Adhesives: Newer Is Not Always Better—Part 1

Latest-generation adhesives often do not measure up to their predecessors in bonding strength and durability.

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In most fields of modern technology, the latest version of a product is usually an improvement over the previous ones. For example, smartphones, hybrid cars, the Blu-Ray disk, and high-definition television represented significant advancements over their predecessors. So why is this continual advancement apparently not the case when it comes to dental adhesives? Over the last 25 years, dentistry has seen significant generational changes, new materials categories, new chemistries, and new clinical protocols with dental adhesives—much of it driven by an effort to simplify or to shorten the bonding procedure. However, not all of the newer materials have necessarily offered improvements to the patient or for the long-term viability/prognosis of the restorations placed. How does the clinician make a rational choice from among more than 65 adhesives still on the market today? Among the so-called fourth-, fifth-, sixth-, and seventh-generation adhesives—alternatively known as the “etch-and-rinse” and “self-etch bonding agents”—which system gives the most consistent, long-term clinical results and has the longest viable bond strength over time? Which system resists oral degradation and allows for the integration of new methodology to treat the hybrid layer for long-term stability while addressing the inevitability of the presence of bacteria and composite polymerization and functional stress?

The current resin-dentin bonding mechanism, whether using etch-and-rinse or self-etch systems, relies on the formation of a hybridized layer that couples adhesives/resin-composites with the underlying mineralized dentin. With the exception of resin tags, which extend down into the dentinal tubules, only the collagen fibers offer physical continuity between the hybrid layer (as it is known after being infiltrated with resin) and the underlying mineralized dentin. The collagen fibers represent millions of fibril anchors, which emerge from the underlying mineralized dentin matrix into the demineralized layer.

In an excellent overview of factors that affect the bond strength of bonding agents, Powers et al1 point out that the type of substrate (ie, superficial dentin, deep dentin, permanent/primary dentin, carious dentin), phosphoric acid/hydrochloric primers, preparation by air abrasion and laser, moisture, contaminants, desensitizing agents, and self-cured/light-cured restorative materials all affect the bond strength; bond strength is reduced by more than 50% when bonding conditions are not ideal. Further, when lasers are used to prepare hard tissues, studies show that bonding to these surfaces may be more problematic than bonding to conventionally bur-prepared preparations.2 Rushing to complete such procedures by reducing the priming time from 20 to 5 seconds can cause a 17% reduction in mean bond strength.3 In contrast, using a 20-second application time to agitate a self-etch adhesive significantly improves the shear bond strength to dentin.4 In addition to agitation, rather than applying a single coat of adhesive resin on dentin, up to four additional coatings increase the bond strength and decrease nanoleakage.5 Multiple research reports attest to the existence of material incompatibilities that depend on formulation, and that bond strengths can be reduced by 45% to 90% or more when incompatible combinations are applied clinically.6,7 Acetone-based adhesives show a high degree of technique sensitivity,8 and over- or under-drying the acid-etched dentin compromises the bond.9 Simplification of the bonding procedure does not necessarily lead to improved bonding performance, especially in the long term.10 Alex11 perhaps has stated it best: “The bottom line is, it is incumbent on every dentist to learn about their specific adhesive system, its idiosyncrasies, its strengths and weaknesses, and how to maximize its performance.”

Practitioners should be aware not only of the immediate bond strengths—whether shear or tensile (the immediate configuration factor [C-factor]) polymerization shrinkage stress is about 24 MPa in a Class I cavity preparation)12 but also, the long-term performance or longevity (patency) of their bonding agent in actual clinical performance.13 Much of the bond testing has been done in a laboratory under ideal controlled conditions, which may not be possible to replicate in a clinical environment, and results may vary depending on the testing methods and devices used.14 Some studies test immediate or 24-hour bond strength only on dentin just below the enamel surface, where bonding is easiest and strongest; and most of these studies have been done in vitro on human or bovine teeth, without positive fluid flow or the positive pressure that exists clinically—both of which can drastically decrease long-term performance. A short, simplified overview of the systems and their clinical behavior follows.

**Fourth-Generation Adhesives**

Compared to current adhesives or bonding agents, those still considered to be the “gold standard” in long-term durability are fourth-generation adhesives (etch-rinse–prime-adhesive resin) or multi-bottle systems (eg, 3M™ ESPE™ Scotchbond™ MP Multi-Purpose Plus, 3M ESPE, www.3mespe.com; ALL-BOND 2© and ALL-BOND 3©, Bisco, Inc., www.bisco.com; Perma Quick, Ultradent Products, Inc., www.ultradent.com; and OptiBond FL©, Kerr Corporation, www.kerrdental.com).15,16 These etch-and-rinse materials still provide the deepest, strongest, most predictable, and long-term bond to enamel.17 This strong layer resists...
microleakage and protects the dentin bond from water degradation, which may contribute to better long-term clinical performance.19-22 Arrais24 has reported that these three-step bonding systems also form the thickest hybrid layer, followed by one-bottle adhesives, with the self-etching adhesives forming the thinnest hybrid layers. It must be noted that strict adherence to etching times is critical, as prolonged phosphoric acid-etching can form a deep demineralized dentin zone that may not be fully impregnated by the primer and adhesive, resulting in low bond strength.23 These products, which bond well to dentinal substrates, have lost some of their popularity due to the fact that they are multi-bottle, multi-step systems, which require etch, rinse, and application of hydrophilic primers followed by a hydrophobic adhesive layer. As such, these systems can be very technique-sensitive, if the sequencing and timing is not exactly adhered to, with some having complicated instructions on how to bond to tooth structure and other dental materials. The so-called fourth-generation bonding agents have the major benefit of being effectively used with self-cure, dual-cure, and light-cured composites as well as indirect restorations without concern. Representative bonding strengths for products in this category are: OptiBond FL, 39 MPa to dentin,26 and Scotchbond MP, 45.6 MPa to dentin.19

