Abstract
Dental adhesives used to bond composite resins to tooth structure have evolved over the last several decades. The earliest bonding systems required an acid-etch technique and were only compatible with enamel, and the challenge has always been to predictably bond to enamel and dentin simultaneously. There can be confusion as to what bonding agents are being described, because there are a number of different labeling categories. With a simplified, logical category description the clinician is better able to understand what each bonding agent is and how it is used. Bonding systems can in fact be differentiated into two distinct classes: etch-and-rinse and self-etch. Both classes of bonding systems work well as long as one understands which to use for different treatment conditions. There is no one universal bonding system that does it all, but recent advances in the chemistries of these adhesives allow many of them to be bonded to all intraoral substrates — to enamel; to dentin; and to all types of dental resins, ceramics and metals. The key to success is to provide your patients with materials and techniques that you can reproduce to achieve the best, longest-lasting clinical results.

Learning Objectives
The overall goal of this article is to provide the reader with information on the classifications, indications and current techniques for restorative clinical success with adhesives. After reading this article the reader should be able to:

1. Describe the differences between etch-and-rinse and self-etch adhesives and relate these categories to other naming systems
2. Discuss the current research evidence comparing etch-and-rinse and self-etch adhesives
3. List and describe the indications for etch-and-rinse and self-etch adhesives
4. Describe the clinical procedure for an etch-and-rinse and a self-etch single-step adhesive

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Dental adhesives used to bond composite resins to tooth structure have evolved over the last several decades. The earliest bonding systems required an acid-etch technique and were only compatible with enamel, and the challenge has always been to predictably bond to enamel and dentin simultaneously. There can be confusion as to what bonding agents are being described, because there are a number of different labeling categories. With a simplified, logical category description the clinician is better able to understand what each bonding agent is and how it is used. Bonding systems can in fact be differentiated into two distinct classes: etch-and-rinse and self-etch. Both classes of bonding systems work well as long as one understands which to use for different treatment conditions. There is no one universal bonding system that does it all, but recent advances in the chemistries of these adhesives allow many of them to be bonded to all intraoral substrates – to enamel; to dentin; and to all types of dental resins, ceramics and metals. The key to success is to provide your patients with materials and techniques that you can reproduce to achieve the best, longest-lasting clinical results.

Introduction

Important advances and innovations in restorative dental treatment that have changed the way we treat patients for the better would certainly include fluorides, local anesthesia, high-speed handpieces, dental radiography and implants. Another innovation that would be near the top of this elite list is dental resin adhesion. Little did Michael Buonocore and colleagues at the Eastman Dental Center in Rochester, New York, realize that the introduction of adhesion, first bonding to enamel, would change the way we practice dentistry. G.V. Black described the retention of restorations based upon cavity design and undercut dentin. Even with the caries removed, because of the limitations of the restorative materials available at the time (gold foil and dental silver amalgam), additional tooth structure needed to be removed to fulfill the requirements for retention of the restorative material. The goal of conservation of tooth structure was limited by the materials that were available up until the late 1960s, when clinical techniques with resin adhesives bonded to etched enamel were introduced using UV-light-cured resin restoratives, a resin sealant and a composite resin that utilized the acid etch technique described by Buonocore. Bonding to tooth substrates is now the standard of care for single-tooth direct placement restorations and has been the driving force in changing how we prepare and restore teeth. With the use of adhesives, minimally invasive dentistry (MID) with a more conservative, tooth-structure saving approach when treatment planning restorative dental procedures is possible. While the majority of restorations placed today are restoration replacements, minimally invasive adhesive restorative dentistry not only relates to the treatment of caries but also to these restoration replacements and to elective esthetic dentistry. There has been a significant change in the principles of cavity preparation design, from the traditional principles of “extension for prevention” described by G.V. Black to a more carious lesion-centered approach. This lesion-centered approach is possible through the advancements in adhesive restorative materials, as well as through the introduction of computer-assisted methods of caries detection, a better understanding of the role of magnification, digital radiography and caries risk assessment of the patient to allow for improved conservative caries management. One of the greatest benefits of a more conservative approach is that it allows the clinician to maintain as much tooth structure as possible.

While enamel bonding and dentin bonding have been pursued in parallel paths, the goal has been to develop a universal adhesive that bonds to all substrates used in dentistry: enamel, dentin, metals, ceramics and composite resin. This author remembers reading an article in 1985 written by Dr. Wayne Barkmeier on the fundamental elements for an adhesive used for bonding restorative materials to tooth structure. Recently these five key prerequisites for successful adhesion to tooth structure were reiterated because they have not changed since then. (Table 1)

Table 1. Key prerequisites for successful adhesion

| 1. The procedure must be safe and biologically acceptable. |
| 2. The level of bond strength must be clinically significant to avoid discoloration at the margins and secondary caries. |
| 3. The bond strength must be routinely achieved so that predictable results are obtained. |
| 4. The bond must be established quickly in order to permit immediate finishing. |
| 5. The bond must be stable in vivo for a clinically significant period of time. |

