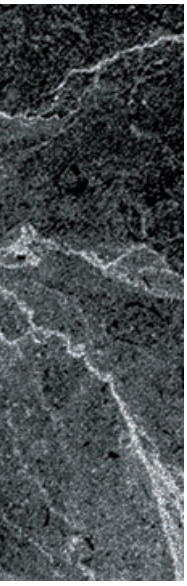

Critical Appraisal

OPTIONS FOR DENTIN/ENAMEL BONDING: PART I

Author and Associate Editor

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Four categories of resin-based dentin/enamel adhesives are currently available. These include the three-step etch-and-rinse, "one-bottle" etch-and-rinse, two-step self-etch primer systems, and "all-in-one" self-etch adhesives. In consecutive issues of the Journal, the Critical Appraisal series will present salient publications on research in each of the categories, beginning with this issue's piece on the three-step etch-and-rinse systems.

A CRITICAL REVIEW OF THE DURABILITY OF ADHESION TO TOOTH TISSUE: METHODS AND RESULTS

J. Demunck, K. Van Landuyt, M. Peumans, A. Poitevin, P. Lambrechts, M. Braem, B. Van Meerbeek
Journal of Dental Research 2005 (84:118–32)

ABSTRACT

Objective: This article evaluated the potential degradation processes involved in loss of adhesion to dentin and reviewed experimental designs used to assess these processes.

Summary: This is a review article that describes a classification of contemporary adhesives, clinical trials and laboratory studies used to evaluate them, and current knowledge of resin-dentin bond durability.

Quoting the authors, "the basic mechanism of bonding to enamel and dentin is essentially an exchange process involving replacement of minerals removed from the hard dental tissue by resin monomers, which, upon setting, become micro-mechanically interlocked in the created porosities." This process, called hybridization or hybrid layer formation, was first described by Nakabayashi in 1982.

Resin dentin adhesives are classified as either "etch-and-rinse" (total-etch) or "self-etch." The etch-and-rinse systems used an etchant, typically 30% to 40% phosphoric acid. In the three-step systems, etching is followed by a priming step and application of a bonding resin. Simplified systems combine the primer and bonding resin into a single solution.

The self-etch approach uses acidic monomers to condition the tooth surface, eliminating the need for a separate etchant that must be rinsed off. The simplified self-etch systems combine conditioner, primer, and bonding resin into a single solution.

The ultimate test of bonding effectiveness remains the clinical trial. Clinical trials of adhesives are done using noncarious cervical lesions, not only for convenience but also because the lack of any inherent macromechanical retention means that ineffective bonding will result in early restoration loss. The value of such clinical trials is somewhat diminished by variations in the dentin substrate, operator skill, occlusal loading, oral hygiene, and other factors. The complex clinical environment makes it difficult to discriminate the precise factors that cause a restoration to fail.

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Various laboratory methods are used to evaluate adhesives—including bond strengths measured in several different ways, artificial aging (by storage in water, thermocycling, or occlusal loading), fracture toughness, fatigue resistance, micro- and nano-leakage tests, and margin analysis.

In regard to the etch-and-rinse adhesives, those that contain acetone as a solvent must be used in a "wet bonding" technique. This can be problematic in complex cavity configurations, so technique sensitivity has been an issue. The one-bottle etch-and-rinse adhesives are less able than the three-step systems to fully infiltrate the collagen network exposed by etching. Technique sensitivity appears to be less with the self-etch than with the etch-and-rinse systems. The dentin bond durability of mild self-etch primer systems is good. Little information on the all-in-one systems was available when this article was published.

Conclusions: Clinical trials using noncarious cervical lesions remain the ultimate test of bonding effectiveness. However, these are costly and time-consuming and cannot reveal the true causes of clinical failure. Several laboratory evaluation methods are available as alternatives.

The findings of any one laboratory study cannot be viewed as absolute. However, adhesives that have performed less well in several independent laboratory studies also appear to be less clinically effective. The authors state, therefore, that the clinical effectiveness of an adhesive can be predicted—which is contrary to popular belief.

The three-step total-etch systems remain the "gold standard" in dentin bonding, and any simplification reduces bonding effectiveness.

