

The clinical effectiveness of adhesive agents in posterior restorations: Which adhesive strategy performs better?

Naji Ziad Arandi, Mohammad Thabet¹

Departments of Conservative Dentistry and ¹Pediatric Dentistry and Orthodontics, Arab American University, Jenin, Palestine

Abstract

The clinical effectiveness of adhesive agents has been mainly evaluated using class V restorations. Clinical studies evaluating adhesives in combination with posterior composites are scarce and of short-term periods. This paper is aimed to review the current literature on the clinical effectiveness of contemporary adhesives when used to restore posterior teeth (Class I and Class II). To conduct this review, Scopus, PubMed, and Google Scholar databases were used to search for peer-reviewed articles on the clinical performance of adhesive agents in posterior composite restorations. Search terms used included “adhesive agents,” “clinical evaluation,” “composite restorations,” “posterior teeth,” “self-etch adhesives,” “etch -and -rinse adhesives,” and “universal adhesives.” To enrich the results, reference mining of the articles that were identified was used to locate other papers. The process of cross-referencing continued until no new articles were identified. No limits were placed on the year of publication, but only articles in English were considered. The current review found that simplification in the adhesive technique so far seems to affect the clinical performance. There is a relative paucity of evidence relating to the performance of universal adhesive agents in posterior restorations. Further long-term clinical studies are needed to evaluate the clinical performance of adhesive agents.

Keywords: Bonding agents, clinical performance, posterior composites, universal bonding agents

Address for correspondence: Dr. Naji Ziad Arandi, Department of Conservative Dentistry and Prosthodontics, Faculty of Dentistry, Arab American University, P.O Box: 240 Jenin, 13 Zababdeh, Jenin, Palestine.

E-mail: Naji.arandi@aaup.edu

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INTRODUCTION

Improvements in dental adhesives have extensively influenced modern restorative dentistry. Dental adhesives have been classified using several methods: generation, solvent type, mechanism of smear layer removal, and the number of clinical steps. In the most commonly used classification method, adhesives are grouped according to the number of clinical steps involved in the procedure. Etch-and-rinse adhesives are grouped into “three-step” or “two-step” systems. The three-step system includes

a separate etchant, primer, and bonding resin applied consecutively. In the two-step systems, etching is followed by the application of a combined primer and bonding resin.

Self-etch adhesives maybe two- or one-step systems: in the two-step self-etch systems, a combined etching and primer agent which simultaneously “condition” and “prime” the dental substrate is applied on the tooth structure and air-dried, followed by the application and polymerization of a bonding resin. The one-step self-etch systems combine etching, primer, and bonding resin in a single application.

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Some one-step systems require mixing materials from two or more bottles before being applied as a one-step adhesive agent.

Self-etch dentine bonding agents have a number of advantages compared to etch-and-rinse systems. They require no postetch rinsing; hence less operator sensitive; less sensitive to the degree of wetness/dryness of the dentine surface; single unit dose packaging possible, hence reduced risk of cross-infection; consistent and stable composition; simultaneous demineralization and resin-infiltration meant that it was not possible to over etch the dentine, which is claimed to reduced levels of postoperative sensitivity. However, the data available on postoperative sensitivity in resin composite restorations bonded with etch-and-rinse versus self-etch systems has been reported not to show differences.^[1]

Recently, universal bonding agents have been introduced. These materials are claimed “Universal” insofar as they may be considered to be capable of being used for direct and indirect dentistry, as well as being suitable for use in whichever etching modality the clinician considers appropriate, namely self-etch, etch-and-rinse or selective enamel etch. When universal adhesives are applied in full self-etch mode, they are one-step self-etch adhesives.

The wide variety of bonding agents currently available makes it difficult for clinicians to choose the best adhesive in terms of material and technique, especially when different clinical situations are considered. Survey studies report an inconsistent attitude of general dentists toward the selection and implementation of adhesive agents and protocols with posterior composite restorations. Arandi and Thabet^[2] reported that 41% of the respondents to their survey in Palestine opted for two-step etch-and-rinse with posterior composites, 10% two-step self-etch and 35% one-step self-etch adhesives. Gilmour *et al.*^[3] investigated the opinions and methods used in placing posterior composite restorations by general dental practitioners. They reported that etch-and-rinse adhesive agents were used most frequently (69% of respondents reported always using this technique) than the self-etch adhesives (14%). Blum *et al.*^[4] reported that 60% of the respondents to their survey in the UK used two-step etch-and-rinse system while 10% used a two-step self-etch adhesives when restoring posterior teeth with resin composite.

Dentists most likely follow the protocol they learned in dental schools. Surveys among dental schools report variations and lack of agreement in teaching posterior composite restorations (including adhesive agents).

