Adhesives: Newer Is Not Always Better—Part 2

Part 2 offers an update and overview of self-etch adhesive systems and addresses postoperative sensitivity associated with total-etch adhesives.

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Part 1 of this article discussed etch-and-rinse adhesives—the so called fourth and fifth generations—with particular attention to methodology in order to maximize their performance. The clinician must be aware of the type of solvent used, and whether the system is a filled resin, as these factors modify the application technique. Because postoperative sensitivity has been identified as a possible result with these etch-and-rinse adhesives, Part 2 addresses how to clinically minimize—or totally eliminate—this problem. The authors also offer an overview of the self-etch adhesive systems and their current status in restorative dentistry. This second article also looks at the lack of longevity of dentin bonding, which may be affected by matrix metalloproteinases (MMPs), and how current research may offer insights on ways current clinical techniques and adhesive systems can be changed to address this issue.

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Desensitizers

Glutaraldehyde is a very effective fixative, or flocculating agent, which has the ability to create a cross-linked protein plug inside the dentinal tubules. It has been accepted extremely well by dentists as a material that reduces or totally eliminates tooth sensitivity.[1] Schupbach[2] has shown that after topical application of glutaraldehyde/hydroxyethylmethacrylate (HEMA) combination products such as G5™ All-Purpose Desensitizer (Clinician's Choice Dental Products, Inc, www.clinicianschoice.com), Microprime G Desensitizing Agent (Danville Materials, www.danvillematerials.com), Gluma® Desensitizer PowerGel (Heraeus Kulzer, www.heraeus-kulzer-us.com), and Calm-It™ Desensitizer (DENTSPLY Caulk, www.caulk.com), to the dentin surface, multiple transverse septa occurred in the lumen of the dentinal tubules down to a depth of 200 µm (0.2 mm). This demonstrated that the combination products effectively create a barrier that eliminates the hydrodynamic mechanism of dentin hypersensitivity. The protein plug in the tubules also decreases the propensity for the negative effects of fluid flow on the ability to bond to the dentin substrate. Glutaraldehyde/HEMA desensitizer products also cross-link collagen (exposed during etching), which results in increased strength and durability of the hybrid layer resin dentin bonds.[3]

The HEMA component of these solutions, which is very hydrophilic, acts as a pre-primer to help facilitate resin infiltration of the exposed collagen, and thereby improve the longevity of the bond.[4] Because these glutaraldehyde/HEMA products also contain water, they act as re-wetting agents. In the case of etch-and-rinse bonding procedures, the "re-wetting after the acid etch acts to expand the demineralised collagen and increase its surface energy, facilitating the diffusion of the hydrophilic resin monomer into the etched dentin."[5] A further benefit of using glutaraldehyde/HEMA combinations is that these products have antibacterial and anti-caries effects.[6]

Liners

Combining the primer and adhesive in the same mixture, as with the fifth-generation bonding agents as well as the seventh generation, places a hydrophilic compound together with a hydrophobic compound, which is problematic, because these two compounds are antagonistic, and, as Pashley states, they tend to be more permeable to water derived from the underlying dentin.[7-9] One way to address this permeability is to decrease the fluid flow by the glutaraldehyde/HEMA products mentioned above, but an additional benefit can be derived by the addition of a hydrophobic, radiopaque, flowable composite liner like De-Mark (Cosmedent Inc., www.cosmedent.com), before placement of the final restoration. A hydrophobic layer not only decreases permeability,[10,11] acting similarly to the last adhesive layer placed in the three-step etch-and-rinse bonding procedure, but it also gives the added benefit of the "elastic bonding" concept, acting as a stress breaker,[12-14] while creating a radiopaque liner beneath the final restoration that cannot be misdiagnosed as caries.

