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Bonding and Curing Considerations for Incipient and Hidden Caries

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The development of polymer-based adhesive material systems has created opportunities to change significantly approaches to the restoration of carious lesions. The tenants of cavity preparation described by Black in 1917 [1] were designed for nonadhesive materials and had retention and resistance forms that forced the operator to remove disease-free tooth structure to accommodate the restorative material. The newer materials have made a minimally invasive [2] approach possible when surgical intervention for treating a carious lesion is unavoidable. Nevertheless, as is true for any new technology, an understanding of the mechanisms of function is critical for a successful restoration that can take advantage of the conservation of tooth structure. This knowledge is particularly necessary when using tooth-colored restorative materials. The explosion of adhesive systems, restorative materials, polymerization devices, and even new cavity preparation devices has led to confusion.

This article discusses a new classification system for cavities, the principles of contemporary dentin and enamel adhesion, the effect of polymerization stress on small cavities, cavity preparation considerations using newer hard tissue surgical devices, the selection of restorative materials, and the principles of restoration refurbishment.

Cavity preparation design considerations for adhesive restorations

Logically, the initiation of treating a carious lesion begins with the classification of the extent and complexity of the cavity. This classification lays the foundation for selection of the cavity design and restorative

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material. Because of the introduction of many new adhesive and restorative materials, the expansion of instrumentation available for cavity preparation, and improved understanding of the initiation and progression of caries, the Black classification of carious lesions by site has a significantly reduced utility. A new classification based on the site and size of the carious lesion has been proposed as a paradigm change in contemporary restorative dentistry [3]. This proposal includes the following descriptors of the lesion site:

Site 1 describes lesions originating in pits, fissures, or other defects on the tooth surface. Included are buccal pits on mandibular molars, lingual grooves on maxillary molars, and erosions on the incisal edges of anterior teeth and occlusal surfaces of posterior teeth. It includes cavities included in Black's class I classification.

Site 2 describes all lesions associated with interproximal contact in anterior and posterior teeth. The site includes all of Black's class II, class III, and class IV lesions.

Site 3 describes lesions associated with enamel or dentin close to the gingival margin. The site includes Black's class V lesions and extends to root surface lesions circumferentially around the tooth.

The second factor in the new classification scheme describes the lesion size. Four stages of the extension of a lesion have been proposed as follows:

Size 1 (minimal) is a lesion that has progressed to the point where remineralization is not feasible and surgical intervention is required.

Size 2 (moderate) describes a larger lesion but one where there is still enough sound tooth structure remaining to support the restoration without necessitating removal of more tooth structure than what was carious.

Size 3 (enlarged) is a more extensive lesion that risks bulk failure of a cusp or incisal corner if unsupported tooth structure is not removed. The cavity design must be enlarged [4] to place the restoration in the position of taking on enough occlusal load to protect the remaining sound tooth structure from undue stress.

Size 4 (extensive) describes a severely compromised tooth that exhibits loss of a cusp or incisal edge.

Mount and Hume [3] proposed that the descriptors be used as illustrated in Table 1. This system is linked to the degree of progression of the lesion and not to the design of the cavity. It has a number of advantages for restorative dentistry. It is simple and easy to communicate and teach. It facilitates the diagnostic consideration of whether to remineralize or intervene surgically in a given clinical situation. It eliminates the need for further modifications to the Black classification scheme such as the recent efforts to promote the recognition of a class VI lesion [5] and to define cavity designs as slots, tunnels, or a hybrid class I and sealant [6]. A very practical

Table 1
Classification of carious lesions based on site and size as proposed by Mount and Hume

	Size			
Site	Minimal (1)	Moderate (2)	Enlarged (3)	Extensive (4)
Pit/fissure (1)	1.1	1.2	1.3	1.4
Contact area (2)	2.1	2.2	2.3	2.4
Cervical (3)	3.1	3.2	3.3	3.4

Data from Mount GJ, Hume WR. A revised classification of carious lesions by site and size. Quintessence Int 1997;28(5):301–3.

value inherent in this system is its use to make appropriate judgments about the selection of a restorative material.

