

Bonding and Bonding Agents

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Dental Unit Waterline Treatment and Bond Strengths (11/04)

Question: What effect does dental unit waterline (DUWL) treatment have on the bond strength of composite resin to tooth structure?

Answer: When using continuously delivered waterline treatment products, the tooth is exposed to chemical agents during preparation and restoration, including adhesive bonding procedures. The impact of the interaction of the continuously delivered dental waterline product and the adhesive procedure should be of concern to the restorative dentist. Several studies have addressed this potential interaction with somewhat equivocal results.¹⁻⁵ A study was conducted by DIS using seven dental unit waterline treatment products, with different chemical compositions, to determine the effects, if any, on microtensile bond strength (μ TBS) to dentin. A synopsis of this study is given below.

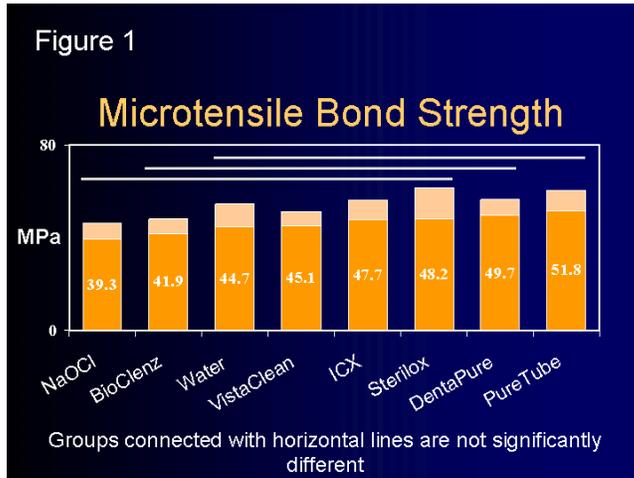


Effect of Dental Unit Waterline Treatment on Microtensile Bond Strengths of Composite Resin to Dentin

Materials and Methods: Sixteen recently extracted third molars (eight groups of two teeth each) were sectioned and rinsed using water from a dental unit (Mini-Troll 4225, A-dec) treated with one of seven different treatment solutions (sodium hypochlorite [4ppm], Clorox; BioClenz, Frontier Pharmaceutical; DentaPure DP40, MRLB International; ICX, A-dec; PureTube BR90, Sterisil; VistaClean, Pelton&Crane; Sterilox, Ultradent) or distilled water (control). Composite resin (Z100, 3M ESPE) was bonded incrementally to the dentinal surface using a two-step total-etch bonding agent (Single Bond, 3M ESPE). Specimens were sectioned in X and Y directions to obtain bonded beams with a cross-sectional area of $0.62 \pm 0.02 \text{ mm}^2$. Fifteen beams per group ($n=15$) were tested in tension in a universal testing machine (Alliance RT/5, MTS) at a crosshead-speed of 1 mm/min. Data were analyzed with 1-way ANOVA/Tukey; $\alpha=0.05$. After microtensile bond strength testing, the specimens were examined with a stereomicroscope at $\times 8$ magnification to determine the failure mode.

Results: Significant differences were found in mean μ TBS among waterline treatments ($p=0.003$). See

Figure 1 below. No significant difference was found between any treatment group and untreated water (control) ($p > 0.05$).



Discussion: Several studies have evaluated the effect of DUWL treatment products on the shear bond strength of resin composite to tooth structure.¹⁻⁵ von Fraunhofer and others¹ found no significant decrease in bond strength when rinsing specimens with ICX solution after dentin conditioning. ICX contains sodium percarbonate, cationic surfactants and silver nitrate. The authors speculate that the surfactants combined with the oxidizing action of the percarbonate could promote adhesive penetration. Similar results were found with this study, which found no significant difference in microtensile bond strength between ICX and water (control). A study by Roberts and others² found a significant loss in shear bond strength with the use of Listerine (Warner Lambert) and Bio 2000 (Micrylium) compared to distilled water. Both Listerine and Bio 2000 contain essential oils, which may have contributed to the adverse effects. The manufacturer of Bio 2000 recommends rinsing the etched surfaces with untreated water when using their product. One study found no reduction in enamel bond strength when this procedure was followed.³

Similar to our study, Roberts and others found that the use of sodium hypochlorite (3 ppm) did not cause a statistically significant loss in dentin bond strength.² Sodium hypochlorite in much higher concentrations has been found to completely remove collagen fibers in dentin and decrease shear bond strength.⁶ Taylor-Hardy and others found a significant loss in enamel bond strengths with the use of a 5-ppm solution of sodium hypochlorite.³ The authors could not explain the exact reasons for the deleterious effects when bonding to enamel.

Most studies evaluating the effect of waterline treatment on bond strengths used treated water only for rinsing the etched surfaces.^{1,2,5} This study, and a study by Taylor-Hardy, also used treated water to prepare the teeth, in order to better simulate clinical conditions.³

Many of the waterline treatment products evaluated in this study are relatively new to the market, with minimal information available in the literature. One recent abstract published in the *Journal of Dental Research* evaluated the effect of VistaClean, which contains a botanical extract from citrus, on the shear bond strength of composite resin to dentin. No significant difference was found between the groups using treated or untreated water.⁴

A two-step, total-etch bonding agent was used in this study. Other types of adhesives (e.g., self-etching) may give different results.

Conclusion: Based on the limitations of this study, no significant differences in microtensile bond strength were found between the teeth restored with untreated water or water containing a dental unit waterline treatment product.

Overall, the effect of dental waterline treatment on the bond strength of composite resin to tooth structure appears to be product specific, with only a few waterline treatment regimens causing a loss in bond strength while the majority apparently have no significant effect.¹⁻⁵ New waterline treatment products continue to be introduced, therefore future research will be necessary to study the effects of these new agents on adhesive dentistry.

