditching.

Fig. 15. The translucency of the margins and chameleon effect of the Concept material allow blending with the adjacent tooth structure.

Resin cements not highly filled will wear more than the ceramic and adjacent tooth. A 1.5- to 2.0-mm reduction in height of the cusp is required, with well-rounded angles on the cuspal preparation. Porcelain provides long-term occlusal stability (more than resin) when full cuspal coverage is needed.

Luting materials

Tooth-colored restorative materials are luted by incorporating adhesive procedures. [39] An important factor in adhesion is the wettability of substrate for the luting agent. Conventional cements such as zinc phosphate, polycarboxylate, and glass ionomer provide primarily mechanical retention. The adhesion is too low for luting tooth-colored restorations. These materials also have high solubility, poor flexural strength, poor color match, and abrasion resistance. Resin luting materials should possess the following properties: durable bonds to tooth structure and restoration, good color match, cusp stabilization, stress-breaking properties, and the capability of reducing the possibility of fracture of the restoration. Lambrechts et al. [40] classified luting composites according to their initiation system or viscosity: autopolymerizing, light cured, or dual cured. Dual-cure luting systems provide extended working times and controlled polymerization, which promotes better overhang control, easier handling, and enhanced color match. If dual-cure cement is used, light curing is needed to prevent decreased hardness of the dual cement. Ceramic inlays can be cured to a depth of about 3 mm.

The viscosity of the luting material affects the wettability of the bonding substrate. Low-viscosity materials may flow out of the luting gap before polymerization. Viscous materials flow under pressure. Ideally, there should be a minimum amount of luting cement volume. The film thickness is influenced by the size of the fillers, cavity geometry, the applied pressure, working time, temperature, and the surface of the substrate.

Inlay and onlay luting technique

The provisional restoration is removed. If a flexible resin is used, it can be removed easily with an excavator. A bonded provisional should be removed with the utmost care so as not to disturb the margins. The internal aspect of the preparation should be cleaned with pumice or air abrasion. If the provisional was bonded, any small areas of remaining bonding resin should be removed carefully with a bur. The restoration is then tried-in. Dental floss should be used initially to evaluate the accuracy of the contacts. If the contacts are too tight, a silicone (Fit-Checker; GC America, Alsip, IL) can be used to determine overcontours that need adjustment. Deficient contacts can be rectified by returning the case to the laboratory or (if a composite restoration) microetching the contact with 50-μm aluminum oxide, placing bonding agent, and then placing the composite. A try-in paste or a water-soluble try-in gel can help determine the accuracy of shade matching. Any remaining try-in material must be carefully removed, especially resin-based try-in materials. A transparent cement is usually the best because the translucent margins of the restoration allow the underlying tooth structure to show through. Slight modification can be made in value and chroma, but major shade differences require fabrication of a new restoration. Once the accuracy of the marginal adaptation, contacts, and shade match is verified, the patient can be anesthetized if necessary. [41]

The internal aspect of the restoration then is microetched with 50-μm aluminum oxide and rinsed. Adhesion to the ceramic material is more variable than to resin composite. The intaglio surface of the restoration has no air-inhibited layer and few unreacted methacrylate groups for a reliable chemical bond. Phosphoric acid is placed to clean the restoration further and to acidify the surface before placing silane. A silane-coupling agent is placed on the etched surface with a brush or a sponge according to the manufacturer's instructions. [42] A rubber dam is placed to provide isolation that is critical to the longevity of the restoration. Retraction cord can be placed if the margin is in the sulcus to limit cement excess and expedite clean-up.

The internal aspect of the preparation is cleaned again with pumice, rinsed, and a high-speed vacuum is used to remove excess water. The preparation is etched with phosphoric acid on enamel for 15 seconds and on dentin for 10 seconds. This can be achieved by etching the enamel initially and after 5 seconds, etching the dentin. The preparation is rinsed for 10 seconds, and excess water is removed with the high-speed vacuum and then blotted dry. A dual-cured bonding agent is applied according to manufacturer's directions but not polymerized. [34] A dual-cured cement is mixed and placed on the internal aspect of the restoration. A transfer device attached to the occlusal surface of the restoration (Pic-n-Stick; Pulpdent, Watertown, MA, or Vivastick, Ivoclar) aids in transferring the restoration to the tooth. The restoration is seated into position with repeated gentle finger pressure. Excess cement can be removed with hand instruments or a brush dampened with bonding agent. Care must be taken to prevent the cement from pulling away at the margins. Superfloss can be used to remove interproximal excess while the restoration is kept in position by a hand instrument. The restoration is tacked into position by light activation of 10 seconds on the buccal and lingual. The remaining excess resin is removed carefully. Glycerin is applied to the margins, and then the restoration is light cured for 60 seconds on the buccal, lingual, and occlusal surfaces. The rubber dam and retraction cord (if used) are removed. Occlusion is checked in centric and lateral excursions. The margins are polished with fine diamonds, finishing burs, aluminum oxide discs or rubber wheels, and points or cups as needed.

Full coverage

Full coverage may be indicated for the following: teeth that exhibit extensive decay, extensive restorations, or excessive wear; teeth with microcracks; extruded teeth; malformed teeth; teeth with short clinical crowns; abutments for fixed partial dentures; and teeth with recession. Full coverage can be all metal, conventional ceramo-metal, Captek (Precious Chemicals; Captek Division, Apopka, FL), all-ceramic materials such as In-Ceram (Vident, Brea, CA), In-Ceram Spinell, In-Ceram Zirconia, Procera, IPS Empress (Ivoclar), OPC (Jeneric Pentron), Cerec (Siemens, Germany), Celay (Vident), and composite with or without fiber reinforcement (Figs. 16–18).

Summary

There are many options for restoring the decimated dentition. [43] Excellent results can be obtained with many of the materials currently available. The restorative option will depend on the size and location of the lesion, adequate isolation for adhesive restorations, caries rate, the patient's age, the aesthetic needs of the patient, occlusal habits, maintenance of maximum tooth structure, the skill of the dentist, and the longevity desired for the restoration. Amalgam is a cost-effective material, and when used properly, it

Fig. 16. Tooth #30 prepared for Targis Vectris crown with supragingival margins.

Fig. 17. Internal coloring, adaptation and proper contouring provide a crown that blends with adjacent dentition and promotes gingival health.

Fig. 18. Proper isolation is critical to long-term longevity.

can provide many years of service. Aesthetic demands, the desire to strengthen teeth, [44] and concern about the safety of mercury in amalgam have increased the use of direct composites, ceramic material, and indirect composites. The main drawback with these materials, however, is their increased technique sensitivity and concerns about their longevity. Gold continues to be a cost-effective and predictable material if placed properly. Full-coverage gold or porcelain fused to metal provides long-term predictability but is more destructive and not as aesthetically appealing. The wide varieties of materials available provide both a challenge and an opportunity to place the most effective material for a particular patient. A thorough understanding of the available materials and their appropriate use is needed to achieve a long-lasting restoration that serves the patient's needs.

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