Contemporary principles of adhesion to dentin and enamel

In addition to facilitating conservative cavity preparations without traditional mechanical retention, effective resin adhesion enhances the clinical behavior of restorative materials by reducing interfacial microleakage [7]. Microleakage, the ingress of oral fluids and flora, has been regarded as a prime cause of recurrent caries, marginal staining, and sensitivity. Creating adhesion for retaining and sealing a restoration involves uniting two dissimilar surfaces: mineralized tooth structure and a restorative material. This process is made more challenging by the dissimilar characteristics of enamel and dentin [8]. The fundamental mechanism of bonding to enamel and dentin is an exchange phenomenon in which minerals removed from hard dental tissues are replaced by resin monomers (Fig. 1). When these monomers are polymerized in situ, they become micromechanically interlocked into porosities created during the demineralization procedure [9].

The most frequently used classification of adhesive systems is based chronologically on the general time of their release into the dental market [10]. Today, up to seven generations are described [11]; however, this

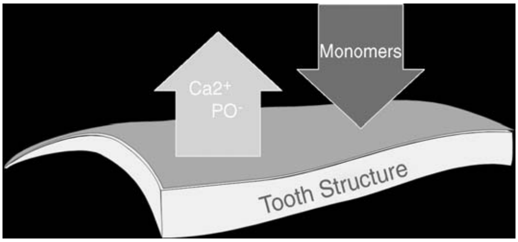

Fig. 1. The prime mechanism of adhesion with contemporary adhesives is replacing the mineral removed from enamel and dentin with resin-adhesive monomers. (*From* Van Meerbeek B, Vargas MA, Inoue S, et al. Adhesive and cements to promote preservation dentistry. Oper Dent 2001;Supplement 6:120; with permission.)

generational classification system lacks a basis in mechanistic function and precludes the adhesives from being described using objective criteria. Van Meerbeek and colleagues [9] have presented a classification system based on the number of clinical steps and, more critically, on how the bonding material interacts with tooth structure. In this classification scheme, three broad mechanisms of adhesion are used to categorize contemporary systems (Box 1).

Total-etch adhesive systems

Materials in this class involve a separate etch and phase step before application of resin monomers. In three-step total-etch systems, the demineralization step is followed by a priming step and application of an adhesive resin. Usually, the primer contains a hydrophilic solvent to facilitate dentin penetration. Two-step total-etch systems combine the primer and adhesive resin into one application.

Bonding to acid-treated enamel was first proposed by Buonocore [12]. Resin monomers penetrate the pits (Figs. 2 and 3) created by the demineralization effect of the acid, allowing a micromechanical mechanism for bonding and sealing enamel. Two types of taglike resin extensions have been described in enamel. Macrotags are formed circumferentially around the enamel prism periphery. Microtags are formed at the center of enamel prisms where the resin is cured into the crypts of dissolved hydroxyapatite crystals [13,14]. Several acids have been proposed for demineralizing tooth structure, including maleic, citric, nitric, and oxalic acids [15,16]. Phosphoric acid has remained the material of choice because of the clinically validated predictable and reliable bond achieved [17]. Because the bond to acid-conditioned enamel is still the best that can be achieved clinically, preserving enamel in the cavo-surface area is one of the most important clinical principles when preparing cavities for adhesive restorations.

Box 1. The three mechanisms of adhesion as proposed by Van Meerbeek and colleagues

Total-etch adhesives
- Three-step: etchant (1), primer (2), and adhesive (3)
- Two-step: etchant (1) and a combined primer/adhesive (2)

Self-etch adhesives
- Two-step: acidic primer (1) and adhesive (2)
- One-step: acid primer and adhesive combined

Resin-modified glass-ionomer adhesives

Data from Van Meerbeek B, Vargas MA, Inoue S, et al. Adhesives and cements to promote preservation dentistry. Oper Dent 2001;Suppl 6:119–43.

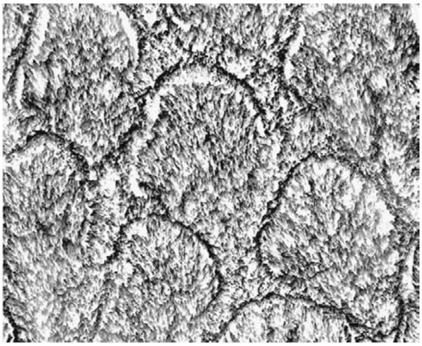

Fig. 2. Scanning electron micrograph of enamel etched with phosphoric acid for 15 seconds. Note the demineralization pattern revealing the periphery of the enamel prism. The electron beam is perpendicular to the surface (original magnification ×300).