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Bleaching and Bonding (11/04)

Question: My patient just completed a regimen of home bleaching. When may I bond composite resin to close a diastema?

Answer: Bleaching products can affect the bond strength of composite resin to tooth structure.¹ Most of the studies evaluating the effect of 10 - 20% carbamide peroxide, a popular bleaching agent for use at home, found a reduction of bond strength of composite resin to enamel compared with unbleached teeth.²⁻⁶ Other studies evaluating the effect of chair-side bleaching agents, such as 35% hydrogen peroxide, showed similar reductions in bond strengths.⁷⁻⁹ Studies investigating the bond strength of composite resin to dentin after bleaching found reductions as well.¹⁰⁻¹² Bond strengths typically return to normal 1 day to 3 weeks after bleaching, depending on the study and the type of bleaching agent.^{2,3,10,13,14}



Several factors may be responsible for the temporary reduction in composite bond strength to bleached tooth structure. Bleaching may cause a reduction in calcium and phosphate content in enamel that may alter, morphologically, the superficial crystalline structure.¹⁵ Also, the oxidizing effect of hydrogen peroxide may alter the enamel and dentin organic matrix.¹⁶ Finally, the hydrogen peroxide may leave residual oxygen that may interfere with the resin infiltration into enamel and dentin or inhibit polymerization of the resin.^{2,17}

So it is recommended to wait a couple weeks after completion of bleaching treatment before bonding.^{1,14} Also, delaying treatment should allow the teeth to stabilize in color and make the long-term shade match more predictable.

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Limitations of Simplified Adhesive Bonding Systems (5/04)

Question: Can you explain the potential incompatibilities between simplified adhesive bonding agents and chemically- or dual-cured composite resins?

Answer: The majority of the adhesive bonding agents available today may be categorized into “etch&rinse” (i.e., total etch) or “self-etch” systems. The “etch&rinse” adhesives have been simplified from three-steps to two-steps by combining the primer and adhesive components (e.g., Prime and Bond NT, Optibond Solo). The newer “self-etch” adhesives have been simplified from two-steps to one step by combining the etchant, primer, and adhesive components (e.g., Prompt L-Pop, iBond). Adverse acid-base reactions and adhesive permeability may contribute to the incompatibility between these simplified adhesives and chemically- or dual-cured composite resins.¹⁻³



Chemically- or dual-cured composite resins are used as core-buildups and bonding indirect restorations and endodontic posts. With the more traditional three-step “etch&rinse” and two-step “self-etch” adhesives, a layer of neutral adhesive resin is always placed as a final increment prior to placement of a composite resin. The new simplified adhesives, by virtue of their combination, contain acidic monomers in the final step prior to composite resin placement. Consequently, uncured acidic monomers from the oxygen-inhibited layer of the cured adhesive are in direct contact with the resin composite. These acidic monomers can adversely react with the basic catalyst components of the chemically- or dual-cured composites. They may also create a hypertonic environment that allows water to osmotically move from the dentinal surface through the permeable adhesive and create superficial water blisters that may disrupt

the bonding between the adhesive and the overlying composite resin. Different types of co-initiators have been introduced in an attempt overcome the catalytic incompatibility. With two-step "etch&rinse" adhesives, a separate bottle of activator solution may be used. Some one-step "self-etch" adhesives directly incorporate different catalysts as part of the adhesive component. However, the increased water permeability of both types of simplified adhesives may still result in a reduction of bond strengths.¹⁻³

For best results, use the adhesive bonding agent recommended by the manufacturer of the composite resin material. Three-step "etch&rinse" adhesive bonding agents work well with chemically- or dual-cured composites.⁴ Carefully follow the manufacturer's instructions if attempting to use two-step "etch&rinse" adhesives. One-step "self-etch" adhesives are typically contraindicated for use with chemically- or dual-curing composite resins.

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The Various Categories of Adhesives (1/04)

Question: What is the difference between the various types of adhesives?

Answer: Adhesives or bonding agents have changed dramatically in the last couple of years. Manufacturers have developed new adhesives that are easier and faster to place. However, simplification does not guarantee equal or improved effectiveness. Current adhesives may be divided into three major categories based on the number of clinical steps and their interaction with the tooth surface. The three categories are "etch&rinse", "self-etch", and "glass-ionomer".¹

Adhesive Categories
Etch&rinse - Three-step - conditioner, primer, adhesive - Two-step - conditioner, (primer & adhesive)
Self-etch - Two-step - (conditioner & primer), adhesive - One-step - (conditioner & primer & adhesive)

"Etch&rinse" adhesives (also known as "total etch") have been around since the early 1990's with the introduction of products such as Scotchbond Multi-Purpose (3M/ESPE, St. Paul, MN) and Optibond FL (Kerr, Orange, CA). These adhesives require three steps that use an acidic conditioner, primer and bonding resin. In order to reduce the placement time and complexity of these multi-step adhesives, manufacturers combined the primer and resin components to create a two-step system. Examples of two-step adhesives are Optibond Solo (Kerr, Orange, CA) and Excite (Ivoclar Vivadent, Amherst, NY). Advantages of the "etch&rinse" adhesives are a good predictable enamel etch and the availability of favorable long-term clinical studies.^{1,2} However, the "etch&rinse" systems are sensitive to the level of dentin wetness after rinsing off the acidic conditioner. Too little or too much remaining water may lead to reduced adhesion.³