Fifth-Generation Adhesives
Fifth-generation adhesives (etch-and-rinse plus [primer and bond!] or the single-bottle systems, such as MPa®™ (CLINICIAN'S CHOICE®, www.clinicianschoice.com); Sealbond Ultima (RTD, Clinical Research Dental, www.clinicalresearchdental.com); OptiBond® Solo Plus (Kerr); Adper® Single Bond Plus (3M ESPE); Prime & Bond® NT™ (DENTSPLY Caulk, www.caulk.com); PQI and Peak™ (Ultradent Products); Excite® (Ivoclar Vivadent, www.ivosclarvivadent.com); and One Step Plus and ACE® ALL-BOND TE™ (Bisco), contain primers and adhesive in a single bottle. This simplifies the bonding technique by eliminating some of the variables regarding the number of bottles and steps required. This single-bottle, etch-and-rinse adhesive type shows the same effectiveness as the fourth-generation systems in terms of microleakage,7 and shows good dentin bond strengths with excellent marginal seal in enamel.28-30 However, not all fifth-generation adhesives are compatible with dual- and self-cure composites or core materials. The lower pH of the oxygen-inhibited layer, or the acidic monomers in some simplified products, are too acidic and thereby de-activate the tertiary amine in chemically-cured composites. This results in no bonding, or weak bonding, with a material such as Sealbond Ultima and One Step Plus contain acetone, a very volatile solvent that should never be pre-dispensed into a deepen dish before the actual clinical bonding procedure, because the evaporation of the solvent will drastically reduce the durability of the bonding agent. Products that use ethanol or acetone need the proper amount of moisture (a moist bonding protocol), to prevent the collapse of the exposed collagen network.31 The amount of impregnation of the hybrid layer can be reduced by 50% if the dentin is over dried.32 Ethanol-based adhesives contained in products such as MPa®, Peak™, and OptiBond Solo Plus generally are more forgiving in clinical application and show the highest microtensile bond strengths.25,30,32 It must be noted here that the 3 to 5 seconds recommended by some manufacturers for the evaporation of solvents is generally not enough to remove even half of the solvent, and therefore extension of this time is recommended.29

The clinician also needs to know whether they are using a filled or unfilled adhesive, as the inclusion of fillers changes the viscosity and thickness of the applied layer. As well, evidence in the literature supports the concept that filled resin provides stress relief at the tooth–restoration interface.24 Not all fifth-generation adhesives are the same in regards to the number of applications (unfilled need more applications), so it is critical to follow the manufacturer’s directions. Some products, such as One Step Plus and Adper Single Bond Plus, require two coats of the adhesive, while others like MPa®™ and PVI require only one.46 Of course a single coat saves material and time, because less of each is required for bonding the restoration. Representative dentin bond strength reported in this category are 42 MPa to dentin for Adper Single Bond Plus27 and 41 MPa for MPa®™.24

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as Prime & Bond NT in its light-cured version showing a bond strength of 0 MPa.28 Some adhesive systems such as OptiBond Solo Plus require a dual-cure activator, which is a resin-free benzene sulphinic-acid/sodium salt solution, which will raise the acidic pH of the oxygen-inhibited layer in order to bond to self-cured/dual-cured products. However, this additional step lowers bond strengths because of the dilution of the adhesive and the inherent permeability of the polymerized adhesive.32 Other products, such as MPa, Sealbond Ultima, and One Step Plus, do not require the use of a dual-cure activator. With a self-cure composite, One Step Plus shows bond strength of 21.4 MPa33 in one study and 19 MPa in another.44 In the later study, MPa showed a bond strength of 18.5 MPa to the self-cure composite; however, when the oxygen-inhibited layer was removed with alcohol, the bond strength more than doubled to 38.9 MPa to the level obtained using light-cured composite.24

The solvents in bonding agents can be either ethanol-based, a nonvolatile solvent, or acetone-based. Products and adhesive into one bottle, which also applies to the so-called seventh-generation or self-etch all-in-one adhesives, increases the hydrophilicity and permeability of the bond, making them more likely to undergo hydrolysis. This is especially true for the unfilled bonding agents, as they create a thinner hybrid layer.43

Conclusion
Part II of this article discusses two techniques to minimize, if not totally eliminate, postoperative sensitivity with etch-and-rinse adhesives using glutaraldehyde/HEMA combinations, as well as a hydrophilic radiopaque liner to decrease the permeability of the bond and thereby increase long-term performance. Part II will also examine the current status of the self-etch adhesives, their categories, and the role of matrix metalloproteinases in the lack of longevity of bonding to dentin. In the future, research data on increasing the longevity of the bond by inhibiting the activity of these proteases may alter current approaches to bonding and newer products may emerge as a result.

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. Dr. Santos is a consultant for R&D to Clinical Research Dental and Clinician’s Choice.

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