Three-step and two-step total-etch adhesives employ the same mechanism for adhesion to dentin. The etch-rinse phase removes the smear layer generated by preparation of the cavity and concurrently demineralizes a 3- to 5-μm deep area of the underlying dentin [18]. Collagen fibrils are exposed following removal of the hydroxyapatite. The resin monomers are then infiltrated in and around the collagen and remaining mineral content and form a microretentive network providing sealing and retention [9]. This interlock was first described in 1982 [19] and is referred to as the *hybrid layer* (Fig. 4) [20]. Resin tags seal the widened unplugged tubules formed during demineralization and offer additional sealing and adhesion through interaction with the walls of the dentinal tubules. Three distinct micromorphologic structures have been observed in the interface between dentin and dental adhesive monomers: (1) the "shag carpet" appearance of the collagen fibrils, primarily in the intertubular dentin; (2) the tubule-wall hybridization, representing the extension of the hybrid layer into the lateral

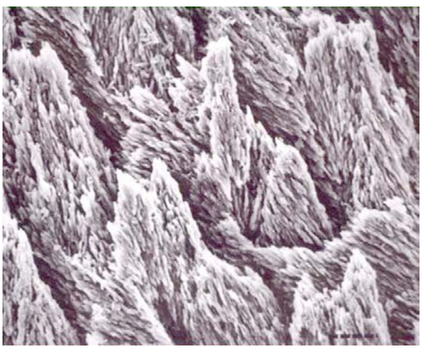

Fig. 3. Scanning electron micrograph of the same specimen shown in Fig. 2 with a low-angle electron beam showing microtag crevices (original magnification ×300).

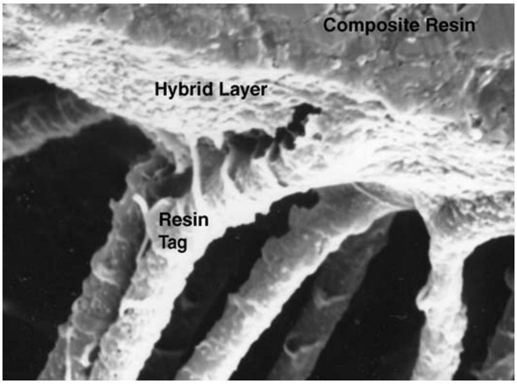

Fig. 4. Scanning electron micrograph of the resin/dentin interface generated with the two-step total-etch adhesive Singlebond (3M/ESPE, St. Paul, Minnesota; original magnification ×5000).

wall area of the dentinal tubules; and (3) lateral tubule hybridization represented by the tiny branch extensions below the cut dentin surface and lateral to the dentinal tubule [9].

Following etching, the function of the primer in a three-step total-etch system is to ensure efficient wetting of the exposed collagen, displace any residual moisture, and transform an essentially hydrophilic surface to a hydrophobic surface by carrying monomers into the interfibrillar spaces. The sequentially applied adhesive layer fills up any remaining space between the collagen, seals the dentinal tubule openings, initiates polymerization, stabilizes the hybrid layer and resin tags, and provides reactive double bonds for the subsequent application and copolymerization with the restorative material. In the simplified two-step total-etch systems, the functions of the primer and adhesive are combined. As a result, higher variability in the results has been reported using these so-called "one-bottle" systems [21,22]. Characteristic of these formulas is a high solvent-to-monomer ratio leading to a risk of too thin a layer being applied in a clinical situation. Clinical success is best with these systems if the solutions are applied in a sufficient amount to allow complete saturation of the exposed collagen fibril network and to establish a suitable layer on top of the hybrid layer to copolymerize with the restorative material. Multiple layers of one-bottle adhesives should be applied, flooding the hard tooth surfaces.