"Self-etch" adhesives have only recently been introduced and are divided into one- and two-step systems. Two-step self-etching adhesives combine the acidic conditioner with the primer in the initial step and use

a bonding resin in the second step. Examples are Clearfil SE (Kuraray, New York, NY) or AdheSE (Ivoclar Vivadent, Amherst, NY). Even further reduction in the number of steps came with the introduction of one-step self-etching adhesives such as Prompt L-Pop (3M/ESPE, St. Paul, MN) and Xeno III (Dentsply Caulk, Milford DE). A major advantage to these self-etching systems is the simultaneous infiltration of the adhesive to the depth of demineralization, which may potentially reduce post-operative sensitivity. Also, unlike the "etch&rinse" adhesives, the dentin need not be rinsed off. The clinician does not need to be concerned about the level of dentin wetness. However, in general, laboratory tests have shown a reduction in bond strengths and only limited clinical data is available.¹ Also, many of the newer self-etching adhesives have limited clinical applications and are primarily indicated for direct bonding of composite resins. A recent development in bonding has been the use of self-etching primers with the two-step "etch&rinse" adhesives instead of phosphoric acid. Manufacturers don't want to be left behind now that self-etching primers have become popular, so they have incorporated these into their product lines. Two examples are One-Step Plus with Tyrian SPE (Bisco, Schaumburg, IL) and OptiBond Solo Plus with Self-Etch Primer (Kerr, Orange, CA).

Resin-modified glass-ionomer (RMGI) adhesive agents are very limited in number, but are mentioned here for completeness. RMGI adhesives, such as Fujibond LC (GC America, Alsip, IL), consist of a mild conditioner and a glass-ionomer adhesive that is mixed and applied in two steps. Potential advantages include chemical as well as mechanical bonding and fluoride release. However, like the self-etching adhesives, very little clinical data is available.

Adhesive Generations
Fourth generation - three-step "etch&rinse"
Fifth generation - two-step "etch&rinse"
Sixth generation - two-step "self-etch" - one-step "self-etch"

Another way to categorize adhesives is chronologically by generation. The manufacturers will commonly identify their new products by generation. The initial generations were unsuccessful primarily due to attempts to bond to the loosely bound smear layer. By the fourth generation, the combination of hydrophilic monomers and stronger conditioners produced significant improvements in bond strengths and clinical retention. The three-step "etch&rinse" adhesives are considered fourth-generation adhesives. The fifth-generation consists of the two-step "etch&rinse" adhesives. The new "self-etch" products are considered the sixth generation.

In summary, there has been a trend toward simplified application with a reduced number of steps. However, faster is not always better. DIS recommends the continued use of "etch&rinse" adhesives, such as Scotchbond Multi-Purpose, Optibond Solo, and Excite, due to favorable long-term clinical and laboratory data. The "self-etch" adhesives have potential because of the possible reduction in post-operative sensitivity. However, laboratory studies have shown a definite overall downward trend in bond strengths, especially with the one-step version.¹ The correlation between laboratory bond-strength studies and clinical success is unknown. However, Prompt L-Pop, a one-step adhesive, has been reported in a recent clinical study as having low retention of composite restorations in non-carious cervical lesions.⁴ DIS recommends caution with any new adhesive agent until longer-term clinical studies are available. Of the self-etching agents available so far, DIS currently recommends the two-step adhesive, Clearfil SE, which has shown very favorable laboratory and short-term clinical results.^{1,5}

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Acid-Etching after Air Abrasion (11/03)

Question: Do we need to acid-etch before placing an adhesive bonding agent after preparation with an air-abrasion unit?

Answer: After an initial introduction back in the 1940's, significant improvements in technology and recent interest in conservative bonding techniques has created a re-emergence of air abrasion in the last several years.¹ A high-velocity stream of aluminum-oxide particles prepares enamel and dentin and at the same time reduces the heat, vibration and noise commonly experienced with rotary instrumentation.² The question exists whether air abrasion produces a micro-retentive surface that is sufficiently receptive to bonding so that acid etching is no longer needed. The preponderance of laboratory studies suggest that it remains beneficial to separately acid-etch air-abraded enamel and dentin when applying an etch-and-rinse adhesive. All but one study found similar or better bond strengths when applying etchant.²⁻¹² A recent study by Van Meerbeek and others¹² found that separate acid-etching significantly increased the microtensile bond strength of Optibond FL (Kerr, Orange, CA) and Z100 (3M ESPE, St. Paul, MN) when bonding to air-abraded enamel or dentin.



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"One-Bottle" Dentin Bonding Agents (Originally published in Jan 1996)

Question: I saw an ad the other day for a new dentin bonding agent that was supposed to be very easy to use because it came in only one bottle. I don't remember the name but I'm interested in knowing if DIS has looked at this product.

Answer: Recently, several products have been introduced to the market that are touted as being "one-step" or "one-bottle" dentin bonding agents. They have drawn a lot of attention because some people claim that they represent the "fifth generation" of dentin bonding agents. The DIS Materials Evaluation Section has evaluated one of them, Prime & Bond (LD Caulk) in DIS 46-13, and is in the process of evaluating another, One-Step (Bisco). The manufacturers of these products claim that they are much easier to use than previous multi-bottle products because they are packaged in one bottle. In addition, they claim that the products take less time to apply. It would seem that having a bonding agent that is supplied in one bottle should simplify the clinical application process, especially when compared with earlier products that came in as many as three separate bottles. Unfortunately, these products are not truly "one-bottle" products because most clinical applications in which they are used still require that an acid etchant be applied to the tooth surface. As a result, the "one-bottle" products actually involve the application of two separate components. Having said that, they do allow you to prime the tooth surface and apply the unfilled resin in one step and, as a result, they do simplify the overall bonding process. You should not, however, assume that this necessarily means that they are quicker to apply than other bonding agents. Although, during DIS tests, One-Step did take less time to apply than many multi-bottle bonding agents, Prime & Bond was no faster. Prime & Bond takes longer to apply because multiple applications are required and these steps take time. One-Step also requires multiple applications, but the steps involved are not as time consuming as those with Prime & Bond. Another disadvantage of Prime & Bond and One-Step is that they are either limited in their range of uses or are not all-inclusive products. For example, Prime & Bond is strictly intended to be used as a bonding agent with directly-placed composite resin. For other procedures, such as porcelain repair, amalgam bonding, and amalgam-to-amalgam repairs, you will need to use a different product. One-Step, while recommended for more than ten different clinical bonding procedures, is not supplied with many of the components necessary to perform the procedures described in its instructions (e.g., hydrofluoric acid, opaquers, silane solution). Purchasing these additional components adds significantly to the cost of the bonding agent.