COMMENTARY

This is an excellent review article from a highly respected Belgian research group that underscores the fact that there is a "gold standard" in resin-dentin bonding. The materials that have demonstrated the overall best performance in the laboratory and in the clinical environment are the three-step etch-and-rinse systems that contain ethanol-based primers. Unfortunately, this class of materials currently receives less attention than the various simplified systems that dominate the market, many of which are unproven.

SUGGESTED READING

Armstrong SR, Vargas M, Fang Q, Laffoon J. Microtensile bond strength of a total-etch 3-step, total-etch 2-step, self-etch 2-step, and a self-etch 1-step dentin bonding system through 15-month water storage. J Adhes Dent 2003;5:47–56.

De Munck J, Van Meerbeek B, Yoshida Y, et al. Four-year water degradation of total-etch adhesives bonded to dentin. J Dent Res 2003;82:136–40.

De Munck J, Shirai K, Yoshida Y, et al. Effect of water storage on the bonding effectiveness of 6 adhesives to Class I cavity dentin. Oper Dent 2006;30:456–65.

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.

CLINICAL EFFECTIVENESS OF CONTEMPORARY ADHESIVES: A SYSTEMATIC REVIEW OF CURRENT CLINICAL TRIALS

M. Peumans, P. Kanumilli, J. De Munck, K. Van Landuyt, P. Lambrechts, B. Van Meerbeek

Dental Materials 2005 (21:864–81)

ABSTRACT

Objective: The purpose of this article was to review the literature on clinical effectiveness of contemporary adhesives, as measured by retention of restorations placed in noncarious cervical lesions.

Materials and Methods: The literature on university-based Class V clinical trials from January 1998 to May 2004 was reviewed for this

paper. Restoration retention rates in peer-reviewed publications and International Association for Dental Research (IADR) abstracts were included. Materials were divided into the four categories described in the previous review (plus a fifth, glass ionomers). For each class of material, the annual failure rate was calculated by dividing the final retention rate by the number of recall years and multiplying the result by 100.

For perspective, the American Dental Association's (ADA) Council on Scientific Affairs has published guidelines for "full acceptance" of adhesives that demonstrate a 90% or greater retention rate after 18 months of clinical service.

Results: In the 6.5-year span covered by the review, only 35 peer-reviewed publications reporting clinical trials of adhesives were found, along with 50 abstracts.

The annual failure rate of three-step etch-and-rinse adhesives ranged from 0 to 16%, with a mean of 4.8%. Eighty-one percent of the three-step systems met the ADA guidelines for full acceptance. The range for one-bottle etch-and-rinse adhesives was 0 to 19.5%, with a mean of 6.2%. Only 51% of these systems met the ADA guidelines.

For self-etching primer systems, the annual failure rates ranged from 0 to 19.3%, with a mean of 4.7%. Some of these were not "true" two-step self-etch primer systems because they included a selective enamel-etching step. Seventy-one percent met the ADA threshold for full acceptance. Annual failure rates of the all-in-one adhesives had the largest range (0–48%) and highest mean (8.1%). Seventy percent of the all-in-one adhesives met the full ADA guidelines.

Conclusions: Of the four categories of resin-based adhesives, the three-step etch-and-rinse and two-step self-etch (self-etch primer) systems provided reliable performance in clinical trials involving restoration of noncarious cervical lesions. Simplification might make adhesive application easier and faster, but at the risk of increased technique sensitivity and reduced clinical performance.

COMMENTARY

This review article is from the same Belgian group that published the De Munck paper described above and reflects the same high quality and comprehensive nature.

For both the etch-and-rinse and self-etch methods of bonding, the clinical performance of the more complex adhesive systems exceeded that of the simplified systems. The three-step etch-and-rinse and self-etch primer systems had the lowest annual failure rates and the least variation from study to study.

Because this Critical Appraisal is focused on resin-based adhesives, the glass ionomer alternative is not included to any great extent. However, it should be noted that glass ionomers actually had the best clinical performance in the studies reviewed by these authors. The annual failure rate of these materials was less than 2%, and even 5-year retention rates were in the 84-to-100% range.

SUGGESTED READING

Bayne SC, Schmalz G. Reprinting the classic article on USPHS evaluation methods for measuring the clinical research performance of restorative materials. Clin Oral Investig 2005;9:1–6.

Heintze SD, Blunck U, Göhring TN, Rousson V. Marginal adaptation in vitro and clinical outcome of Class V restorations. Dent Mater 2009;25:605–20.