Following acid conditioning and removal of the smear layer, the dentin surface should be treated properly to ensure full penetration of the adhesive monomers. A certain level of moisture is recommended in the dentin to prevent the exposed collagen scaffold from collapsing and impeding the penetration of the adhesive agent [18]. This clinical technique is often called "moist bonding" [23]. Dehydration of acid-treated dentin through air-drying is thought to induce surface stress that leads to a destruction of the spongy-like quality of the collagen, causing the formation of a coagulate that creates a barrier to the applied resin [24]. Although this technique maintains open interfibrillar spaces by keeping the loose quality of the collagen intact, it is imperative that dentin surface water is completely replaced by monomers. Remaining moisture can lead to incomplete polymerization of the hybrid layer and emulsification of the adhesive with concomitant gaps left in the adhesive film [25]. In short, acid-treated dentin should not be kept too wet or too dry. This restricted window of opportunity for effective adhesion and bonding may make these systems somewhat technique sensitive [21]. The variation in performance owing to residual dentin moisture is universally accepted as a characteristic of single-bottle systems. Although some investigators have reported that three-step total-etch systems form an effective hybrid layer in moist and dry dentin [26], others have recommended the moist bonding technique for the best performance of even three-step product systems [15,27,28].

A total-etch approach involves simultaneous conditioning of the enamel and dentin surfaces. When this concept was first introduced in the early 1990s, so-called "dentin-kind" etchants (usually, 10% to 20% phosphoric acid) were used so that the depth of dentin demineralization would not exceed the diffusion depth of the adhesive monomers. Unfortunately, these conditioners insufficiently prepared enamel [29,30]. It has become apparent that the enamel requires conditioning with more aggressive 30% to 40% phosphoric acid preparations. Good clinical technique should be followed to avoid overetching the dentin. The etchant should be placed on the enamel first, which is etched the longest (at least 15 seconds), followed by etching the dentin for 15 seconds at a maximum.

Several clinical steps are proposed for maximizing the clinical effectiveness of three-step and two-step total-etch adhesive systems:

1. Do not overetch dentin (no more than 15 seconds) or underetch enamel (not less than 15 seconds).
2. Do not overdry dentin; keep dentin moist.
3. Apply primer (in three-step systems) or primer/adhesive (in two-step systems) with an active application and using fresh material for at least 15 seconds.
4. Completely evaporate any volatile solvents.

Self-etch adhesive systems

An alternative approach to bonding is to employ acidic monomers that are not rinsed from the tooth and that simultaneously condition and infiltrate dentin and enamel. Formulations in this self-etching category can involve two application steps with an acidic resin primer followed by an adhesive resin (two-step self-etching adhesive), or can be combined into a solution or mixture that employs only one application to the tooth (one-step self-etching adhesive). These systems can also be characterized in terms of a strong (less than 1) or mild (2 or above) pH. The adhesion mechanism for bonding to dentin and enamel with these systems is similar to that of total-etch systems, that is, micromechanical retention to enamel and hybridization of dentin.

Although hybridization of dentin occurs with mild pH self-etching adhesives, resin tag penetration and hybrid layer depth are less pronounced. In contrast to total-etch systems, hydroxyapatite is not completely removed from the collagen scaffold, and the remaining mineral may serve as a receptor for an intermolecular reaction between the mineral crystal and resin monomers with reactive functional groups. Using x-ray photoelectron spectroscopy, a primary ionic bond has been observed to form between hydroxyapatite and the two carboxyl groups of 4-methacryloxyethyl trimellitic acid, a monomer in Unifil Bond, a self-etching adhesive system (GC Dental Products, Tokyo, Japan) [31]. Some investigators have hypothesized [9] that, owing to this chemical bonding or because of a more intimate contact between the resin monomers and the hydroxyapatite-coated collagen, better bonds will result, leading to less hydrolytic degradation of the adhesive interface.

Lower pH self-etching systems have been shown to have nearly identical interfacial hybrid layer structures to that generated with total-etch adhesives. Nearly all hydroxyapatite is removed, and any chemical interaction between the functional monomers in the adhesive and the mineral phase of the tooth is minimized [9]. These strong acid self-etching systems exhibit deep resin tag penetration nearly indistinguishable from that in total-etch systems; however, the morphologic evidence may not always translate into clinical effectiveness. In one clinical study, a one-step system exhibited a loss of retention of cervical restorations of over 30% after only 1 year [32]. One recent laboratory study reported a wide range of dentin bond strengths among several newer self-etching adhesives [33].

