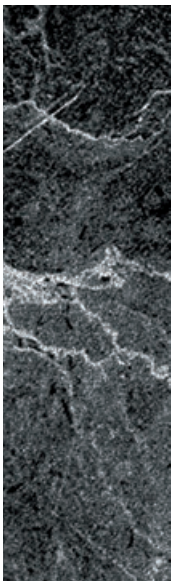
Ask the Experts



OPTIONS FOR DENTIN BONDING

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QUESTION: Is there currently a "best" option for bonding resin-based materials to dentin?

ANSWER: Not for any case! In the Buonocore memorial lecture, published in *Operative Dentistry* in 2003, Van Meerbeek and colleagues stated that "the data presented confirm that conventional three-step etch & rinse adhesives still perform most favorably and are most reliable in the long-term."[1] This article was placed to investigate if this is still true today, 2 years later.

Today's focus is not only on initial bond strengths after 24 hours of water storage or evaluating marginal integrity after 5,000 cycles of thermocycling, as it was a decade ago, but also on the long-term durability of the resin-dentin bond. The problem of long-term exposure to water is not entirely solved, even for the gold standard three-step etch and rinse adhesives. It is logical that the deeper the demineralization that occurs in dentin, the more difficult it is for the primer and bonding agent to fill the demineralized layer entirely. If complete resin infiltration does not take place, nanoleakage occurs, with ingress of water that will affect the hybrid layer. If one could accomplish the total-etch, wet bonding technique "perfectly," the demineralized dentin would be completely saturated with resin, and everything might work well for decades.

If the total-etch technique is not accomplished perfectly, what happens? It is possible that phosphoric acid might be too strong, too acidic for dentin if it is not handled properly, and etching can result in undesirable exposure of the collagen network. In contrast, a mild self-etching primer multibottle system in combination with a separate phosphoric acid enamel etch is successful over years, as shown by the original Syntac (Ivoclar Vivadent, Schaan, Liechtenstein) adhesive[2] or ART Bond (Coltene, Altstaedten, Switzerland). These are truly multi-step self-etch adhesives on dentin but require phosphoric acid-etching on enamel because the maleic acid of the primer is not strong enough to create an adequate etching pattern in enamel. The same is true with OptiBond FL (Kerr, Orange, CA, USA): the pH of the primer is 1.8, making it a sort of self-etching primer as well (at least on dentin). Although the original instruction manual for OptiBond FL advises the total etch-approach, some operators prefer to omit that in deep cavities and instead rely on the self-etching potential of the primer there (Prof. Bernd Haller, University of Ulm, Germany, personal communication, 2004). As long as everything is done properly, this will

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work in the long term. This shows that we have worked with self-etching adhesives on dentin for a long time now—without realizing it!

The essential issue is that nanoleakage must be prevented, and this can be achieved most easily with self-etch adhesives. For example, although the bond strength to dentin decreased over time (7 years) for a three-step etch and rinse adhesive, there was no significant decrease observed for a two-step self-etch adhesive.[3] Incomplete exposure of the collagen network with the remaining hydroxyapatite provides some protection, helping prevent hydrolysis over time. There is existing knowledge that "mild" two-step self-etch adhesives with a pH of ⊕2 closely approach conventional three-step systems (Figure 1) in bonding performance.

In contrast, the "strong" self-etching adhesives might predispose the patient to hydrolysis of the collagen network in the long term.[1,4] Only in short-term water storage (30 days) is a reduction in the resin-dentin bond strength significantly independent of the "mild" or "strong" approach.[5] Some newer products therefore have acidity in the "intermediate" range.[6]

Self-etch adhesives, including the mild ones, are able to provide suitable bond strengths to enamel in vitro, even after 1 year of water storage.[7] Therefore, on enamel, acidity might be less important than was expected years ago.[8] But when evaluating the clinical scenario, the results are sometimes contradictory. For example, separate reports on Clearfil SE Bond (Kuraray, Tokyo, Japan) have shown that marginal integrity and marginal discoloration worsen with time (18 months)[9] or that results are excellent after 2 years.[10] It has been proposed that the results might be improved by an additional enamel etching for the mild self-etch systems even when it did not show significance in the clinical situation.[11]

The negative issues of a low pH (strong self-etch adhesive) regarding long-term stability of the hybrid layer in dentin seem to be more pronounced than any potential advantage of a more distinguished etching pattern on enamel. Although in indications that require optimal bond strength of mild self-etch adhesives to enamel an additional phosphoric acid-etch is possible, it is not possible to make a strong adhesive become mild on dentin.