Since then, significant advances in the development of dental adhesives have been accomplished. The adhesives currently available offer reliable adhesion between restorative materials and tooth structure.
Enamel and dentin bonding: An historical perspective

In 1955, Buonocore described a clinical technique that utilized diluted phosphoric acid to etch the enamel surface and provide for retention of unfilled, self-cured acrylic resins. The resin mechanically locked to the microscopically roughened enamel surface, forming small “tags” as it flowed into the 10-to-40-micrometer-deep enamel microporosities and then polymerizing. (Figure 1) The first clinical use of this technique was for the placement of sealants. The combination of acid etching enamel and adhesive composite resin restorations afforded the benefits of reduction or elimination of microleakage at the enamel margins with a decrease in sensitivity, less discoloration at the margins, lower rates of recurrent caries and improved retention of the restoration.

The effectiveness and success of etched enamel/resin bond has been demonstrated in many reported clinical trials.

Unlike enamel bonding, dentin bonding has seen an evolution in its viability. Effective dentin-bonding materials should fulfill several goals. (Table 2)

Table 2. Goals for effective dentin-bonding materials

- The material should be retentive to dentin at a clinically acceptable level, and it should be able to withstand intraoral forces of occlusion and mastication.
- The bond should be instantaneous once the material has set.
- The material and technique must be biocompatible.
- The material should resist the forces of polymerization shrinkage of composite resins and the coefficient of thermal expansion and contraction to eliminate microleakage.
- The material should create a long-lasting bond to dentin.
- Postoperative sensitivity must be minimized or eliminated.

The earliest research in 1956 with dentin bonding focused on chemical adhesion of resins to the inorganic components of dentin. This created a very weak bond, the basis for which was the presence of the dentin smear layer. Other attempts using similar technologies for dentin bonding were not very successful. These products had limited success and the search for a better adhesive to dentin continued. Another research path for dentin bonding investigated the use of an etch-and-rinse (total-etch) approach by etching the enamel and dentin simultaneously with phosphoric acid. At the time, there was concern that phosphoric acid placed on dentin would cause pulpal inflammation and necrosis. Jennings and Ranly demonstrated that the pulpal effect of phosphoric acid on dentin for one minute was minimal. Early results reported with dentin etching were disappointing because the adhesive resin used was the same unfilled hydrophobic Bis-GMA bonding resin used for etched enamel. The hydrophobic resin would not wet the moist, vital dentin and predictable adhesion could not be produced.

Contemporary adhesives

The breakthrough in the etch-and-rinse (total-etch) approach was first described in the late 1970s by Fusayama and coworkers, Bertolotti and Kanca. They demonstrated the success of the etch-and-rinse (total-etch) adhesive bond based upon the addition of a hydrophilic monomer, usually hydroxyethyl methacrylate (HEMA), to the primer and adhesive. This hydrophilic monomer allows the adhesive resin to penetrate the peritubular dentin and dentinal tubules. (Figure 2) Simultaneously, Bowen was investigating the use of a dentin primer that in fact was a self-cure adhesive that was painted on the enamel and dentin, and that produced clinically acceptable bonds. In recent years self-etch adhesives for bonding to enamel and dentin have been introduced, and some adhesives have added fillers to improve physical properties. While the earlier generations of adhesives to dentin were disappointing in their clinical performance, contemporary adhesives are demonstrating excellent clinical success.
Classification of bonding systems

The development of improved adhesion systems using different chemistries with a variation in the numbers of reagents and steps for application led to several descriptions of the categories and classification of adhesives. With no standard on how adhesives were classified and described, there was some confusion among clinicians and researchers alike. With the development of two different classes of bonding systems that relied on the use of phosphoric acid as a surface etchant came the classification and description of bonding systems based upon generational time-line changes. Fourth-generation bonding systems were referred to as total-etch multi-bottle (multi-step) systems, and fifth-generation systems were referred to as total-etch single-bottle bonding agents that contained both primer and adhesive. Both fourth- and fifth-generation products required a total-etch with phosphoric acid before adhesive placement.

It is obvious that the more steps required to bond a restoration, the greater the potential for inconsistency of timing of application, rinsing, drying, rewetting dentin and maintaining a controlled operative field during treatment. Manufacturers responded to this by putting research efforts into the development of simplified adhesive systems and reduction in the number of steps required. Thus the earliest self-etching bonding systems were introduced. These did not require the additional steps of applying phosphoric acid, rinsing and drying before adhesive application. The classification system became more confusing in that bonding systems that had the additional step of phosphoric acid etching were referred to as total-etch, and those adhesives that did not require the additional step of phosphoric acid were referred to as self-etch. Other bonding systems continued with generational descriptions building on the fourth- and fifth-generation model, and the self-etching systems were referred to as sixth and seventh generation. These terminologies do not adequately describe the current adhesives that are being used for composite resin bonding.