These systems may have several advantages. They eliminate clinical steps. Because the dentin moisture content is of no concern, a greater advantage is eliminating from the clinical procedure a preoccupation with the dentin condition. Self-etching systems also have the advantage of removing the risk of incomplete dentin infiltration because of their simultaneous demineralization/penetration of the resin monomers. Nevertheless, concern is often raised regarding the bonding effectiveness of self-etching adhesives to enamel. Numerous laboratory studies have shown diminished enamel bonding effectiveness compared with conventional phosphoric acid conditioning [34–37]. Although some researchers have shown that this reduction in bonding is mitigated by bonding to prepared instrumented enamel when compared with intact enamel [38], long-term controlled clinical trials are not available to show whether the long-term durability of the enamel interface using self-etching adhesives is compromised or equal to that achieved with conventional etching. Some reports suggest that there is increased enamel margin staining using some self-etching adhesives when compared with total-etch adhesives [39,40].

The simplicity of these systems with respect to placement has led investigators to suggest that less postoperative sensitivity will be reported by patients following the placement of direct composite resins when self-etching adhesives are used. One study showed no difference in postoperative sensitivity [41], whereas another noted that the depth of the cavity and the use of a base or liner were the most significant factors with respect to sensitivity [42]. The growing scientific evidence base suggests that post-operative sensitivity may depend more on the clinical technique employed than the class of adhesive systems used.

Until long-term clinical evidence is available to validate the clinical effectiveness of self-etching adhesives, especially with respect to enamel sealing and bonding, several clinical steps are recommended in an effort to maximize their clinical performance:

1. Application to enamel and dentin that has been at least coarsened by a bur
2. Application of the acidic primer for a contact time of at least 15 seconds
3. Application of the acidic primer with agitation
4. Repeated applications of the primer with fresh material

Glass-ionomer adhesives

The third approach to adhesion using contemporary materials involves the acid-base reaction of a glass ionomer interacting with tooth structure. The most popular materials in this class consist of conventional glass-ionomer restorative materials that have been diluted by adding more resin phase, creating the class of materials termed *resin-modified glass ionomers* [9]. When used clinically, a mild acid treatment (polyalkenoic acid) removes the smear layer and minimally exposes surface collagen. The first bonding mechanism of these materials involves resin interdiffusion around the exposed collagen, creating a micromechanical bond following the principle of hybrid layer formation previously described. In addition, chemical bonding is created by the ionic interaction of the calcium in the hydroxyapatite crystals with the carboxyl groups of the polyalkenoic acid during the setting reaction of the material [43]. Unfortunately, the pH of the polyalkenoic acid is not sufficient to create a deep enough etch pattern to generate high bond strengths to enamel.

Because of their generally low resistance to abrasion and higher susceptibility to fracture, these materials are not often suited for posterior restorations.

Polymerization considerations for resin-based restoratives

Although the adhesive properties of bonding systems facilitate elimination of macromechanical retention in cavity designs, other characteristics of resin-based restorative systems are important to understand when employing these materials in smaller cavity preparations. In general, the physicochemical properties of resins, such as wear resistance, radiopacity, handling, and esthetics, are regarded as clinically sufficient [44]. The main drawback of this material class is polymerization shrinkage [44]. Although newer formulations are associated with significant improvements, immediate and delayed polymerization shrinkage stresses can lead to destruction of internal and external marginal adaptation of the restoration to the cavity wall [45,46]. Understanding how stress develops during polymerization can lead to clinical solutions to control the negative effects of shrinkage. These forces and their negative sequela are affected by several factors, including the following:

- The size of the cavity (volume)
- The cavity configuration [46]
- The degree of extension toward dentoenamel junction
- The quality of enamel and dentin
- The bond strength of the adhesive
- The intrinsic composition and structure of the restorative material (shade, filler characteristics)
- The reactivity of the composite initiator system
- The thickness of composite increment
- Light intensity and position
- The cavity configuration (ratio of bonded to nonbonded surface area)

Not all of these factors carry equal weight in how marginal stress is influenced and generated. For example, when a thin increment (less than 1 mm of composite) is polymerized using a powerful curing device (above 600 mW/cm^2), an almost uniform distribution of polymerization stresses will be developed [47]. Although competing curing techniques have been proposed, such as high to low intensity and pulsed or stepped curing, the lack of a consensus regarding these techniques suggests that these alternative approaches have not optimized curing [44]. One can conclude that, except for practical clinical considerations, the curing protocol has little influence on the quality of the restoration if enough energy is used to bring the material to an optimal conversion rate in a reasonable time.