In laboratory bond strength testing of Prime & Bond, DIS found that it bonded very strongly to dentin. In fact, its values were similar to those of multi-bottle products. DIS has not completed bond strength testing of One-Step, but data reported by the manufacturer indicate high values.

As with most dental products, it is probably best to avoid generalizing about them when trying to decide which brand to purchase. While some of these products do simplify clinical bonding procedures, others do not. It is safe to say that they represent a step forward in adhesive dentistry but are not a panacea. Before you make a decision about purchasing a specific bonding product, it is important to carefully review the uses for which the bonding agent is intended, its cost, and the contents of the kit. For more information on Prime & Bond and One-Step, please call DIS or the products' manufacturers (LD Caulk (800) 532-2855 and Bisco (800) 247-3368).

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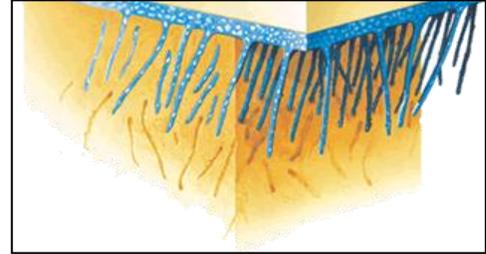
Using Dentin Bonding Primers on Enamel (Originally published in Sept 2000)

Question: Using dentin bonding agents is really confusing. I'm never sure if I should apply the primer to the enamel after etching or not. Instructions differ from product to product as to whether or not this is a good idea. Is there a general rule that I can use for all products?

Answer: Research has shown pretty conclusively that primers from most current-generation bonding products should be applied to etched, moist dentin. This helps the primer act as a link between the moist tooth surface and the bonding resin. The question is, does the primer do the same thing for enamel that it

does for dentin. Specifically, does it improve the bond strength between the adhesive resin and the enamel as it does between resin and dentin? And if so, should the primer be applied to etched enamel that has been dried or left moist? This is a question with very practical applications because commonly in bonding situations, the enamel and dentin surfaces are juxtaposed. This makes it almost impossible to keep from applying the primer to enamel, even if you don't intend to.

Unfortunately, research has been somewhat equivocal on this question. Some studies show that applying the primer to etched enamel reduces bond strength.^{1,2} Other studies indicate that the effect on bond strength is product specific: for some bonding agents, primer application to etched enamel increases bond strength while for others, it decreases bond strength.³⁻⁵ It is important to note that in all these studies, the primer was applied to etched, dried enamel. Is there a difference when the primer is applied to moist enamel?



Recently, a study was published that evaluated the effect of three dentin bonding primers on the bond strength of resin composite to moist and to dry etched enamel.⁶ In the study the multi-component products, Scotchbond Multi-Purpose (3M) and OptiBond FL (Kerr), were evaluated as well as the one-component product, Single Bond (3M). After measuring the bond strength to various combinations of groups, the results were that for the multi-component products, the bond strength was unaffected when primer was applied to etched, dried enamel. The bond strength was significantly increased when primer was applied to etched, moist enamel. For the one-component product Single Bond, moisture on etched enamel did not affect bond strength. The authors concluded that primer application to etched, dried enamel does not affect the bond strength, however the use of primer on etched, moist dentin is critically important to enhance bond strength.

, on the basis of this recent research, it appears that primers should be used on enamel as well as dentin in all preparations for resin restorations. Temper this advice, however, with the recommendation that all products should be used as their manufacturers direct. When there is a question about any aspect of a product's application, always follow the instructions that are provided.

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Latest Developments in Adhesive Dentistry (Originally published in Jan 2001)

Question: At a meeting I attended last week, one speaker spent a lot of time talking about self-etching dentin bonding agents. I thought those were old hat. Is there something new about them I'm missing?

Answer: One of the latest developments in adhesive dentistry has been the introduction of self-etching bonding agents. Instead of the traditional three-step products that separately etch the dentin, prime it, and bond to it, the self-etching



primer products are provided as two-part or two-step systems. They consist of a self-etching primer (also known as an acidified primer) and a separate adhesive resin. The acidified primer does the job of both the etchant and primer of the three-part products. No separate acid-etching step for the dentin is required. (It is important to note that some of these products require separate acid etching of uncut enamel.) Usually, the products are simpler and faster to apply than three-part systems because they require fewer steps. The acidified primers, for example, are applied to the smear layer-covered dentin (and cut enamel), allowed to remain for a short period of time, and are not rinsed off.

