5 Pillars for Successful Dental Bonding—*The Clinical Hypothesis*

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Introduction

Successful dental bonding depends on 5 key elements: in-vivo efficacy without post-operative pain, marginal integrity, bond compatibility, long-term durability, and consistency of strength and adhesion. Any claim to these 5 elements should be supported by relevant data and independent research.

Dental bonding is a critical step for the success of both direct and indirect restorations. A dental bonding agent is a functional component for any dental restoration—providing adhesion, sealing and maintaining structural integrity for lasting restorations. However, not all bonding agents are equal due to the different chemistries and the application techniques used. In the case of bond failures, the bonding agent may not be the sole culprit, but rather the failure of the clinician to understand the fundamentals of bonding or the specific techniques for a particular dental bonding system.[1]

Not all "advances" have resulted in improved clinical performance. Fewer steps, fewer bottles of agents, or increased speed may not always equate to increased long-term bond strengths.[2] As a result, there has been—and continues to be—a lack of general, objective guidance regarding the use of bonding agents. It is amazing, when speaking before dental groups, to hear of the many different methods employed by dentists to select and use bonding agents. Many use protocols that stray wildly from the actual recommended or ideal methods for using a particular bonding agent. They often "pick and choose" protocols from different systems, which may not be applicable to their particular system.

A 5-step litmus test can be used to help clarify the many gray areas of dental bonding. This 5-step litmus test—or 5 Pillars of Bonding—was developed by:

1. Evaluating the results of a series of extensive interviews and discussions with clinicians from around the world performed by a leading dental manufacturer[3]
2. Researching published articles and papers as to strengths and weaknesses of different bonding agents
3. Reviewing many products currently available from leading dental adhesion manufacturers

This 5 Pillars concept has been designed to serve as a report card style checklist that clinicians can use to evaluate any bonding agent to make sure it makes the grade. Whether a clinician switches bonding agents regularly or if he or she has been using the same bonding agent for years, use of this evaluative methodology can help a clinician determine the clinical effectiveness of his or her current bonding agent or of another bonding agent being considered. Today's advanced technologies, procedures, and new materials demand the best bonding systems.

In-Vivo Efficacy Without Post-Operative Pain

Pain has often been associated with visiting the dentist, but pain in itself is a broad classification of adverse events that can be experienced before, during, or after the office visit. Sensitivity is probably the most frequently reported adverse event (related to pain).

Post-operative sensitivity can be caused by many factors, including pulpal overheating, bacterial invasion, microleakage, polymerization shrink-

age stress, and improper occlusion.[4-8] However, the most widely accepted cause of post-operative sensitivity has been attributed to the Hydrodynamic Theory.[9] This postulates that fluid flow within dentinal tubules can cause a painful stimulus. Dentinal tubules are opened or exposed when using the total-etch technique and applying the acid primer to the prepared dentin surface. If these tubules are over-exposed to acid, improperly rinsed, underdried, or over-dried, the bonding resins will not properly re-seal the dentinal tubules.[10] The aspect of totally resealing opened dentinal tubules is critical to reducing post-operative pain.

Post-operative sensitivity can take the form of a mild stinging to one that is so painful normal oral functions (such as drinking and eating) become unbearable. The total-etch procedure is associated with a higher incidence of patient-reported post-operative sensitivity.[11] This technique is fraught with many procedural sensitivities that if not rigidly followed can result in problems.

The self-etch bonding agents were developed to reduce post-operative sensitivity caused by incomplete sealing of the opened dentinal tubules. Since the primer molecule contains an acidic end and a resin end, the dentinal tubules are never left open. As the dentinal tubules are demineralized by the acidic primer they are simultaneously infiltrated by the resin.[12] Dentists report decreased post-operative sensitivity when using the self-etch technique.[13] Researchers have reported less technique sensitivity since the moisture level of the dentinal surface is less critical to obtaining adequate bond strengths to dentin.[14] Variations in operator technique do not have as detrimental an effect on clinical success with the self-etch technique as they do with the total-etch technique.[15]

Though self-etch bonding agents lowered the patient-reported incidence of post-operative sensitivity they also lowered the bond strengths to enamel.[16] The primer molecule used with self-etching systems is not as acidic (pH is not as low) as the phosphoric acid used in total-etch systems. They do not create the same enamel etching pattern. This is especially evident on margins of unprepared enamel. Patients returning to the office months later displayed a brown stain outlining the margins.