The claim of the Leuven group made in 2003 is still true today and is supported by newer articles from the same group[12,13] and others.[14–16] Many newer studies support the belief that some two-step self-etch adhesives approach the quality of three-step etch and rinse systems

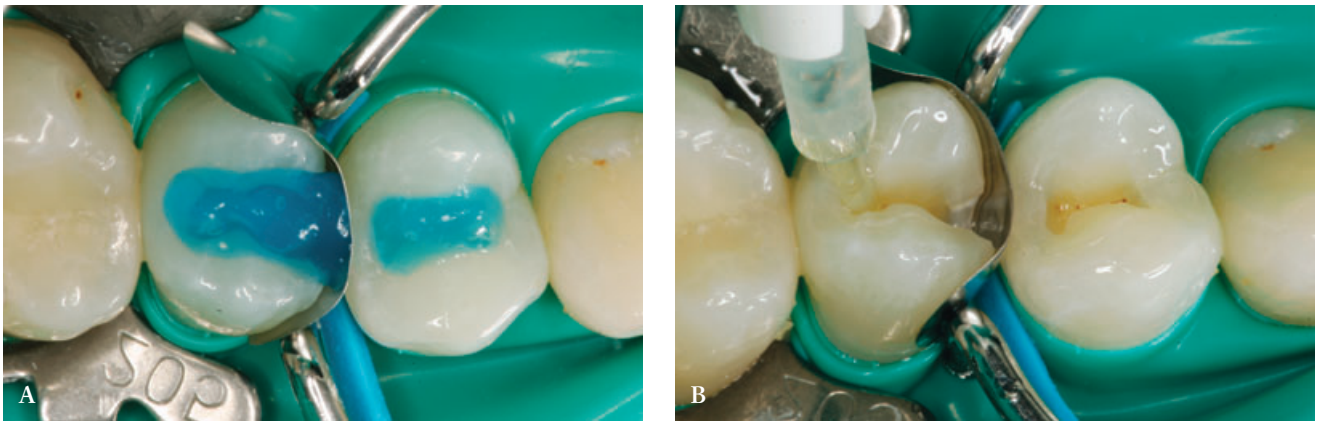

Figure 1. A, B *Clinical example of the use of an etch and rinse adhesive. In Class II situations they are the first choice to ensure a homogeneous bonding layer. The easier evaporation of the solvent compared with self-etch systems is a significant issue in favor of conventional systems.*

for dentin bonding.[16] It can be stated that the three-step etch and rinse adhesives and two-step self-etch adhesives provide reliable and predictably good clinical service. In contrast, an inefficient clinical performance has been reported for some one-step self-etch adhesives.[13] When ranking the different types of adhesives in terms of overall quality and long-term bond durability, the following list would be valid today:

1. Three-step etch and rinse adhesives
2. Two-step self-etch adhesives
3. Two-step etch and rinse adhesives
4. One-step self-etch adhesives

Figure 2. Using a self-etch adhesive in a Class V restoration with rubber dam isolation. If no rubber dam is used and the phosphoric acid etchant contacts the gingival margin, sulcular bleeding often will occur after rinsing. This will not happen with a self-etch adhesive; a "white line" at the gingival margin will be the only visible evidence of any superficial necrosis.

Therefore, some work is still left for research and development in the field of simplified one-step self-etch adhesives. When working with the all-in-one systems, the most important thing to know is that they are technique sensitive.[17] It is possible to obtain the best results with those products (Figure 2), but they require a proper application protocol and sufficient application of the material.[18,19] The variety within self-etch adhesives overall differs more between the individual products than between the philosophies of etch and rinse versus self-etch adhesives.[20] The results with self-etch materials also differ among research centers, perhaps depending on the application procedures, that is, strictly following the instruction manual or meeting the true clinical demands of the individual application protocol. On the other hand, there is still a need for improving even conventional etch and rinse systems; no system available is able to completely seal a cavity![21]

Table 1 compares the performance of current self-etch adhesives with the etch and rinse-approach.

What is the consequence for the general practitioner now? Have self-etch adhesives improved so much that total-etch adhesives are no longer necessary? The answer is clear: "No!" Some (but not all) self-etch adhesives have reached the level of three-step etch and rinse-adhesives. In some cases they perform better than the conventional etch and rinse approach, but in others they do not. There are still indications in which etch and rinse-adhesives are a suitable choice, but this depends on the demands of the individual operator.