There is some discussion in the dental materials community about the wisdom of allowing the treated smear layer to remain after etching, but the products seem to perform well and achieve strong bonds to dentin. One advantage that manufacturers of some of these self-etching primer products claim is that they dramatically reduce post-treatment sensitivity because they etch and prime simultaneously. As they do, the entire depth of demineralized dentin is infiltrated with resin and well sealed. Examples of self-etching primer products include Clearfil Liner Bond 2V (Kuraray) and Clearfil SE Bond (Kuraray) (top right). Other more recently introduced products that feature a self-etching primer are 3M ESPE's Prompt L-Pop, J. Morita's One-Up Bond F, and Parkell's Touch & Bond. These three are actually even simpler to apply than other self-etching primer products because they are one-step or one-component products. Their manufacturers claim they etch, prime, and bond all in one step. Although one-step products would be a significant advance in adhesive dentistry, DIS recently evaluated Prompt L-Pop and found it had several important shortcomings (see DIS 61-20). For the evaluation of One-Up Bond F, see DIS 62-14). As new innovations are made in adhesive dentistry, DIS will keep you informed.

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Technique Sensitivity and Dentin Bonding Products (Originally published in Jan 2001)

Question: Most of the lecturers I've heard talk about bonding products say you should follow the manufacturers' directions. Is there any real proof that making minor mistakes like over etching the tooth or overdrying the bonding agent has a negative effect on their performance?

Answer: You are quite right about the fact that most informed lecturers make a point of underscoring how important it is to follow the manufacturer's instructions when placing a particular bonding product. Sometimes, although the recommendation to follow the manufacturer's instructions sounds reasonable enough, it can be a different matter to do so in a clinical situation. First of all, manufacturers have traditionally not been very helpful in the design of their instructions. Until the last few years, instructions often came in multi-language booklets and were printed in small font sizes that made it very difficult to read them. Also, they were laid out in a format that make it challenging to find the particular instructions you needed for a specific clinical procedure. Fortunately, over the years manufacturers have been responsive to complaints they have received about the user-unfriendliness of their instructions. Now, although they still provide detailed instructions, most also include summary instruction cards that contain graphics to help make it easier to use them correctly. One of the first companies to do this was Bisco with the All-Bond line of products. Many companies soon followed suit, some by introducing the concept of color-coded cards keyed to particular components of their kits (e.g., OptiBond, Sybron/Kerr) and cards that were mostly graphics. These innovations have made it much easier to follow the directions. Even when the instructions are provided in a user-friendly manner, it can often be difficult to apply products as directed simply because of patient management problems. The bottom line is that it can be tough to follow directions to the letter.

Although we know it is important to read and follow the instructions, until recently it has been difficult to back up this recommendation with scientific evidence. However, an article recently published in the journal *Operative Dentistry* has shown how important it is to follow directions. In this study (Frankenberger et al, *Oper Dent* 2000;25:324-330), simulated application mistakes were made when using three popular bonding products to bond resin composite to extracted human teeth. Some of the errors included prolonged etching of tooth structure, excessive drying after etching, drying the primers immediately after placement, and excessive drying of the primers. Bond strength and marginal integrity were assessed for the bonding agents (Syntac Classic, Vivadent; Scotchbond Multi-Purpose Plus, 3M; Prime & Bond 2.1,

Dentsply/Caulk) as measures of their performance. Results indicated that application errors caused dramatic decreases in the adhesives' performance for all three products. Clearly then, it is important to apply bonding agents as directed. Specifically, they should be placed for the recommended amount of time, dried or not dried as instructed, and light activated for the correct length of time using an adequately intense light source.

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Proper Handling of Amalgambond (Originally published in Jan 2001)

Question: Yesterday, I had a very unexpected thing happen while I was treating a patient using Amalgambond. My assistant had mixed the base and catalyst and was using a cotton roll to clean up some leftover liquid. He placed the cotton roll on a patient napkin where it began to smolder and then flame. I had never heard of something like that. The flame wasn't large and it went out pretty quickly, but I'd like to know if this is specific to Amalgambond or can other bonding products cause this?



Answer: Amalgambond is the only bonding product that exhibits this behavior. It has been known for some time that the catalyst of Amalgambond (and Amalgambond Plus), tri-n-butyl borane, can cause paper to smolder if it is applied to it. On Parkell's web site (<http://www.parkell.com/>), the Material Safety Data Sheet (MSDS) for the catalyst notes that it is a relatively unstable, volatile liquid that can "(g)enerate heat when exposed in the air and may cause spontaneous combustion of cotton, gauze or other flammable materials." For that reason, Parkell provides guidance for properly handling the catalyst. If you spill some of the catalyst or have mixed base and catalyst to clean up, use a slightly damp cloth towel. Do not use a dry piece of gauze, paper, or cotton and never discard the cloth towel or towelette in a trash receptacle. Immediately after wiping up the liquid, you should run the cloth under running water, wring it out, and then let it dry in the open. Other measures for avoiding this problem include mixing the base and catalyst immediately before use, cleaning up any excess catalyst and base as soon as possible, and never leaving the catalyst syringe uncovered.

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Cross compatibility of Resin Composites and Dentin Bonding Agents (Originally published in Jan 2000)

Question: Our clinic has the 3M ESPE's Scotchbond Multi-Purpose Adhesive Plus as our primary bonding product. Do we need to use 3M ESPE's composite resin with it or can we use another company's composite if we want to?