All adhesives used today exhibit the same phenomena for adhesion, i.e., micromechanical locking to the etched enamel prisms and to dentin through hybridization.

There have been several attempts to better describe the different bonding systems based upon the steps required and the chemistry of the adhesives. In 2003, Van Meerbeek et al. proposed a rational, logical categorization and classification of the current adhesives based upon what is required to achieve the adhesive interface to enamel and dentin.

(Table 3) Based upon the current adhesives being used in our practices, the classification of adhesives can be broken down into two distinct categories: etch-and-rinse (E&R), which is also referred to as total-etch (TE), and self-etch (SE).

<table>
<thead>
<tr>
<th>Table 3. Classification of adhesives according to Van Meerbeek et al.23</th>
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<tbody>
<tr>
<td><strong>Etch-and-Rinse Adhesives (also referred to as Total-Etch)</strong></td>
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<tr>
<td>Three-step multiple-bottle etch-and-rinse adhesives (3-E&amp;R)</td>
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<tr>
<td>Two-step single-bottle etch-and-rinse adhesives (2-E&amp;R)</td>
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<tr>
<td><strong>Self-Etch Adhesives</strong></td>
</tr>
<tr>
<td>Two-step multiple-bottle self-etch adhesives (2-SEA)</td>
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<tr>
<td>One-step multiple-bottle mix self-etch adhesives (1-SEA)</td>
</tr>
<tr>
<td>One-step no-mix self-etch adhesives (1-SEA)</td>
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Etch-and-Rinse approach

The etch-and-rinse (E&R) or total-etch (TE) adhesives can be recognized by the initial application of a 10%-40% phosphoric acid to the enamel/dentin followed by the mandatory rinsing step. The enamel etching leaves a microscopically roughened surface to bond to and removes the dentin smear layer. The enamel surface can be completely dried with air, but the dentin should remain damp and glossy. To leave the dentin slightly damp, the wet dentin can be blotted dry or after air drying can be rewetted with a slightly damp cotton pellet. This will leave the dentin as a damp, glossy surface. An adhesive resin is then applied. The adhesive resin is provided as either two bottles, a separate dentin primer and separate adhesive (also referred to as three-step etch-and-rinse) (3-E&R) (e.g., ProBond, Dentsply-Caulk; Optibond FL, Kerr; ScotchBond MP, 3M-ESPE), or a single bottle that contains both primer and adhesive (also referred to as two-step etch-and-rinse) (2-E&R) (e.g., Prime and Bond NT, Dentsply-Caulk; XP Bond, Dentsply-Caulk; Optibond Solo Plus, Kerr; One Step Plus, Bisco). Many of the single-bottle etch-and-rinse systems are provided as a unit dose. Based upon the evidence to date, bonding to enamel is best accomplished with this technique. In vitro and in vivo research has demonstrated that etch-and-rinse adhesives can reliably bond to both enamel and dentin.

The duration of enamel etching has been suggested as 15-30 seconds, while research has demonstrated that for most clinical situations dentin should be etched for only 15 seconds. Dentin age can also have an effect on adhesion, and it has been recommended to increase etching time to 30 seconds for sclerotic dentin (found in patients in the age range of 55-60 years and older), the rationale being that compared to normal dentin, sclerotic dentin exhibits hypermineralization and is resistant to phosphoric acid etching.

Clinical success with etch-and-rinse adhesives is dependent on the basic clinical technique:
1. Prepare the tooth (all classes of cavity preparations; can be in enamel-only Class IV, facial veneers, porcelain veneers).
2. Etch with a phosphoric acid (range of concentration 10%-40%) for 15-30 seconds (15 seconds for normal dentin and 30 seconds for sclerotic dentin).
3. Rinse with air-water spray for 10 seconds.
4. Dry the tooth, leaving the enamel frosty, dentin glossy (moist).
5. Apply adhesive system of choice using a rubbing action, light cure.
6. Apply restorative material; light cure.
Self-etch adhesives

Self-etch adhesive systems are aqueous mixtures of acidic functional monomers, usually phosphoric acid esters with a pH value higher than that of phosphoric acid gels. The SE approach does not require a separate etching step because the etchant is incorporated into the adhesive (either in a separate self-etching primer or in the adhesive). Additionally, the step of rewetting with water is eliminated because SE adhesives contain water and are never completely dried from the tooth. SE adhesives do not remove the smear layer, instead incorporating it into the adhesive. Investigations have demonstrated that SE systems provide hybridization and infiltration of dentin similar to that seen with etch-and-rinse adhesives. There has been concern about the quality of bonding of SE adhesives to enamel. If enamel is left unprepared, it is resistant to etching and adhesion with most SE adhesives. For preparations that include both dentin and enamel, it is recommended that the enamel be prepared with a bur or diamond to optimize the bond to the enamel. Currently, the use of an SE adhesive for restoring Class IV incisal edge fractures, esthetic facial veneering and diastema closures with direct composite resin and bonding porcelain veneers is contraindicated.