Sixth-Generation Adhesives

The self-etch systems, or sixth-generation adhesives, are classified into two types. Type I adhesives, which are self-etch priming systems such as Clearfil™ SE Bond (Kuraray America, Inc. Dental, www.kuraraydental.com), Prelude SE (Danville Materials), and Ultradent Peak™ SE (Ultradent Products Inc., www.ultradent.com), use a self-etching primer followed by the application of an adhesive. These systems are gaining in popularity due to the fact they are not as clinically technique-sensitive, and are easy to use,[15] with less reported post-operative sensitivity. However, controlled clinical studies show no difference in postoperative sensitivity as compared with etch-and-rinse systems when proper clinical protocol is used.[16,17]

With most of the self-etch systems, the clinician may sacrifice marginal seal and longevity.[18,19] In order for a self-etch system to provide a good enamel marginal seal, the pH must be lower than 1.5 to effectively condition uncut enamel, and prevent marginal leakage; however, some of these products are mildly acidic, having a pH as high as 3.3. The research literature is replete with studies showing that these self-etch adhesives have more marginal defects,[20] poor penetration with less adhesion,[21] and increased microleakage[22] in enamel when compared to etch-and-rinse systems,

with a somewhat better result with instrumented enamel.[23,24] This is worrisome because the enamel bond helps to protect the dentin bond from long-term degradation. Some clinicians still incorporate the use of a phosphoric acid on the enamel margins when using a self-etch product to enable increased bonding to the enamel.[25] Using this technique, the clinician achieves a more predictable bond on the enamel margin; however, depending on control of the phosphoric acid, this technique can lead to clinical variability, and/or more permeability of the bond and sensitivity. The reason self-etch systems tend to minimize postoperative sensitivity is that the smear layer on the dentin surface and smear plugs in the dentinal tubules are left intact. If the phosphoric acid migrates onto the dentin surface during placement or the washing step, it can remove the smear layer and plugs, which allows fluid movement within the tubule; this leads to decreased tensile bond strength and sensitivity.[26]

If this is a preferred technique, the clinician may want to consider a phosphoric acid such as Ultra-Etch (Ultradent), which has the ideal viscosity for placement on vertical surfaces without migration. A recognized variable in the self-etch systems is the thickness of the smear layer, with diamond burs creating a thicker smear layer than carbide burs, resulting in less adhesion to dentin when the thick smear layer cannot be fully penetrated by the self-etch system.[27,28] The self-etching primers, which are not rinsed off, are an acidic monomer, which may not be fully neutralized; this creates a demineralized zone below the hybrid layer that can compromise bond strength.[29] A concern with self-etch systems is that they may not have resin penetration into or obturate the dentin tubules, thus allowing pulpal fluids to penetrate past the smear plug and into the hybrid layer.[30] "The higher the micropermeability, the higher the risk of defects at the resin–dentin interface, which may represent the pathway for hydrolytic and enzymatic degradation of the collagen and resin dentin bonds over time."[31] This causes what is known as a "hydrolytic" or "water-tree" effect, which breaks downs the bond from the inside out, reducing both in-vivo and in-vitro bond strengths.[32]

As a general rule, self-etching systems are more ideally used in posterior restorations for prevention of sensitivity. In addition, due to a less predictable bond to enamel, which can lead to additional staining secondary to microleakage, these self-etch systems are not ideal for anterior restorations. When the level of enamel etching is of concern (ie, the pH is above 1.5), phosphoric-acid–etching may be indicated. However, some of these Type I adhesives, such as Peak SE, which has the highest bond strength in this category of 50 MPa to dentin,[33] has an adhesive, Peak™ LC Bond Resin (Ultradent), that can be used in the anterior dentition with an etch-and-rinse phosphoric-acid technique. Many of these products do have catalysts for use with dual-cured composites and can be compatible with self-cure.

Type II self-etch adhesive systems such as All-Bond SE® (BISCO, Inc., www.bisco.com), Brush & Bond® (Parkell, www.parkell.com), Futurabond® NR (VOCO America, Inc., www.vocoamerica.com), Touch & Bond® (Parkell), Adper™ Prompt™ L Pop™ (3M ESPE, www.3mespe.com), and Xeno III® (DENTSPLY Caulk), use a self-etch primer and adhesive that are mixed together prior to placement. These self-etching primer/adhesives should not be confused with the self-etching primers of Type I systems. Both Type I and Type II systems leave the smear layer intact before placement and thereby limit postoperative sensitivity. However, Type II systems have all of the same drawbacks as Type I, and can have 35% lower bond strength, because no hydrophobic adhesive layer is placed. As mentioned above, the hydrophobic resin layer helps to prevent water-induced interfacial changes.[34] It is important to note that thermocycling, which is used to more closely mimic oral conditions, leads to further lowering of the bond strength of these hydrophilic systems.[35] The remaining acidity and permeability of these Type II products make them incompatible with self- or dual-cured composites and core materials. Touch & Bond, for instance, demonstrates extremely low bond strengths of 12 MPa to enamel and only 2 MPa to dentin.[36]