Answer: This is a question that I frequently receive at DIS and it is an important one. Quite commonly, representatives from dental product companies will encourage you to purchase their company's bonding agent and resin composite by claiming that the result will not be as good if you don't. In other words, they say that using their bonding agent with a competitor's resin composite (or vice versa) will produce an inferior result. The research, however, does not support this claim. No clear evidence exists that using a bonding agent from one manufacturer with a resin composite from a different manufacturer has an adverse effect on parameters such as microleakage¹ or bond strength.^{2,3} Evidence does exist that appears to show a difference in bond strength between resin composites, which has led some researchers to recommend using the same manufacturer's resin composite and bonding agent.⁴ The differences, however, may well be due to differences in strength between the types of resin composites^{5,6} (e.g., hybrids versus microfills) rather than a result of compatibility differences between bonding agents and resins. Likewise, a difference in microleakage found in one study was attributed to the resin composite type rather than brand.¹

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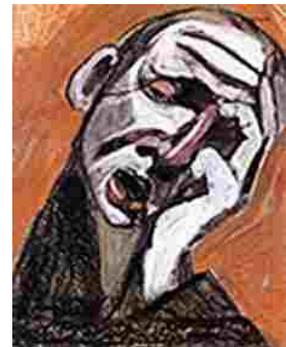
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Post-treatment Sensitivity and Self-etching Primers (Originally published in Jan 2002)

Question: I was involved in one of the recent DIS product evaluations where we used Clearfil SE Bond from the Kuraray company. We were struck by the fact that patients reported having no post-treatment pain after we placed posterior composites using that bonding agent. Is Clearfil SE Bond known for this?

Answer: DIS recently completed evaluations of Clearfil SE Bond (Kuraray) as well as Prompt L-Pop (3M ESPE), One-Up Bond F (Tokuyama/J. Morita), and Touch & Bond (Parkell) dentin bonding agents (DBAs). For all these products, users reported that many of their patients were pain-free following treatment. Even patients who commonly experienced sensitivity following the use of other bonding agents were comfortable. What these bonding products have in common is that they use self-etching primers: that is, the etchant and the primer are in one liquid. Most of these products are simple to use and very fast to apply because what was previously two separate steps (etching and priming) has now become one. Some of the self-etching primer DBAs such as Prompt L-Pop, One-Up Bond F, and Touch & Bond use one liquid for the whole bonding procedure. Others like as Clearfil SE Bond and Clearfil Liner Bond 2V (Kuraray) have two liquids (the self-etching primer and the bonding resin). Regardless of the number of liquids they use, an interesting finding has been reported for these products, which is that the incidence of post-treatment sensitivity has decreased.



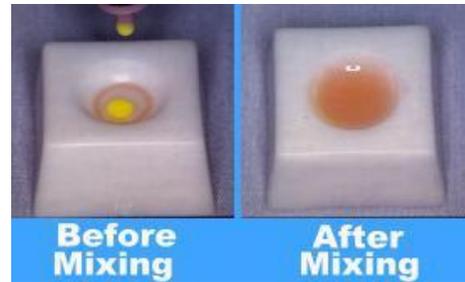
There are several theories as to why this is the case. The first is that the pH of these self-etching liquids is higher than that of the total etchants used with other bonding products. For example, the self-etching primers in Clearfil SE Bond and Clearfil Liner Bond 2V have pH values of 2.0 and 2.8, respectively. Phosphoric acid total etchants, on the other hand, often have a pH of about 1.0; some are even lower. While this doesn't sound like a big difference, it means that the self-etching primers are more mild and do not etch dentin as deeply. This, in turn, leads to the second reason some researchers believe there is less sensitivity. Since the etched, demineralized dentin is relatively shallow, it is easier for the resins in the DBA to infiltrate it and seal the tooth structure. While they don't form as thick a hybrid layer as total-etch DBAs, these products have generally exhibited good bond strengths in the DIS laboratory. The last reason why post-treatment sensitivity is reduced is because, unlike total-etch products, self-etching DBAs do not call for rinsing and drying the dentin after they have been placed. Some people believe that having remnants of the smear layer on the dentin surface helps provide an extra protective layer which may help reduce post-treatment pain. Some or all of these factors may contribute to less sensitivity. As clinicians, we can further reduce the possibility of post-treatment pain by placing the self-etching DBAs properly. This includes ensuring that the treatment area is well isolated and applying the DBAs exactly as their manufacturers recommend. Post-treatment pain is unpleasant for patients and frustrating for dentists, so these products are a welcome addition to our materials armamentarium.

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Making Dentistry More Colorful (Originally published in Jan 2002)

Question: I read the DIS evaluation of One-Up Bond F, the new bonding product distributed by J. Morita. Its color-changing property sounds like a good idea. Are there any other products that use this idea?

Answer: One-Up Bond F is the first product DIS has evaluated that uses color changes to assist clinicians in placement. To review, One-Up Bond F (DIS 62-14) is one of the new "single-application" bonding products. That means that it etches, primes, and bonds with one solution. To make the solution, however, you mix a drop from Bottle A with a drop from Bottle B. This is where the color-change chemistry comes into play. After proper mixing, the solution becomes pink which serves as an indicator to the assistant or dentist that he/she has mixed the liquids thoroughly together (see picture at right). The pink color also makes it easy to check that the product is being applied to the intended areas of the tooth. Now, a second color change comes into play. When you light activate the bonding agent, the pink liquid becomes nearly colorless: this serves as a reminder that you have properly light activated it. During our evaluation, clinical users found these color changes to be helpful.



Other manufacturers are incorporating this type of chemistry into their products. Two recently introduced products that DIS is evaluating are sealants called Clinpro (3M ESPE) and Helioseal Clear Chroma (Ivoclar Vivadent). Clinpro is pink when it is expressed out of its dispensing syringe. 3M ESPE claims this makes it easy to see exactly where it is being placed. It then turns white when light activated. Helioseal Clear Chroma uses almost a reverse concept, because it is clear after being placed and light activated, and only undergoes a color change (to green) when it is again exposed to a light curing unit. The color change is temporary and is purported to make it easier for clinicians to assess retention and completeness of coverage at future appointments.



DIS expects that other products will be marketed in the near future that use color-changing components in similar ways to assist clinicians in their proper application. Please read the evaluations of Clinpro and Helioseal Clear Chroma when they are published in a future issue of Dental Items of Significance.