Perhaps the most important factor related to shrinkage and stress is the cavity size and configuration. Stress relief in a curing composite is determined by the ratio between the free and bonded surfaces. A deep but constricted occlusal surface cavity has the potential for generating more marginal stress (and thus a marginal gap) than a large cavity that extends to the marginal ridge and interproximal area. One approach to help manage this factor is to use a multilayered placement technique. This technique reduces the overall polymerization stress by increasing the number of increments and giving them an optimal geometry to maximize the total free surface area [48]. In small cavity preparations, the potential for the highest stress generation exists if the configuration has an unfavorable bonded to nonbonded ratio. A major challenge for the clinician is to balance the principal of preservation of sound tooth structure with the demand for creating a cavity geometry that is more favorable for stress reduction or that facilitates a layering approach. Although when the cavity is small, a bulk placement can be accomplished in minimally invasive cavities [49], this approach is probably only applicable to Hume classifications 1.1 and 1.2. In Hume classifications 2.1, 3.1, and larger, the cavity form may demand that access be made to allow placement of layers to minimize marginal stress.

Polymerization stresses can also be mitigated by a liner or base made of a lower modulus material, such as a thick adhesive resin layer [50], a flowable composite resin [44], or a glass ionomer or compomer [44,51]. When used in these situations, the ''elastic'' material provides the potential of stress absorption at the junction between the higher modulus restorative material and the mineralized tooth. Using a glass ionomer in a lamination or ''sandwich technique'' can take advantage of the best features of ionomers and resin composites [52]. The glass ionomer is placed first, lining the dentin and taking advantage of this material's adhesion and fluoride-releasing characteristics. A composite resin is then placed over the glass ionomer, maximizing wear resistance and esthetics of the restoration [53,54].

Effects of cavity preparation instruments on bonding

In addition to conventional rotary instrumentation, air abrasion devices and lasers are available for cavity preparation. The air abrasion technique uses the kinetic energy of a stream of aluminum oxide particles to abrade the target tooth surface. Purported advantages include reduced noise and vibration leading to better patient acceptance of the restorative procedure [52]. In addition, cavity preparations performed with air abrasion have more rounded internal line angles than cavities prepared with rotary instrumentation. It has been hypothesized that this cavity geometry decreases the internal stresses developed during resin polymerization, leading to a better seal of the restorative material to the cavity wall [55,56]. Air abrasion has limitations in patients with asthma or dust allergies and in clinical situations where open wounds or recent surgical sites are present. Although some investigators have suggested that air abrasion may eliminate the need for acid conditioning of enamel and dentin, simplifying the bonding procedure, numerous in vitro studies have not substantiated the elimination of the acid-conditioning step when using air abrasion [57–60].

Erbium, chromium: yttrium-scandium-gallium-garnet, and erbium: yttrium-aluminum-garnet lasers have been approved for use in cutting cavity preparations on dental hard tissues. Such cavity preparations are similar to those created by air abrasion techniques, and laser use provides similar advantages, including less noise, vibration, and better patient comfort and acceptance. Similar clinical results have been reported with lasers when compared with rotary instrumentation [61]. As is true for air abrasion, it has been suggested that laser cut dentin and enamel do not require acid etching before application of the resin monomers [62]. A critical flaw in that study was the use of a very acidic total-etch adhesive system that behaved in a similar fashion to contemporary self-etching systems. Later investigations evaluating bonding to laser-treated surfaces have documented the need for acid etching with total-etch adhesive systems [63]. A potential disadvantage of the laser instrumentation is the need to manage excessive heat generation and the resultant detrimental effects on the pulp. When lasers are used correctly, excessive heat can be avoided [61,64].