Manufacturers have made attempts to reduce sensitivity in several ways: decreasing the pH, using separate acidic primer molecules for dentin and enamel, and using different solvents. However, due to the poor etching ability of most self-etch products, some clinicians reverted back to the use of phosphoric acid, which may re-introduce the onset of post-operative sensitivity.

Preventing post-operative sensitivity should be the first-line strategy for minimizing pain and enhancing patient care.

Some have begun to advocate a "selective-etch" technique[17] where only the enamel is etched with phosphoric acid, washed, and dried. The self-etch bonding agent is then placed on the untreated dentin and the treated enamel. The challenge is to control the placement of the etchant so that it only touches enamel. Acid placed on the dentin will result in decreased bond strengths when used with traditional self-etch bonding agents and can reintroduce post-operative sensitivity.

Recently, "universal" bonding agents have been developed that do not show the detrimental effects of having the dentin exposed to phosphoric acid and subsequently covered with these bonding agents. The manufacturers of these universal bonding agents suggest that dentists can choose to use their bonding agents in whatever mode they choose—self-etch, total-etch, or selective-etch. However, there is always a diminution of enamel bond strengths when the enamel is not pre-etched and the potential for an increase in post-operative sensitivity when the dentin is etched.

Preventing post-operative sensitivity should be the first-line strategy for minimizing pain and enhancing patient care. A sensitive restoration, no matter how esthetic or durable, is not considered successful or desirable by a patient. Bonding agent in-vivo clinical data should not only evaluate clinical effectiveness of the material, but also measure and report the onset of post-operative sensitivity.

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Marginal Integrity

The seal between the interface of a prepared tooth and restorative material is paramount for long-term clinical success. The bonding agent must first achieve adequate strength to withstand the forces of shrinkage stress that occur when the resin is polymerized. Most conventional composites shrink in the range of 1% to 4% by volume upon polymerization. If there is inadequate bond strength, a gap will occur that allows leakage. Since composite materials do not contain inherent anticarious properties that prevent recurrent decay, the marginal seal is critical.

The mouth is a hostile environment. The dental restoration should have the strength and stability to resist the chewing forces constantly exerted on the teeth. Due to these extraordinary forces, the dental bonding agent may be the first part of the restoration to weaken and ultimately cause failures. Thus, as the foundation of the restoration, the bonding agent must possess high enough marginal integrity to resist these exceptional forces, while effectively keeping the restoration anchored. Additionally, high marginal integrity maintains a stable and sealed margin to prevent the influx of bacteria and the potential for secondary caries. This holds true for both direct and indirect restorations.

Therefore, marginal integrity—both in-vitro and in-vivo evaluations—is one of the key functional parameters for a bonding agent to measure its ability to withstand the physical forces of the oral environment.

Bond Compatibility

Dental bonding agents must have the ability to bond to a number of different substrates. Effective bonding to enamel is critical to seal the restorative interface where the heavy forces of occlusion often occur. Dentin bonding is important to seal and protect the pulp in deep restorations and to adhere well with root surface restorations. Bonding to uncured as well as cured composite is critical. It is important to be able to bond effectively to porcelain with today's esthetic indirect restorations that rely heavily on adhesion rather than retention. Finally, they must bond effectively to all the different metals that are used in dentistry.

Bonding agents are called upon to work with direct and indirect placement techniques, with areas that can be reached with a curing light and areas that cannot be reached, and with materials that have different modes of setting. This is quite a variable list of materials and circumstances in which they must bond.