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The New Prompt L-Pop (Originally published in Jan 2002)

Question: I read your review of Prompt L-Pop in DIS 61 and noted its "Marginal" rating. I saw an ad the other day for a new Prompt L-Pop. Is this a new version? If so, how does it differ from the original Prompt L-Pop?

Answer: Yes, the all-in-one bonding agent Prompt L-Pop is now available in a reformulated version. The new version is being called Prompt L-Pop 2 by some clinicians although 3M ESPE refers to it simply as Prompt L-Pop. The new version can be identified by the fact that its box bears a round, blue sticker on the front; the original version's box had a red sticker. The new sticker says "For all curing lights-Halogen, Plasma, Laser, LED."

There are four changes that have been made to the product. First, it has been reformulated with a different photoactivator, camphoroquinone. 3M ESPE claims that this allows the product to be light activated with a variety of curing lights, such as halogen, laser, light-emitting diode, and plasma arc. Second, a subtle yellow tint has been added to the adhesive. This serves



two purposes. First, since it is added only to the first blister of the blister pack, it acts as a visual check that the product has been properly activated by thorough mixing. It also makes it easier for clinicians to see where they have applied the product. The third change has been to provide application brushes with a smaller head. Unfortunately, they are only available as a separate order. The final change has been to the product's application technique. The new technique calls for applying the mixed Prompt L-Pop by rubbing it into the tooth surface with **moderate finger pressure** and then lightly drying. It is **then light cured for 10 seconds** prior to placing the restorative resin. Changes to the original technique are listed in bold. No mention was made with the original version of using moderate pressure when applying the product and light curing after application was an optional step. 3M ESPE claims that a separate light curing step makes it easier to place the resin composite or compomer and may improve Prompt L-Pop's performance.

No studies comparing the old and new versions of the product have yet been published, however early testing by an outside organization found no difference in their bond strengths to enamel or dentin. This relatively low bond strength along with the product's very limited clinical uses (for bonding direct, light-cured resin composites and compomers) resulted in the original version being rated "Marginal" by DIS (see DIS 61-20).

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Bracket Bonds that are Too Temporary (Originally published in May 2002)

Question: I am having a problem with an unusually large number of orthodontic brackets debonding when I use a self-etching, orthodontic bonding agent. I'm following the manufacturer's instructions. Do you have any ideas why this is happening?

Answer: Bonding systems have undergone a lot of changes over the past few years. The most recently introduced products are those that have primers that have been modified with various acidic components. The pH of these acidified or self-etching primers has been reduced to the extent that their manufacturers claim that they can effectively etch enamel to the same degree as phosphoric acid. Some of these bonding agents take the form of a single liquid applied to the tooth (e.g., One-Up Bond F, Tokuyama/J. Morita; Touch & Bond, Parkell; Prompt L-Pop, 3M ESPE) while others are two separate liquids (Clearfil SE Bond and Clearfil Liner Bond 2V, Kuraray). Both types, though, are said by their manufacturers **not** to require a separate etching with standard phosphoric acid. Although it is true that these products' primers do have a lower pH, some recent studies have shown that they may not have the same capacity as phosphoric acid to effectively etch UNCUT or UNPREPARED enamel.¹ Furthermore, other studies suggest that some of the new products require more than one application of the bonding agent for increased bond strength.² It has also been reported that auto-cure orthodontic resins (e.g., Concise, etc.) do not work well with the self-etch systems because the primer's acidity has been shown to interfere with the resins' polymerization.³

So when bonding to uncut enamel, what can you do to overcome these limitations of self-etching bonding agents? First, you should consider using a separate phosphoric acid etchant, followed by a thorough rinsing of the etched surface. Make sure the tooth surface is left as the manufacturer recommends before applying the bonding agent (i.e., moist vs dry). Also, you should place multiple coats of the bonding agent before light curing it. Finally, you should lute the orthodontic brackets using only light-activated resins, if possible. If these solutions still do not work, or if you consider them too time consuming or bothersome, you can always go back to using a traditional bonding product that doesn't employ a self-etching primer. Some of these include Excite (Ivoclar Vivadent), OptiBond Solo (SDS/Kerr), Scotchbond Multi-Purpose Adhesive (3M ESPE), PermaQuik (Ultradent), and Single Bond (3M ESPE).

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Fifth-Generation Bonding Agents: Are They a Thing of the Past? (Originally published in Sep 2002)

Question: I see a lot of ads for bonding agents that don't need to be used with phosphoric acid. Is this the latest thing in bonding?

Answer: Dentin bonding agents (DBAs) that don't require a separate phosphoric etchant acid are called "self-etching primer" products. They bond to dentin and cut (i.e., prepared) enamel by etching the tooth with an acid that is already in the bonding agent. In other words, no separate phosphoric acid etching is necessary with them. Self-etching primer DBAs come as either two bottles (a self-etching primer, followed by a separate adhesive) or one (etchant, primer, and adhesive all-in-one). Examples of each type are given in the table below.