A chief complaint among practitioners has been the rate of postoperative sensitivity observed following placement of Class I, II and V composite resin restorations, especially using etch-and-rinse adhesives. However, several clinical studies have found no differences in postoperative sensitivity with etch-and-rinse or SE adhesives. In fact, the conclusion of one study stated that postoperative sensitivity may depend on the restorative technique and variability among operators rather than on the type of enamel-dentin adhesive used. Postoperative sensitivity may, however, be linked to using a TE adhesive bonding to desiccated dentin. Since SE adhesives contain water and require no rinsing or drying, the dentin remains moist, which may account for reports of minimized postoperative sensitivity. Santini and coworkers investigated microleakage around Class V restorations bonded with etch-and-rinse and SE adhesives, concluding that SE systems were as reliable as TE systems.

Clinical success with self-etch adhesives is dependent on the following basic clinical technique:
1. Prepare the tooth (preparations that are self-retentive, e.g., box-like Class I, II, III and V, and Class V NCCL with an enamel bevel; not Class IV, not facial veneers, not porcelain veneers).
2. Apply the SE adhesive following the manufacturer’s timing and application instructions. This is very product specific.
3. DO NOT RINSE. Air-dry the tooth following the timing and intensity of air spray from the product instructions; do not take any shortcuts.
4. Light cure the adhesive.
5. Apply restorative material.
6. Light cure.

Adhesion to tooth structure: Clinical challenges

Not all dentin and enamel is equally bondable. Factors influencing the bond include the presence of amalgam restorations, caries and other tooth conditions that can affect the quality of etching and the quality of adhesion to enamel and dentin. There has been a trend to replace defective amalgam restorations with composite resins. When removing an amalgam restoration it is not unusual to find discolored enamel and dentin present due to the leaching of metallic ions and corrosion products into the dentin tubules. Harnirattisai et al. found no differences in adhesion between normal dentin and discolored amalgam-affected dentin with either an etch-and-rinse adhesive or a self-etch adhesive. However, bonding to caries-affected dentin has been shown to be reduced. Fluorosed enamel and dentin can also be more difficult to bond to. For enamel fluorosis, the recommendation is to prepare the enamel with a bur or diamond to improve bonding. For fluoride-rich dentin, self-etching adhesives provide better bonding. Of note, with the increased interest in tooth whitening and the availability of over-the-counter peroxide-based products, the clinician may not know if their patients are bleaching their teeth. Research supports waiting at least one week after bleaching before any restorative procedure with either an etch-and-rinse or SE adhesive to prevent interference with bonding adhesion and material setting.

An area of recent investigation has been the compatibility of TE and SE systems with self-cure and dual-cure composite resins. There is contradictory evidence on whether or not SE and TE single-bottle adhesive systems bond well to self-cure and dual-cure composite resins due to the acidity of the single-bottle primer-adhesive. Some studies have demonstrated a decreased bond and other studies have demonstrated no effect. Some recent studies evaluating TE and SE systems and their compatibility with dual-cure and self-cure composite resins have demonstrated some changes in chemistry that have resulted in composite resin-adhesive compatibility. This variability requires that the clinician review the manufacturer’s recommendations for use with self-cure and dual-cure composite resins.

There has been concern over the durability and longevity of the bond to dentin, and the in vivo bond strength to dentin has been shown to decrease over time for some adhesives. The mechanism of bond degradation has been attributed to the loss of hybrid layer integrity, which then compromises resin-dentin bond stability. A number of researchers have focused on the matrix metalloproteinases (MMPs) within the collagen that may be partially responsible for hybrid layer degradation. To prevent or decrease the degradation of bonding using either TE or SE adhesives, a number of chemical reagents that are known to inhibit MMPs have been evaluated. Chlorhexidine (CHX) has been shown to have an inhibitory effect on MMPs, and a number of studies have evaluated the successful use of CHX to inhibit the degradation of adhesion to dentin. Other MMP
inhibitors that produce results similar to those of CHX have also been investigated, including polyvinylphosphonic acid\textsuperscript{101} and quaternary ammonium methacrylates\textsuperscript{102}. Another approach to inhibiting bond degradation has been to use ethanol instead of water when wetting the dentin\textsuperscript{103,104}. With a better understanding of improving bond durability by using protease inhibitors, there will be changes in adhesive chemistries to reflect the need to inhibit MMPs with recommendations with TE adhesives to apply CHX for one minute after etching and/or to use CHX as a primer before use of an SE.\textsuperscript{105-107} Some manufacturers are reviewing the addition of CHX or other MMP inhibitors into SE adhesives.

**Clinical applications**

The recommendations for the use of adhesive systems are product specific. A summary of the indications and clinical applications for each adhesive system is provided in Table 4, based upon the clinical evidence and clinical reports.