Not every single MPa in bond strength will turn out to become clinically evident in terms of less marginal discoloration or restoration loss. Better marginal seal in in vitro studies performed in a standardized manner will hardly provide the same level of information obtained in a clinical study. The most popular self-etch adhesives—many of which are in the group with the least optimal results—are reported to be clinically successful in daily practice when the customers are interviewed. If they were not satisfied with their product, it would be easy for them to change to another one; the variety of available products has never been bigger than it is now! Therefore, to evalu-

TABLE 1. COMPARISON OF THE PERFORMANCE OF CURRENT SELF-ETCH ADHESIVES WITH THE ETCH AND RINSE APPROACH

	Etch and Rinse	Self-Etch
Hybridization of dentin	😐 Difficult to perform but stable and durable over time when done properly	☺ Easy to perform, durable; primarily for mild self-etch adhesives
Bond to enamel and marginal integrity on enamel	☺ Excellent	😐 Fairly good and clinically acceptable; can be improved by additional phosphoric acid-etching
Postoperative sensitivity	😐 Good chance for this, especially with overetching or overdrying of the dentin	☺ Less chance of this, but not impossible
Water solubility of the adhesive	☺ Withstands hydrolysis fairly well when nanoleakage is absent	😐 Higher; some call them a "semipermeable membrane"
Color stability of the adhesive	☺ Good color stability, good choice for high-end esthetic restorations	😐 Not that good; owing to its hydrophilicity, good chance for water uptake (stains accompany the water) in the adhesive
Ease of use	😐 If operator is well trained and potential errors are recognized, not difficult to use	😐 Easier to use but technique sensitive, too; most difficult is the removal of the water from the adhesive

ate the true clinical success in the average dental office, handling properties, storage demands (store it in the refrigerator or not), packaging, dispensing, and so on might be at least as significant as the research data.

So what is better now, a self-etch or an etch and rinse adhesive? This question is hard to answer. Both perform well in the hands of an operator who knows what he or she is doing. In contrast, even the best adhesive will perform poorly in the hands of some "wet-fingered" dentists. This question is similar to choosing a beer or a wine with dinner. Both have the same indication, but they taste different. With the beer, owing to its lower content of alcohol, one can drink a larger amount of liquid before getting drunk, whereas the other one might have a more distinctive taste. And it is a matter of taste. As there are "beer drinkers" and "wine drinkers," there are others who might choose a beer in some situations and a wine in others. The same is true with adhesives; in some indications, a conventional etch and rinse adhesive is the better choice, in others the self-etch approach is better, as shown in Table 2. The choice of an adhesive can be compared with the choice of the "best" car (among German cars, of course!). If you have a long-distance drive planned and you have free choice of your vehicle, a Mercedes S-Class might be your first choice. It is convenient, safe, and reliable in the long term. This is comparable to three-step etch and rinse adhesives, no matter if this is an OptiBond FL, a Scotchbond Multi-Purpose Plus (3M ESPE, St. Paul, MN, USA), or a Syntac Classic (Ivoclar/Vivadent, Schaan, Liechtenstein) or a Gluma Solid Bond (Heraeus Kulzer, Hanau, Germany) (Figure 3).

But when you reach your final destination in a busy city and you must find a parking space, you might wish that you had chosen a

different type of car, one comparable to the Smart from the same manufacturer. This is designed especially for large cities and small parking lots, comparable to self-etching adhesives as a philosophy and with their particular clinical advantages in the Class V or in pediatric dentistry (Figure 4). The easier use there might result in better clinical results, even if the reverse is true in in vitro studies.

TABLE 2. ADVANTAGES AND DISADVANTAGES OF SELF ETCH AND ETCH AND RINSE ADHESIVE IN THE PARTICULAR BLACK CAVITY

Class	Etch and Rinse	Self-Etch
I	☺☺ Cavity surrounded by enamel: ideal	☺ Because of the easy access and good chance for a proper solvent evaporation, good results should be expected on enamel; add phosphoric acid-etching when in doubt, but only on enamel
II	☺☺ Excellent	😐 Not that promising for some self-etch adhesives owing to the difficulty in properly evaporating solvent from the proximal box and to obtain a surface entirely covered by the adhesive
III	☺☺ Excellent	☺ Because of the easier access than a Class II, better results should be expected here
IV	☺☺ Enamel margins and high esthetic demands; etch and rinse is first choice	😐 Because of potential discoloration of the adhesive layer, not good for high esthetic demands
V	😐 Much dentin to bond to, easier chance of obtaining a gingival bleeding after rinsing of the phosphoric acid when not using rubber dam isolation; this is the most inconvenient cavity for an etch and rinse system	☺ No bleeding will occur if the self-etch adhesive touches the gingiva, no replacement of wet cotton rolls (as required after rinsing off the phosphoric acid) necessary when not working with a rubber dam
Pediatric dentistry	😐 Good choice only when working under rubber dam isolation	☺ No disturbance of the operative procedure by rinsing and suction, no replacement of wet cotton rolls necessary when not working with the rubber dam
Self-curing resin composites	☺ Works properly	☹ Negative interaction with the acidic groups of the adhesive; this problem can only be solved by covering with a bonding resin from a three-step etch and rinse adhesive system[22]
Fissure sealing	☺ Works properly	☹ Not a good choice if enamel is uncut

Figure 3. S-Class Mercedes for long distance rides: reliable and safe for most indications, comparable to three-step etch and rinse adhesives.