Van Meerbeek B, Peumans M, Gladys S, et al. Three-year clinical effectiveness of four total-etch dentinal adhesive systems in cervical lesions. Quintessence Int 1996;27:775–84.

RESTORING CERVICAL LESIONS WITH FLEXIBLE COMPOSITE

M. Peumans, J. De Munck, K.L. Van Landuyt, P. Kanumilli, Y. Yoshida, S. Inoue, P. Lambrechts, B. Van Meerbeek

Dental Materials 2007 (23:749–54)

ABSTRACT

Objective: The purpose of this clinical trial was to determine whether the use of a flexible composite can improve the longevity of composite resin restorations in noncarious cervical lesions.

Materials and Methods: Seventy-one subjects were enrolled in the study, and 142 noncarious lesions were restored. Teeth were randomly assigned for treatment with either of two three-step etch-and-rinse adhesive systems—Permaquick (Ultradent Products, South Jordan, UT, USA) or OptiBond FL (Kerr, Orange, CA, USA). All lesions in the OptiBond group were restored using a microhybrid composite, Prodigy (Kerr). Those treated with Permaquick were divided into two groups for restoration with either Amelogen Hybrid (Ultradent) or Amelogen Microfill (Ultradent). (Note: Microfill materials have lower elastic moduli than hybrids, so Amelogen Microfill is the "flexible" composite in this study.)

All restorations were placed by two specially trained and experienced dentists under rubber dam isolation. Short enamel bevels were placed. The composite restorative materials were placed and light-cured in two increments.

The restorations were evaluated by two trained examiners at 6 months and 1, 2, 3, 5, and 7 years after placement. The examiners were blinded as to type of restorative material. They used a standard set of criteria for evaluation, with the most important criteria being retention, marginal integrity, and marginal staining.

Results: At 7 years, 112 of the original cases were available for recall (80.3% recall rate). The 7-year retention rates were 94% for OptiBond FL/Prodigy, 92% for Permaquick/Amelogen Microfill, and 87% for Permaquick/Amelogen Hybrid. Differences between groups were not statistically significant.

Defect-free margins were rare (fewer than 30% of restorations) at 7 years but were generally minor and were similar in the three groups. Most marginal staining was rated as superficial and localized. A small percentage of restorations (3–6%) were rated as having clinically unacceptable marginal stain and these were replaced.

Conclusions: The performance of three adhesive/composite combinations was reliably good during this 7-year clinical trial. The stiffness of the composite restorative material did not affect restoration longevity.

COMMENTARY

Although the etiology of most noncarious cervical lesions is multifactorial, it is quite likely that one of the etiologic factors in some lesions is tooth flexure. The same flexural stresses that contribute to lesion initiation and progression conceivably could contribute to deterioration of restorations in the cervical area. Some authors have proposed that the use of more flexible restorative materials might absorb tooth flexure stresses, allowing them to be compressed rather than dislodged.

In comparing the two restorative materials used with the same adhesive in this study, the hybrid has an elastic modulus of 14.7 GPa and the microfill has a modulus of 6.9 GPa. Despite this large difference in stiffness, the retention rates of the two composites were not significantly different. The authors' conclusion that composite stiffness had no effect on the performance of

cervical restorations, therefore, is correct.

It should be noted that both of the adhesives tested in this study are filled materials that form a relatively thick layer at the tooth interface. There is some evidence that this thick and relatively flexible layer can act as an "elastic buffer" of shock absorber that could dissipate stress regardless of the restorative material placed over it. Thus, the results of this study might not apply to adhesives that do not easily form the thicker bonding layer (e.g., many of the one-bottle etch-and-rinse systems). In such cases, it is possible (but not proven) that the use of a flexible restorative material or flexible liner could improve the durability of a cervical restoration. Similarly, a flexible material might be beneficial in teeth under heavy occlusal forces.

SUGGESTED READING

Browning WD, Brackett WW, Gilpatrick RO. Two-year clinical comparison of a microfilled and a hybrid resin-based composite in non-carious Class V lesions. Oper Dent 2000;25:46–50.

Reis A, Loguercio AD. A 24-month follow-up of flowable resin composite as an intermediate layer in non-carious cervical lesions. Oper Dent 2006;31:523–9.