<table>
<thead>
<tr>
<th>Table 4. Clinical applications for adhesive systems.</th>
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<tr>
<td><strong>Etch-and-Rinse (Total-Etch) Adhesive Systems</strong></td>
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<tr>
<td>Multiple-bottle (3-E&amp;R): All uses including self-cure composite resin cores and dual-cure composite resin cementation</td>
</tr>
<tr>
<td>Single-bottle (2-E&amp;R): Direct composite resin placement and with systems that have an activator use with self-cure and dual-cure composites is acceptable</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Self-Etching Adhesive Systems</strong> (not indicated with self-cure or dual-cure composites unless the manufacturer makes the recommendation and has a self-cure activator)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple-step systems (2-SEA): Direct placement Class I, II, III and V with prepared enamel</td>
</tr>
<tr>
<td>Single-step mix systems (1-SEA): Direct placement Class I, II, III and V with prepared enamel</td>
</tr>
<tr>
<td>Single-step no mix (1-SEA): Direct placement Class I, II, III and V with prepared enamel</td>
</tr>
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</table>

Use of any adhesive is manufacturer specific for use with self-cure and dual-cure composite resin systems. Currently, self-etching systems can be used for Class IV incisal edge repair, facial veneering and porcelain veneers with a light cure cement (or flowable composite as a luting agent) with the use of a total-etch of the enamel surface with phosphoric acid etchant. As more evidence becomes available in clinical trials this recommendation may change. Also, if phosphoric acid is used with an SE adhesive, only the enamel needs to be etched.

**Anterior direct composite resin restorations:** Class III, IV, V and facial veneers

When preparing Class III, IV and V restorations, as well as facial veneer preparations, the type of preparation will determine whether an etch-and-rinse or self-etch adhesive technique will be used. When shade matching is important due to the margin of the preparation being in an esthetic area, an esthetic blend of composite resin from restoration to tooth is better accomplished using a cavosurface margin bevel in esthetic areas. At gingival margins, if the enamel is very thin or if the margin is on the root surface, no bevel should be placed.

**Figure 3a. Maxillary lateral incisor with distal caries and mesial temporary restoration**

**Figure 3b. Completed ML and DL preparations maxillary lateral incisor**

**Figure 3c. Restoration of both preparations using an SE adhesive (Xeno IV) and micromatrix hybrid composite resin (TPH3)**
Class III restorations can be required to replace a defective restoration or due to initial caries. Class III preparations with box-like features and retentive walls can be restored with TE or SE adhesives. (Figure 3) When using a self-etch adhesive with a Class III preparation, it is important to follow the manufacturer’s directions, especially the length of time the adhesive is on the tooth as well as whether or not the self-etch adhesive needs to be agitated during placement since this is product dependent.

Class IV preparations can be required due to initial caries, a defective restoration or when there has been a traumatic fracture. Typically, the Class IV restoration is placed for teeth that have been fractured. Class IV preparations generally rely upon enamel adhesion for retention; the same is true when placing direct composite resin facial veneers. In both circumstances, the current evidence recommends that a TE adhesive be used with etching of the enamel surface, typically for 15-30 seconds. (Figure 4)

Figure 4a. 14-year-old patient with amelogenesis imperfecta

Figure 4b. Direct esthetic bonding after minimal tooth preparation using a TE adhesive (Prime and Bond NT) and highly polishable, esthetic micromatrix hybrid (Esthet-X HD)

Class V lesions are classified as non-carious cervical lesions (NCCL), caries or a combination. Preparing the enamel surfaces with a 1-2 mm long bevel using a diamond bur and roughening and cleaning the dentin surface with a round bur or diamond before the adhesive procedure are important for success with either TE or SE adhesives. Margins on root surfaces should not be beveled. For Class V carious lesions, there is a definitive outline form and depth, usually with a box-like design. For these preparations, since they are retentive, either a TE or an SE adhesive technique can be used.

**Posterior direct composite resin restorations: Class I and II**

With the use of an etch-and-rinse adhesive technique with composite resin, clinical studies have demonstrated that composite resins can be considered amalgam alternatives in routine-sized preparations. In contrast to amalgam, composite resins today are highly esthetic, reinforce tooth structure and can conserve more tooth structure in their preparation design. Occlusal caries can be very minimal or more extensive. For preventive resin restorations, it is generally recommended that a TE adhesive be used with a flowable composite resin. (Figure 5) For more extensive Class I where the extent of the caries or the removal of a defective restoration provides for a more box-like preparation design – which improves the self-retentive characteristics of the restoration – either a TE or an SE can be used. For Class II preparations that are box-like and retentive, either a TE or an SE adhesive system can be used successfully. To avoid marginal staining, with both etch-and-rinse and self-etch adhesives it is critical to lightly prepare the enamel by roughening beyond the cavosurface margins and etching beyond the margins, using either a phosphoric acid etchant for an etch-and-rinse adhesive or using a self-etch adhesive. The reason for roughening the enamel is that composite is difficult to finish and polish to the cavosurface margins because the composite translucency matches the tooth shade.