Seventh-Generation Adhesives

Among the self-etch adhesives—also called "all-in-one" or seventh-generation adhesive systems—are G-Bond™ (GC America, www.gcamerica.com), iBond® (Heraeus Kulzer, www.heraeus-dental-us.com), Xeno® IV (DENTSPLY Caulk), Adper™ Easy Bond (3M ESPE), AdheSE® One (Ivoclar Vivadent, www.ivoclarvivadent.com), and Clearfil® S^3 Bond (Kuraray). They are very similar to sixth-generation systems, with the biggest difference being that all the components are pre-mixed in one bottle. This one-bottle solution etches, primes, and bonds all at the same time. These self-etch adhesives are permeable membranes and are the most hydrophilic of the adhesive categories.[37] As such, water sorption by polymers (composites) causes plasticization and lowers mechanical properties.[38] Residual acidity causes an adverse reaction with chemically cured composites and core materials, creating a reduction in bond strength with permeability, also a further cause of bond strength reduction.[39] Swift states that for these single-step self-etch adhesives, the bond strength to chemical-cured composites can be enhanced with the adjunctive use of co-initiators, based on sodium salts of aromatic sulphinic acids, but he notes that it might not apply to all simplified adhesives.[40] This generation of self-etch adhesives also has the highest pH values which results in one-fifth the bond strength to enamel versus the three-step etch-and-rinse system,[41] and a higher percentage of leakage at the margins.[42] In general, the all-in-one seventh-generation bonding agents show lower bond strengths, with G-Bond having a bond strength of 12.5 MPa to dentin and 15.4 MPa to enamel.[33]

Biologic Considerations

It is well known that intraoral, in-vivo bonding of composite resin to dentin decreases with the age of the restoration.[43] Bonding stability is affected negatively by factors such as permeability, lack of full penetration of the bonding agent to the full depth of the etched dentin, and the etching process itself (etch-and-rinse or self-etch). Etching dentin results in a superficial exposure of the collagen fibers and other collagen-associated proteins. Subsequent use of the dental adhesive system allows resin infiltration of the collagen and results in the formation of the hybrid layer. Degradation of collagen fibers associated with the hybrid layer by proteolysis results in a gradual reduction in dentin bond strengths.[44] The end result of the collagen degradation is the loss of continuity between collagen fibrils in the hybrid layer and the underlying mineralized matrix into which they are anchored. This eventually leads to lower bond strengths, increased nanoleakage, and dentin/pulpal sensitivity, and it ultimately leads to the replacement of the restoration sooner than expected. Matrix metalloproteinases (MMPs) are among other collagen-associated proteins exposed by the etching process and can slowly degrade collagen in the hybrid layer.[45] As well, it is thought that mildly acidic monomers present in dental adhesives can activate MMPs, making them prone to degrade the acid-etched, unprotected collagen fibers.[46] Early reports have shown that glutaraldehyde cross-links fibers, making it more difficult for the collagen-associated MMPs to break down the collagen fibers associated with the hybrid layer.[47] In this way, glutaraldehyde is able to help establish a more stable hybrid layer. Other protein cross-linking agents are currently being investigated. MMP inhibitors such as chlorhexidine show promise for initial stabilization of the hybrid layer.[48-53] In response to this ongoing investigation and work on stabilizing the long term-bond, Peak™ LC Bond Resin has recently added chlorhexidine to its formulation.

Conclusion

Making a decision on a suitable dental adhesive is not easy, as there are many factors to consider. The driving factor should be choosing the product and/or procedure that will offer the best quality of care for patients, and deliver the most predictable long term-results. The predictability of fourth- and fifth-generation adhesives has been unmatched. Ongoing research may lead to advances in dental chemistry that result in stable, long-term attachment to both enamel and dentin.

Disclosure

Dr. Boksman was previously a part-time paid consultant to Clinician's Choice and Clinical Research Dental, holding the title of Director of Clinical Affairs.

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