Van Meerbeek B, Willems G, Celis JP, et al. Assessment by nano-indentation of the hardness and elasticity of the resin-dentin bonding area. J Dent Res 1993;17:1434–42.

12-YEAR CLINICAL EVALUATION OF A THREE-STEP DENTIN ADHESIVE IN NON-CARIOUS CERVICAL LESIONS

A.D. Wilder, E.J. Swift, H.O. Heymann, A.V. Ritter, J.R. Sturdevant, S.C. Bayne
Journal of the American Dental Association 2009 (140:526–35)

ABSTRACT

Objective: The purpose of this study was to evaluate the effects of acid-etching dentin on the long-term performance of cervical restorations bonded using a three-step etch-and-rinse adhesive.

Materials and Methods: One hundred noncarious cervical lesions in 53 patients were restored using OptiBond Dual-Cure (Kerr) adhesive and Herculite XRV (Kerr) hybrid composite. (Note: OptiBond Dual-Cure was recently taken off the market, but a similar material—OptiBond FL—remains available.) OptiBond Dual-Cure was a three-step etch-and-rinse adhesive that could be used with the total-etch technique involving both dentin and enamel or with selective etching of enamel only.

Six operators placed restorations under isolation with cotton rolls and retraction cord. Tooth preparation was limited to producing a definite finish line where needed; no bevels or mechanical retention was placed. OptiBond Dual-Cure was the adhesive used in all restorations. In 50 teeth, only the enamel was etched (30 seconds); in the other 50 teeth, the enamel was etched for 15 seconds, and then the etchant gel was extended to the dentin for 15 seconds. The composite restorative material was applied and cured incrementally.

The restorations were evaluated at recalls ranging to 12 years and were rated according to standard modified United States Public Health Service (USPHS) criteria. As in the Peumans study reviewed above, the primary outcome variables were retention, marginal integrity, and marginal stain.

Results: The 12-year recall rate was 46%. The retention rates were 93% in the selective-etch group and 84% in the total-etch group; however, the difference was not statistically significant. The overall retention rate was 89%. Marginal integrity was excellent at 12 years, with 90% of the restorations rated in the highest category. Only 27% of restorations failed to rate in the highest category for absence of marginal stain.

Conclusions: The retention and other characteristics of a dual-cure three-step adhesive were excellent at the 12-year recall, and were not affected by the etching technique.

COMMENTARY

This is one of the longest clinical trials of dentin adhesives that has been published to date. The original purpose of the study was to determine whether acid-etching of dentin affected the performance of the three-step adhesive OptiBond Dual-Cure. This was one of the first three-step adhesives available that included a phosphoric acid-etching step not only for enamel but also for dentin.

However, that original purpose has little meaning today. The more relevant aspect of this study is its length—that is, the fact that the restorations have been tracked for so long with a relatively high recall rate. Remarkably, nearly 90% of the restorations available for recall were retained and in generally good condition after 12 years of clinical service—and these restorations were placed without benefit of enamel bevels or other retention enhancements. The results of this study provide good clinical evidence supporting the "gold standard" status of the three-step adhesive systems.

SUGGESTED READING

Breschi L, Mazzoni A, Ruggeri A, et al. Dental adhesion review: Aging and stability of the bonded interface. Dent Mater 2008;24:90–101.

van Dijken JW, Pallesen U. Long-term dentin retention of etch-and-rinse and self-etch adhesives and a resin-modified glass ionomer cement in non-carious cervical lesions. Dent Mater 2008;24:915–22.

van Dijken JW, Sunnegårdh-Grönberg K, Lindberg A. Clinical long-term retention of etch-and-rinse and self-etch adhesive systems in non-carious cervical lesions. A 13 year evaluation. Dent Mater 2007;23:1101–7.

THE BOTTOM LINE

1. Three-step etch-and-rinse adhesives are considered the gold standard for bonding resin-based materials to tooth structure.
2. Evidence for the dentin bonding efficacy of these adhesives is provided by laboratory testing, including methods for artificial aging, and clinical trials, including one at 12 years.
3. The three-step etch-and-rinse adhesives bond well, not only to dentin but also to enamel.
4. In general, simplified adhesives have not performed as well as the three-step gold standard either in laboratory testing or in clinical trials.

Editor's Note: We welcome readers' suggestions for topics and contributors to Critical Appraisal. Please address your suggestions to the section editor:

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