Figure 5a. Pit and fissure caries on the first maxillary molar and first premolar
Some general guidelines to improve clinical success with posterior composite resins include:
1. Excellent isolation with a dental dam or other isolating devices
2. Right-angled enamel margins in stress-bearing areas
3. To minimize postoperative sensitivity, use an SE adhesive and a low-shrink composite (Figure 6)
4. Adequate light curing in the proximal box of a Class II (at least 10-20 seconds with a high-intensity light [greater than 1100 mW/cm²] (Figure 7), 20-30 seconds with a conventional quartz halogen curing light) for the adhesive and first increment of composite resin placed in the proximal box to ensure polymerization of the adhesive and composite resin over the distance to the end of the gingival margin.\(^{114}\)

Following these guidelines, successful posterior composites can be placed. (Figure 8)
**Foundations/cores for fixed prosthodontics**

Before preparation and restoration with a crown, if there are substantial defects or the tooth has been endodontically treated, a foundation/core must be placed first. While dental amalgam has been a highly successful restorative material for foundation/cores for crown and bridge, the use of dual-cured composite resins has become more prevalent. The use of dual-cure composite resins for foundations/cores rather than light-cured composites is recommended due to the depth of these more extensive preparations and, in the case of endodontically treated teeth, the lack of reliable light curing of a composite resin within the pulp chamber of a posterior tooth. Colored composite resin core materials (blue colored) or composites that are more opaque in appearance can also be used to allow for differentiation between tooth structure and composite for crown margin placement. The clinician must follow the manufacturer’s instructions to ensure adhesion between the TE or SE adhesive and the composite. As stated earlier, many light-cure-only adhesives are not recommended with self-cure and dual-cure composites. The authors use a dual-cure TE or an SE adhesive with an activator when placing composite resin cores. (Figure 9)
**Expanded clinical applications with TE adhesives**

Teeth that are periodontally compromised with loss of attachment and bone height have increasing levels of mobility. Tarnow and Fletcher described three primary rationales for controlling tooth mobility with periodontal splinting\(^\text{115}\): 1) primary occlusal trauma 2) secondary occlusal trauma and 3) progressive mobility, migration and pain on function.

Periodontal splinting has been found to improve periodontal prognosis.\(^\text{116, 117}\) In recent years, conservative splinting of periodontally compromised teeth using a total-etch adhesive technique with a continuous woven-fiber reinforcement has been described and become a well-accepted technique.\(^\text{116,119}\) (Figure 10)
As our patients retain their teeth longer, destructive loss of tooth structure on the biting surfaces of posterior teeth and the incisal edges of anterior teeth is caused by attrition due to normal function and parafunction. This loss of tooth structure is frequently observed in the anterior region as the cupping of exposed dentin in the incisal edges with enamel chipping. (Figure 11) If an intervention occurs before anterior teeth demonstrate moderate to severe wear, the wear can be reduced.120 For these cases a conservative approach is a definitive preparation using either a small pear-shaped bur (#329 or #330) or a small round bur (#1/2 or #1) into the dentin to a depth of 1.0 mm, leaving a shell of enamel that will be bonded to. (Figure 12) This depth into the dentin allows for adequate composite resin longevity as the restoration functions. A periodontal probe should be used to verify the pulpal depth of 1.0 mm of the tooth preparation of all enamel walls. Using a TE adhesive technique with an etching time of not more than 15 seconds, the teeth can then be restored. (Figure 13) These restorations have demonstrated good durability.

Conclusion

Multiple generations of adhesive systems have been developed in the last 40 years. Many of these have required multiple steps that include etching with phosphoric acid, rinsing with an air-water spray, drying, rewetting the preparation, applying the primer, drying, applying the adhesive resin and light curing. More recently, simplified systems have been introduced where the adhesive provides for the etching, primer and adhesive all in one. The clinician needs to evaluate the clinical requirements of any adhesive restorative system he or she selects for restoring the natural dentition. Long-term clinical trials with posterior composite resin restorations, porcelain veneers, crowns, and resin and ceramic inlays and onlays provide strong evidence of clinical success and durability when using a total-etch adhesive technique. Additionally, it has been found that the restorative technique and variability among operators may relate to the presence or absence of post-operative sensitivity rather than the type of enamel-dentin adhesive used. Of note, when using an etch-and-rinse technique the dentin should remain damp and glossy and not be desiccated prior to application of the adhesive, to reduce the risk of sensitivity. While the multiple-bottle etch-and-rinse adhesives are still the gold standard for all-purpose bonding, based upon the current clinical evidence and the recommendations of manufacturers, SE adhesive systems can be used successfully for the restoration of Class I, II, III and V preparations. Whichever system the clinician selects to use, he or she should follow the manufacturer’s recommendations for clinical applications to ensure clinical success.