Figure 4. The Smart: a perfect choice for busy cities with limited parking space, comparable to self-etch adhesives in Class V restorations or pediatric dentistry.

REFERENCES

1. Van Meerbeek B, De Munck J, Yoshida Y, et al. Buonocore memorial lecture. Adhesion to enamel and dentin: current status and future challenges. Oper Dent 2003;28:215–35.
2. Krämer N, Frankenberger R. Clinical performance of bonded leucite-reinforced glass ceramic inlays and onlays after eight years. Dent Mater 2005;21:262–71.
3. Burrow MF, Harada N, Kitasako Y, et al. Seven-year dentin bond strengths of a total- and self-etch system. Eur J Oral Sci 2005;113:265–70.
4. Koshiro K, Inoue S, Sano H, et al. In vivo degradation of resin-dentin bonds produced by a self-etch and an etch-and-rinse adhesive. Eur J Oral Sci 2005;113:341–8.
5. Naughton WT, Latta MA. Bond strength of composite to dentin using self-etching adhesive systems. Quintessence Int 2005; 36:259–62.
6. De Munck J, Vargas M, Iracki J, et al. One-day bonding effectiveness of new self-etch adhesives to bur-cut enamel and dentin. Oper Dent 2005;30:39–49.
7. Miguez PA, Pereira MP, Swift EJ Jr. One-year tensile bond strengths of two self-etching primers to bovine enamel. J Esthet Restor Dent 2004;16:243–8.
8. Pilecki P, Stone DG, Sherriff M, Watson TF. Microtensile bond strengths to enamel of self-etching and one bottle adhesive systems. J Oral Rehabil 2005;32:531–40.
9. Perdigão J, Carmo AR, Anauate-Netto C, et al. Clinical performance of a self-etching adhesive at 18 months. Am J Dent 2005;18:135–40.
10. Van Meerbeek B, Kanumilli P, De Munck J, et al. A randomized controlled study evaluating the effectiveness of a two-step self-etch adhesive with and without selective phosphoric-acid etching of enamel. Dent Mater 2005;21:375–83.
11. Van Landuyt KL, Kanumilli P, De Munck J, et al. Bond strength of a mild self-etch adhesive with and without prior acid-etching. J Dent 2005;34:77–85.
12. De Munck J, Van Landuyt K, Peumans M, et al. A critical review of the durability of adhesion to tooth tissue: methods and results. J Dent Res 2005;84:118–32.
13. Peumans M, Kanumilli P, De Munck J, et al. Clinical effectiveness of contemporary adhesives: a systematic review of current clinical trials. Dent Mater 2005; 21:864–81.
14. Frankenberger R, Tay FR. Self-etch vs etch-and-rinse adhesives: effect of thermo-mechanical fatigue loading on marginal quality of bonded resin composite restorations. Dent Mater 2005;21:397–412.
15. Reis A, Grandi V, Carlotto L, et al. Effect of smear layer thickness and acidity of self-etching solutions on early and long-term bond strength to dentin. J Dent 2005;33:549–59.
16. Shirai K, De Munck J, Yoshida Y, et al. Effect of cavity configuration and aging on the bonding effectiveness of six adhesives to dentin. Dent Mater 2005;21:110–24.
17. Van Meerbeek B, Van Landuyt K, De Munck J, et al. Technique-sensitivity of contemporary adhesives. Dent Mater J 2005;24:1–13.
18. Ernst CP. Positioning self etching adhesives: "versus" or "in addition to" phosphoric acid etching? J Esthet Restor Dent 2004;16:57–69.
19. Van Landuyt KL, De Munck J, Snauwaert J, et al. Monomer-solvent phase separation in one-step self-etch adhesives. J Dent Res 2005;84:183–8.
20. Strydom C. Self-etching adhesives: review of adhesion to tooth structure part II. SADJ 2005;60:8, 10–3.
21. Suppa P, Breschi L, Ruggeri A, et al. Nanoleakage within the hybrid layer: a correlative FEISEM/TEM investigation. J Biomed Mater Res B Appl Biomater 2005;73:7–14.
22. King NM, Tay FR, Pashley DH, et al. Conversion of one-step to two-step self-etch adhesives for improved efficacy and extended application. Am J Dent 2005;18:126–34.

Editor's Note: This installment of "Ask the Experts" exceeds the feature's usual length. However, given the complexity of the topic and the level of interest in it, we asked Dr. Ernst to provide greater than usual detail in his response.

Editor's Note: If you have a question on any aspect of esthetic dentistry, please direct it to the Associate Editor, Dr. Edward J. Swift Jr. We will forward questions to appropriate experts and print the answers in this regular feature.

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