COMPENDIUM SPECIAL REPORT:

Adhesion

By Gary Alex, DMD

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Adhesive Dentistry: The Good, the Bad, and the Ugly

Gary Alex, DMD*

Every so often in the annals of dental history, something spurs a paradigm shift in the way dentistry is practiced. Such a change is often induced by a new material, technique, or technological breakthrough. The development of sophisticated adhesive systems (that began in the late 1980s and continues to this day) is one such example. Indeed, the so-called "cosmetic revolution" in dentistry blossomed in large part due to advances in adhesive technology. It is the ability to bond various materials, in a reasonably predictable fashion, to both enamel and dentin substrates that allows dentists to routinely place porcelain veneers; direct and indirect composites; and a plethora of other restorative and esthetic materials. In fact, the longevity and predictability of many current restorative procedures is wholly predicated on the dentist's ability to bond various materials to the tooth tissues.

In the 1990s, adhesive dentistry was a hot topic. It was new, it was sexy, and it captured the imagination and energy of almost all involved in dental materials research. Manufacturers were quick to jump on the adhesive bandwagon, developing and marketing their own systems as well as providing grant money for adhesive research. Well-known and respected lecturers and opinion leaders spoke and wrote enthusiastically about the power of adhesive dentistry. The euphoria surrounding adhesive dentistry—supplemented by a healthy dose of sometimes dubious marketing claims—encouraged many dentists to "push the envelope" based on their faith in these new adhesive systems. For example, it was not uncommon to bond porcelain veneers onto teeth that were aggressively prepared, well into dentin, leaving little or no enamel available for bonding. The belief was the new adhesive systems could bond restorative materials to dentin as well as—or better than—they could to enamel. This conviction appeared well founded as laboratory testing often showed that some adhesive systems were, in fact, capable of generating bond strengths to dentin that rivaled and often surpassed bond strength to enamel. It wasn't until the passage of time that chinks in the armor of adhesive dentistry began to appear.

The fact is, many adhesive systems, both then and now, do bond extremely well to both dentin and enamel. What many dentists do not realize is that as time goes by there appears to be a trend toward a decrease in bond strength to dentin while bond strength to enamel remains relatively stable. This became all too apparent to many clinicians when porcelain veneers and other restorations they bonded primarily to dentin substrates began to de-bond and fail with the passage of time. Long-term bonding to dentin is still a potential "Achilles heel" of adhesive dentistry. To this day, many clinicians still seem unaware of this fact and continue to aggressively prepare teeth into dentin and bond in restorations that may not be predictable over the long-haul. In the case of a porcelain veneer, when there is little enamel left to bond to, full coverage is often a more predictable treatment alternative.

The difficulty in long-term bonding to dentin, as compared to enamel, is partially explained by the morphologic, histologic, and compositional differences between the two substrates. Dentin is a highly variable substrate—superficial, middle, and deep dentin can vary significantly in structural and chemical composition. Enamel on the other hand is quite consistent throughout and is significantly more mineralized than dentin. These facts, coupled with the fact that dentin contains significant amounts of water and collagen within its matrix, present a significant challenge for consistent and reliable long-term dentin bonding. The dental literature is replete with long-term studies that demonstrate a worrisome trend toward gradual degradation on the dentin/adhesive interface. Microleakage, nanoleakage, hydrolysis, dentin permeability, pulpal pressure,

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polymerization shrinkage stress, "water tree" formation, insufficient hybrid layer formation, phase separation, dentin tubule orientation, occlusion, enzymes released by bacteria, and operator error have all been implicated as potential causes of deterioration of the dentin/adhesive interface over time. Another issue—and paradox—is the chemistry that makes adhesive systems so effective initially also contributes to their eventual breakdown. One reason for the success of current adhesive systems is the use of hydrophilic monomers that enable them to interact with dentin, which is an inherently moist substrate. The problem is that these same hydrophilic groups that facilitate initial primer/resin interaction with the tooth substrate can become a liability in the long term by encouraging water sorption and hydrolysis of the adhesive interface. The "ideal" dentin bonding agent would be hydrophilic when first placed but would then somehow become completely hydrophobic once polymerized. Unfortunately, no such chemistry exists. One could argue that the next best thing would be gradation from hydrophilic to hydrophobic as one moves from the tooth surface to the restorative interface. Indeed, this is the strategy employed by the original three-step total-etch (4th generation systems) and two-step self-etching systems (6th generation systems)—that is, the initial placement of a hydrophilic primer, which is then overlaid by a relatively hydrophobic bonding resin. In any case, many researchers and some manufacturers are looking for the best compromise regarding this hydrophilic vs hydrophobic dilemma. At least one manufacturer has recently introduced a new adhesive system that is essentially a modification of the company's well-known and successful three-step total-etch system, redesigned to minimize water sorption over time.

The take-home message is that while many adhesive systems are quite effective, they are not perfect. They are not a panacea. It is important to understand the limitations of these systems as well as how to optimize their performance. It is important to understand when a total-etch system might be indicated and when a self-etching system is a good choice. Most clinicians are already aware that adhesive systems today can generally be placed into one of four categories: three-step total-etch systems (4th generation), two-step total-etch systems (5th generation), two-step self-etching systems (6th generation), and one-step or "all in one" self-etching systems (7th generation). Each system, no matter which category, contains an acidic conditioner/component, a dentin primer, and a bonding resin. Acidic treatment of tooth tissues creates a zone of demineralization that is subsequently (total etch) or concurrently (self etch) infiltrated with various bifunctional primers and resins. As most dentists also know, the trend in recent years has been toward the simplification of adhesive systems. While this seems to make sense, clinicians should be aware that in vivo and in vitro research often demonstrates reduced efficacy with simplified systems. This seems to be particularly true of one-bottle/one-step systems (7th generation). The use of lasers to prepare hard tooth tissues has also become more popular. Once again, dentists using this preparation modality should be aware that studies show that bonding to laser-prepared tooth surfaces may be more problematic than bonding to conventionally bur-prepared preparations.

Dentists can use some very basic techniques to maximize adhesive system performance. For example, adhesive systems generally employ acetone, ethanol, water, or a combination of these as solvents for their particular monomers. It is important to evaporate these solvents by air drying for an adequate period prior to polymerization (warm-air drying is particularly effective). Inadequate solvent evaporation results in incomplete resin polymerization that could contribute to leakage and breakdown of the adhesive interface. The number of adhesive coats also can profoundly affect material performance. Laboratory studies show many systems' performances improve when the number of adhesive coats exceeds manufacturers' recommendations. In the case of direct composites, the use of resin-modified glass ionomer (RMGI) liners has been shown in many studies to be more effective in reducing microleakage than using adhesive systems only (the adhesive is placed after the RMGI has been placed). A common technique with a popular two-step self-etching system is to first ring the enamel with phosphoric acid to ensure adequate bonding to enamel. In the case of bonding in porcelain veneers, when the bonding substrate is predominantly enamel, one could make a very compelling argument that a total-etch system might be a better choice than a self-etching system because many self-etching systems do not bond as predictably to enamel.

Proper management of the adhesive interface is crucial for the predictable placement of many current dental restorative materials. This requires an understanding of the materials being utilized, the substrate being bonded to, and a correct and precise clinical protocol. 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.