References


Questions

1. ________ have improved the way we treat patients.
   a. Fluorides
   b. Local anesthetics
   c. Dental resin adhesion innovations
   d. all of the above

2. ________ described the retention of restorations based upon cavity design and undercut dentin.
   a. Buonocore
   b. Black
   c. Ferrante
   d. all of the above

3. ________ has been the driving force in changing how we prepare and restore teeth.
   a. Fluoride-releasing cement
   b. The electric handpiece
   c. Bonding to tooth substrates
   d. all of the above

4. ________ has/have contributed to the ability to have a lesion-centered approach to restorative treatment.
   a. Advancements in adhesive restorative materials
   b. Caries risk assessment
   c. The introduction of computer-assisted methods of caries detection
   d. all of the above

5. ________ is a key prerequisite for successful adhesion to tooth structure.
   a. A safe and biologically acceptable procedure
   b. Bond strength that is clinically significant
   c. A bond that is stable in vivo for a clinically significant period of time
   d. all of the above

6. ________ wrote an article in 1985 on the fundamental elements for an adhesive used for bonding restorative materials to tooth structure.
   a. Dr. Wayne Swift
   b. Dr. Wayne Barkmeier
   c. Dr. Dwayne Smith
   d. none of the above

7. Establishing a bond slowly ________.
   a. is essential for bond strength
   b. is essential for adequate finishing
   c. a and b
   d. none of the above

8. ________ is a phenomenon for all adhesives used today.
   a. Micromechanical locking to the etched enamel prisms
   b. Bonding to dentin through hybridization
   c. Micromechanical locking to etched dentin crystals
   d. a and b

9. For successful dentin bonding, the bond should ________.

10. ________ is a goal for an effective dentin bonding material.
    a. Retention at a clinically acceptable level
    b. Biocompatibility
    c. A long-lasting bond to dentin
    d. all of the above

11. The success of the etch-and-rinse adhesive bond was demonstrated by several researchers, based upon the addition of a ________ to the enamel/dentin.
    a. hydrophilic monomer
    b. hydrophobic monomer
    c. hydrophilic polymer
    d. hydrophobic polymer

12. Some adhesives have added ________ to improve physical properties.
    a. fluoride
    b. fillers
    c. carbonate
    d. none of the above

13. The etch-and-rinse adhesives can be recognized by the initial application of a ________ to the enamel/dentin.
    a. 10%-20% phosphoric acid
    b. 10%-40% phosphoric acid
    c. 10%-20% acetic acid
    d. 10%-40% hydrochloric acid

14. The etch-and-rinse technique is also known as the ________ technique.
    a. self-etch
    b. total-etch
    c. no-etch
    d. none of the above

15. With the etch-and-rinse technique, prior to bonding the enamel surface can be ________ with air, and the dentin should remain ________.
    a. completely dried; dry
    b. partially dried; dry
    c. completely dried; damp and glossy
    d. none of the above

16. Based upon the evidence to date, bonding to enamel is best accomplished with the ________ technique.
    a. self-etch
    b. no-etch
    c. etch-and-rinse
    d. none of the above

17. The etch-and-rinse technique involves the use of a ________ adhesive resin.
    a. one-bottle
    b. one- or two-bottle
    c. three-bottle
    d. none of the above

18. ________ is a requirement for clinical success with etch-and-rinse adhesives.
    a. Rinsing with air-water spray for 10 seconds after etching
    b. Drying the tooth after rinsing
    c. Leaving the enamel frosty and dentin glossy (moist) after drying
    d. all of the above

19. The self-etch technique involves the use of ________.
    a. a separate etchant
    b. a four-bottle technique
    c. a one-step or two-step technique
    d. a and c

20. Self-etch adhesive systems are aqueous mixtures of ________.
    a. acidic functional polymers
    b. acidic functional monomers
    c. alkaline functional polymers
    d. alkaline functional monomers

21. The self-etch approach ________.
    a. requires a separate etching step
    b. does not require a separate etching step or retreating
    c. requires an additional retreating step
    d. a and c

22. Currently, the use of an self-etch adhesive for direct composite restoration ________ is contraindicated.
    a. of Class IV incisal edge fractures
    b. of esthetic facial veneering
    c. for diastema closures
    d. all of the above

23. Sclerotic dentin ________.
    a. exhibits hypemineralization
    b. is resistant to phosphoric acid etching
    c. exhibits hypermineralization
    d. all of the above

24. It has been recommended to increase etching time to ________ for sclerotic dentin.
    a. 20 seconds
    b. 30 seconds
    c. 40 seconds
    d. 50 seconds

25. Several clinical studies have found ________ differences in postoperative sensitivity with etch-and-rinse or self-etch adhesives.
    a. major
    b. minimal
    c. no
    d. none of the above

26. When using a self-etch adhesive, the area ________ after adhesive application.
    a. must be rinsed
    b. must not be rinsed
    c. must be light-cured
    d. b and c
27. ________ is more difficult to bond to:
   a. Caries-affected dentin
   b. Fluorosed enamel
   c. Fluorosed dentin
   d. all of the above

28. ________ is a matrix metalloproteinase inhibitor that has been used to decrease or prevent bond degradation:
   a. Chlorhexidine
   b. Quaternary ammonium methacrylate
   c. Polyvinylphosphonic acid
   d. all of the above