Although air abrasion and laser cavity preparation are effective and sometimes more conservative techniques for cavity shaping, no clear advantage exists for these technologies when they are evaluated solely for improving adhesion and bonding.

Selection of the material for restoring incipient and hidden caries

The explosion of direct placement tooth-colored restorative materials has left many practitioners confused regarding appropriate material selection for a range of clinical situations. Nevertheless, when they are evaluated carefully, there are more similarities than differences when considering different commercial products in a given class.

Glass ionomers and resin-modified glass ionomers have had a long record of clinical use as a definitive restorative material. They are ideally suited for the sandwich technique previously described because of their fluoride release, dentin bonding, and relatively lower modulus when compared with resin composites. Although they are well suited for restorative procedures in primary teeth [65], cervical restorations [66], fissure sealants [67], and proximal restorations in anterior permanent teeth, they do not have high mechanical properties and generally cannot be well polished; therefore, the use of these materials is limited in scope. Patients deemed at moderate to high risk for caries in Hume classes 1.1, 2.1, and 3.2 to 3.4 and patients in whom a large percentage of the cavo-surface margin is in dentin instead of enamel are the best candidates for glass ionomers and their resin derivatives.

In low-caries risk patients, when most of the margin interface is in enamel, a composite resin is usually preferred. These materials generally offer excellent esthetics and polishability, high resistance to fracture, and excellent abrasion resistance. One of the main discriminating characteristics of composite resins is the tactile handling component. There are large differences in the available resins based on the viscosity of the material. Materials ranging from very low (flowable) to very high (packable) viscosity are available, and the selection of a specific formula may be based on the particular preference of the operator and the size of the cavity to be restored. Low-viscosity flowable materials are often recommended for small cavities, preventive resin restorations, and class V lesions [68]. They offer the significant advantage of facilitating a gap-free adaptation to the cavity wall, but, because of a generally lower filler load, they shrink more and wear more than a more viscous material. Their use should be restricted to Hume class 1.1, 2.1, and site 3 lesions. They can also be used as a liner in larger cavities where a more traditional restorative resin is placed above the liner, similar to the sandwich technique described using glass ionomers. In particularly small cavities, the operator must select a material that can be intimately adapted to the cavity wall so that macrovoids are prevented.

Refurbishing bonded restorations

The most widely cited reason for replacing an existing adhesive restoration is the diagnosis of secondary caries [69]; however, secondary caries is usually localized, and, particularly with tooth-colored restorations, it is hard to distinguish stained, ditched margins, and caries. By completely removing a restoration in the absence of progressing decay along the interfacial wall between the restoration and the tooth, additional healthy tooth structure is removed unnecessarily [70]. A more conservative approach has been advocated that entails a pilot "exploratory" cavity preparation adjacent to a suspicious margin. With this method, defects are well delineated, and a definitive diagnosis can be made without completely removing the complete restoration [71]. If the main portion of the restoration is satisfactory, the pilot cavity can be restored with an appropriate material.

Successful repair of a resin-based material, especially after an extended period in the oral environment, is not a trivial problem. Bonding to freshly cut enamel or dentin in a pilot cavity designed to refurbish a resin restoration would be the same as any bonding procedure; however, resin composites absorb water from the oral environment, and, after a short time, reactive bonding sites in the restoration are no longer available for reaction with a freshly applied adhesive agent [72]. Surface roughening and air abrasion have been employed as ways of facilitating a durable bond to old composite. The best surface preparation for bonding new composite to old composite is the specialized air abrasion system Co-jet (3M/ESPE, St. Paul, Minnesota). Using a tribolized carbon-coated abrasive particle and a silane-coupling agent, high and stable bonds are possible in resin repair situations [73].

Summary

Contemporary adhesive systems and restorative composite materials can successfully seal and restore teeth and can facilitate the use of a minimally invasive cavity preparation technique. These systems give the operator the potential to reinforce damaged teeth and preserve healthy tooth structure. The adhesion principles rely on strict adherence to excellence in clinical technique. Differences in clinical results may depend more on the operator's adherence to good clinical technique than the specific material selected.

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