Two-Bottle Products	One-Bottle Products
Clearfil SE Bond (Kuraray) Clearfil Liner Bond 2V (Kuraray)	Prompt L-Pop (3M ESPE) One-Up Bond F (Tokuyama/J. Morita) Touch & Bond (Parkell)

Perhaps the most recent development in bonding has been the addition of self-etching primers to the fifth-generation bonding agents. Fifth-generation DBAs, also known as "one-bottle" or "one-component" DBAs, have been available since the mid-1990s and include such products as Single Bond (3M ESPE), OptiBond Solo Plus (SDS/Kerr), PQ1 (Ultradent), Excite (Ivoclar Vivadent). Their manufacturers don't want to be left behind now that self-etching primers have become popular, so they have incorporated these into their product lines. Until very recently, the fifth-generation DBAs consisted of a single bottle or syringe that contained both the primer and the adhesive. The tooth structure needed to be treated with phosphoric acid before they were applied. Now, in response to the latest self-etching primer products, the manufacturers of some of the fifth-generation DBAs are selling them with self-etching primers that are used in place of the phosphoric acid. Why do this? Well, the manufacturers claim that using a self-etching primer reduces post-treatment sensitivity and shortens the clinical procedure. In addition, you no longer have to be concerned about how moist the tooth should be at the time of application. Two examples of fifth-generation DBAs now available with self-etching primers are One-Step Plus with Tyrian SPE from Bisco and OptiBond Solo Plus with Self-Etch Primer from SDS/Kerr. If you One-Step Plus or OptiBond Solo Plus and want to reduce the possibility of post-treatment sensitivity, you may want to consider trying a self-etching primer with it. Please note, though, that not all fifth-generation DBAs come with self-etching primers; the only ones currently available are the SDS/Kerr and Bisco products. By the time this is posted to the web, however, others may have come to the market.

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To Bond or not to Bond? (Originally published in Jan 2003)

Question: I have been told to bond all of my amalgam restorations at my base. Should I be placing a resin adhesive so routinely?

Answer: Many laboratory and several clinical studies over the last decade have evaluated the potential advantages and disadvantages of bonding amalgam to tooth structure.

Multiple laboratory studies have found definite advantages with bonded amalgam restorations with increased retention,¹ fracture resistance,^{2,3} and marginal seal.⁴ Staninec found that the use of adhesives provided greater retention than grooves or dovetails.¹ Oliveira and others found improved fracture resistance in large MOD preparations when bonding amalgam over the use of copalite alone.² A study by Burgess and others found no difference in the strength of complex amalgam restorations using four TMS pins or bonding, but the combination of the two significantly increased the forces necessary for fracture.³ Studies have also shown increased retention of amalgam when bonding with resins containing filler particles.⁵ The more viscous bonding agent may improve penetration into the amalgam during condensation.⁶ Also, research has shown a reinforcement of remaining tooth structure with bonded amalgam restorations.⁷ However, the ability to maintain this reinforcement over time remains equivocal with some studies showing no increase in fracture resistance after aging and thermocycling.^{8,9} The use of an adhesive agent under amalgam has been shown in laboratory studies to decrease microleakage.⁴ Again, the long-term significance of this decrease is unknown.

Most of the clinical studies have found no decrease in post-operative sensitivity^{10,11} and no difference in the performance of bonded amalgam restorations compared with traditional mechanically-retained restorations.^{6,12} Contrary to popular belief, the preponderance of clinical investigations has demonstrated no difference in sensitivity reported by patients receiving amalgam restorations with or without resin adhesives.^{10,11} Summitt and others published a clinical study comparing the performance of bonded versus pin-retained complex amalgam restorations and found no difference after five years between the two techniques. They concluded that bonding with a filled bonding resin (Amalgabond Plus, Parkell Inc., Farmingdale, NY) was a satisfactory method of retaining large amalgam restorations replacing entire cusps.⁶ So, should you place an adhesive agent under all of your amalgam restorations? Given the added cost, time and technique sensitivity of using adhesive liners, there appears to be no clinically-demonstrated benefit in bonding conventional preparations which contain customary retentive features.¹³ However, given the advantages of increased retention, strength and marginal seal found in laboratory studies, the bonding of amalgam may be justified adjunctively with traditional mechanical retention in large restorations replacing a cusp, when tooth structure may need some reinforcement, and for crown foundations.¹³

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The Numbers: Is That All There is to It? (Originally published in May 2003)

Question: All the ads for dentin bonding products contain claims about their bond strengths. Is this an important thing and should I base my decision to buy the product on it?

Answer: You're right in that manufacturers commonly tout the bonding ability of their products by featuring the product's shear bond strength to dentin. Often, they provide a chart and compare their product to other popular bonding agents. Obviously, they are depending on you to think higher is always better. Bond strengths are just one of many factors you should look at when deciding to buy a bonding product. In fact, it may be one of the less important ones. Let's look at how bond strength is measured. The test to measure shear bond strength is done by using the bonding agent to bond a cylinder of resin composite to the ground dentin surface of an extracted tooth. After storage in water (and possible cycling between hot water and cold water baths), the amount of force required to shear the composite cylinder from the dentin is measured. The average number for the group of specimens is then calculated and represents the "shear bond strength." As you can see, this laboratory test is only a rough approximation of what we need the bonding product to do intraorally. What it will be required to do in bonding a composite restoration to a tooth depends on many factors, including the size of the restoration, amount and type of dentin and enamel to which it will be bonded, the forces applied to the restoration, and the appropriateness of the technique used to apply the adhesive. So, the way to interpret the numbers given in an ad for a bonding agent is first to keep in mind that lab tests are only a screening test. They provide a rough idea as to how the bonding product compares to other similar products, and are most valuable in identifying products that significantly underperform. You should also be aware that just having the bond strength number alone doesn't tell the whole story. It is also important, for example, to know where the failure happened (e.g., between the adhesive and tooth, within the tooth, within the composite. etc.) because this tells something about the significance of the numbers. Finally, you should also remember that the numbers are only going to be featured by manufacturers when their products outperform their competitor's products. In other words, regardless of the number, the company that is advertising will always compare its product to competing brands which have not performed as well.

The bottom line is that bond strength is only one factor (and perhaps a minor one) to consider. More important factors are how the adhesive has performed in clinical studies, and the product's ease of use, cost, and range of clinical uses. DIS has evaluated more than 20 bonding products over the past few years and serves as a source of current information about these products. Please call us with any questions you have on selecting or using a dentin bonding agent.

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