29. When preparing Class III, IV and V restorations, the type of ________ will determine whether an etch-and-rinse or self-etch adhesive technique will be used.
   a. etchant
   b. lesion
   c. preparation
   d. a and b

30. Research supports waiting at least ________ after bleaching before any restorative procedure with an etch-and-rinse or self-etch adhesive.
   a. one week
   b. two weeks
   c. three weeks
   d. one month

31. Class III preparations with box-like features and retentive walls can be restored with ________.
   a. self-etch adhesives only
   b. total etch adhesives only
   c. self-etch or total-etch adhesives
   d. none of the above

32. A minimally invasive preventive resin preparation can be performed with a ________ bur.
   a. large carbide
   b. large pear-shaped diamond
   c. end-cutting
   d. fissurotomy

33. The mechanism of dentin bond degradation has been attributed to the loss of ________.
   a. hybrid layer integrity
   b. prisms
   c. the sealed surface
   d. all of the above

34. For preventive resin restorations, it is generally recommended that a ________ adhesive be used with a flowable composite resin.
   a. self-etch
   b. total-etch
   c. self-etch or total-etch
   d. none of the above

35. To avoid ________, with both etch-and-rinse and self-etch adhesives it is critical to lightly prepare the enamel.
   a. dentin discoloration
   b. marginal staining
   c. fracture
   d. none of the above

36. One approach to inhibiting bond degradation has been to use ________ instead of water when wetting the dentin.
   a. acrylamide
   b. ethanol
   c. essential oils
   d. fluoride rinse

37. Postoperative sensitivity ________.
   a. may be linked to using total-etch adhesive bonding to desiccated dentin
   b. may depend on the restorative technique rather than the type of adhesive system used
   c. is a chief complaint among practitioners following placement of Class I, II and V restorations
   d. all of the above

38. With the use of an etch-and-rinse adhesive technique, clinical studies have demonstrated that composite resins can be considered ________.
   a. inferior alternatives to amalgam
   b. amalgam alternatives in routine-sized preparations
   c. equivalent to cast gold crowns
   d. a or b

39. An esthetic blend of composite resin from restoration to tooth is better accomplished using a ________ in esthetic areas.
   a. line angle bevel
   b. cavosurface level
   c. cavosurface margin bevel
   d. none of the above

40. The use of ________ composite resin is recommended for foundations/cores.
   a. light-cured
   b. dual cure
   c. light-cured or dual cure
   d. none of the above

41. ________ described three primary rationales for controlling tooth mobility with periodontal splinting.
   a. Fletcher and Lang
   b. Tarnow and Fletcher
   c. Tarnow and Lang
   d. Tarnow and Buser

42. If phosphoric acid is used with a self-etch adhesive, ________ need(s) to be etched.
   a. only the enamel
   b. only the dentin
   c. both the dentin and the enamel
   d. none of the above

43. If phosphoric acid is used with an etch-and-rinse adhesive, ________ be etched.
   a. only the enamel
   b. only the dentin
   c. both the dentin and the enamel
   d. none of the above

44. Colored (blue) composite resin is used for ________.
   a. Class I restorations
   b. sealants
   c. foundations/cores
   d. all of the above

45. Conservative splinting of periodontally compromised teeth using a ________ adhesive technique with a(n) ________ woven-fiber reinforcement has been described.
   a. self-etch, intermittent
   b. self-etch, continuous
   c. total-etch, continuous
   d. none of the above

46. Destructive loss of tooth structure on the biting surfaces of posterior teeth and the incisal edges of anterior teeth is caused by ________.
   a. attrition due to normal function
   b. attrition due to parafunction
   c. periodontal disease
   d. a and b

47. Anterior teeth with incisal edge tissue loss can be restored using a ________ adhesive technique with an etching time of not more than ________.
   a. self-etch; 10 seconds
   b. total-etch; 10 seconds
   c. self-etch; 15 seconds
   d. total-etch; 15 seconds

48. ________ clinical trials with posterior composite resin restorations provide strong evidence of clinical success and durability when using a total-etch adhesive technique.
   a. Short-term
   b. Long-term
   c. No
   d. none of the above

49. ________ adhesives are still the gold standard for all-purpose bonding.
   a. Single-bottle self-etch
   b. Single-bottle etch-and-rinse
   c. Multiple-bottle self-etch
   d. Multiple-bottle etch-and-rinse

50. Based upon the current clinical evidence, self-etch adhesive systems can be used successfully for the restoration of ________ preparations.
   a. Class I and II
   b. Class III
   c. Class V
   d. all of the above
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1. Describe the differences between etch-and-rinse and self-etch adhesives and relate these categories to other naming systems.
2. Discuss the current research evidence comparing etch-and-rinse and self-etch adhesives.
3. List and describe the indications for etch-and-rinse and self-etch adhesives.

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   Objective #1: Yes No
   Objective #2: Yes No
   Objective #3: Yes No
   Objective #4: Yes No

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