With newer dental bonding agents being introduced, the question often arises whether these agents can be used with light-cure, self-cure, and dual-cure resin materials. It is often difficult to know until a failure occurs, such as a de-bond. Most currently available single-bottle total-etch and self-etch bonding agents do not adequately bond to self-cured or dual-cured composite resins.[18] They require the use of an additional activator, which have shown inconsistent and diminished results among different manufacturers.[19]

These types of self-cure and dual-cure systems are often used in situations where the success of the restoration is highly dependent upon the bond strength; for example, restorations under crowns (crown or core buildups), post and cores, and indirect tooth-colored inlays and onlays. To obtain reliable bonding results, dentists may have to purchase multiple bonding systems that use different adhesion protocols. Staff may often be confused as to the different procedures and may make critical errors.

Bonding agents have a finite shelf life, which may result in outdated materials being thrown away or unavailable when needed. The net effect is a fragmented approach to perform dental bonding for the many procedures—causing confusion and procedural errors by the staff, which may lead to sub-optimal clinical results.

Evidence should be derived from studies investigating bonding agent compatibility with all resin curing modes (light-cure, self-cure, and dual-cure), and the effectiveness on multiple substrates.

Long-term Durability

Long-term durability can be compromised by physical and chemical stresses. Biting forces stress

the durability of bonding agents. Temperature fluctuations expand and contract the restorative materials at a different rate than tooth structure, creating stress on the bonding interface. In addition, unusual habits or biting patterns can create premature de-bonding.

Sometimes it's the things you can't see that make the difference between clinical success or failure. The ability of the bonding agent to resist the harsh environment of the mouth—commonly referred to as durability—is critical. The oral recipe of a damp environment filled with aggressive microorganisms, coupled with the enzymatic properties of oral fluids, can lessen the durability and overall function of the bonding agent. This occurs at the microscopic level and cannot be seen.

Hydrolytic degradation can be especially problematic in self-etching, one-bottle systems.[20] Water permeating through the dentin hybrid zone dramatically weakens the bond. Matrix metalloproteinase (MMPs) have been shown to significantly reduce dentin bond strengths by attacking the collagen.[21]

Long-term bond durability studies that replicate the oral environment are a must to reassure that the bonding agent can chemically withstand the oral environment.

Consistency of Strength and Adhesion Performance

Bond strength is an important parameter to evaluate when choosing a bonding agent; however, as presented by most manufacturers, it is a one-dimensional measure that is an entry to compete. However, there is no clear evidence of how the bonding agent will perform in the hands of other dentists outside the manufacturers' labs who have mastered the ability to optimize their product's results. Therefore, the reporting of bond strength becomes more robust and better tied to predicted clinical performance when it is performed by multiple third party investigators showing reproducible and consistent values.

One of the most important parameters to master with total-etch bonding agents is the proper moistness of the dentin since it has a significant effect on the bond strengths. The use of different bonding agent solvents also may have an effect on bond strengths. Acetone-based bonding agents have the potential to provide high dentin bond strength values but have the widest range of results due to their dependency on having the proper moisture on the dentin surface.[22] Alcohol-based bonding agents provide more consistent bond values without the extremes, but the solvent may be more difficult to evaporate before curing.[23]

Ultimately, the bond between the restoration and the tooth is the foundation for success, supported by the 5 Pillars.

In a large dental practice with multiple staff members, it is important to use materials and techniques that are not technique sensitive. It does not matter if a particular bonding agent can produce outstanding results some of the time, it needs to give good results all of the time. The best evaluation of bond strengths is evidence derived from multiple in-vivo clinical trials.

Summary

We have discussed the 5 Pillars of bonding, which can be used to evaluate a bonding system. There are significant differences between bonding systems. It is important to select the systems that consistently produce durable, strong, sealed restorations that are not sensitive. Ideally, there should be little variation in technique for direct, indirect, self-cure, dual-cure, and light-cure applications. The techniques to master excellent results should be straight forward and easily understood by all. Ultimately, the bond between the restoration and the tooth is the foundation for success, supported by the 5 Pillars.

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