Kanzow *et al.*^[5] Investigated the teaching and operative techniques for posterior composite resin restorations in 33 dental schools in Austria, Germany, and Switzerland. The most commonly reported bonding approach taught was the etch and rinse technique (88%) followed by the use of self-etch adhesives (36%). The most common type of adhesive bonding agent used for posterior composites was Optibond FL (70%). Universal adhesives were taught at nine dental schools (27%). Awad *et al.*^[6] investigated the teaching of direct posterior composite restorations to undergraduate dental students in the Kingdom of Saudi Arabia. Three-step etch-and-rinse adhesive systems were taught in 8 and not taught in 5 schools. On the other hand, two-step etch-and-rinse adhesive systems were taught in all 13 schools. Two-step and one-step self-etch adhesive systems were taught in 5 and 10 schools and not taught in 8 and 3 schools, respectively. Other studies reported the brands commonly taught in dental schools. A survey investigating the teaching and operative techniques of posterior composite restorations in 16 dental schools in Oceania (Australia, New Zealand, Fiji and Papua New Guinea) reported that the most common bonding agents were ‘Scotchbond Universal’, OptiBond™ All-In-One, Optibond Solo Plus, G-bond, and Clearfil.^[7] Another survey conducted among 10 dental schools in UK reported that the most common brands of bonding systems taught were “Prime & Bond NT” and “Scotchbond.”^[8] A survey investigating the teaching of the placement of posterior resin-based composite restorations in 15 Spanish dental schools reported that the most common adhesives were: “Excite;” “Optibond Solo/Optibond Solo Plus;” and “Prime & Bond NT.”^[9] In a similar survey among 18 dental schools in Iran, the most common brands of bonding systems taught were “Excite;” “Single Bond;” and “Clearfil SE Bond.”^[10]

REVIEW

Most comparisons on the performance of adhesive agents were carried out *in vitro*. Much of the bond testing has been done in a laboratory under ideal controlled conditions, which may not be possible to replicate in a clinical environment, and results may vary depending on the testing methods and devices used. Clinical testing of dentin adhesives remains the ultimate proof of effectiveness because *in vitro* studies may only speculate on the clinical behavior of these systems. The clinical performance of adhesives to the tooth structure has been thoroughly investigated using Class V cavities.^[11,12] However, studies investigating the performance of adhesive agents in the stress-bearing posterior cavities (Class I and Class II) reported that the location factors of the cavities and type

of masticatory forces might affect the performance of restorations and adhesive agents.^[13,14] Table 1 shows a summary of adhesive agents evaluated by various studies reviewed. The “modified Ryge criteria” or the United States Public Health Service (USPHS)^[15] were originally proposed by Cvar and Ryge is widely used for the clinical assessment of dental restorations.^[16] The criteria are considered valid for comparison purposes among studies at different observation periods. Categories such as occlusion, postoperative sensitivity, fracture, retention and others are into account. For each category, a score is assigned to the restoration as follows: A (Alpha)- restoration which is clinically ideal, B (Bravo)- restoration showing minor deviations from the ideal but nevertheless acceptable (except for retention and secondary caries), C (Charlie)- restoration which should be replaced for preventive reasons to avoid the likelihood of future damage and D (Delta)- restoration requiring immediate replacement. Authors do not always use the same criteria or definitions to assign the scores. In 2007, Hickel *et al.* proposed a new system based on three criteria categories: esthetic, functional and biological. Each category was divided into subcategories to allow for a more detailed description and analysis. Each subcategory was

scored according to a five-step grading of the restoration. The criteria defined by Hickel *et al.* was approved by the Science Committee of the FDI World Dental Federation in 2007^[17,18] and considered in 2008 as “Standard Criteria.”^[19,20] Their use was thus recommended in clinical trials assessing dental restorations in terms of materials, operative technique/intervention, as well as in clinical practice to determine whether a restoration should be maintained, repaired or replaced.^[17,18]

Retention, marginal integrity, and marginal discoloration are usually the key parameter used to judge upon clinical effectiveness of adhesives. The occurrence of marginal deterioration has been reported mostly dependent on the adhesive system employed in the restorative procedure.^[21,22]

TWO-STEP ETCH-AND-RINSE VERSUS THREE-STEP ETCH AND RINSE

Gallo *et al.*^[23] evaluated the clinical performance of Class I and II composite restorations (Solitaire 2, Heraeus Kulzer, Inc., Amonk, NY, USA) with a three-step etch-and-rinse adhesive (Gluma Solid Bond) and a two-step ethanol-based etch-and-rinse (Gluma Comfort Bond) adhesive. A modified USPHS scale was used to evaluate the restorations. The study revealed high clinical efficacy at 2 years for all restorations placed regardless of the bonding agent used. However, the study noted that the comparison of marginal discoloration at 2 years approached significance, where the three-step etch-and-rinse adhesive performed better than the two-step etch-and-rinse. Burke *et al.*^[24] placed Solitaire 2 in Class I and II restorations with Gluma Solid Bond or Gluma One Bond, a two-step acetone-based etch-and-rinse adhesive agent. They reported no differences between adhesive systems. In addition, 99% of the Solitaire 2 resin composite restorations performed satisfactorily at 1-year recalls. The literature reports that two-step etch-and-rinse systems can be more susceptible to water degradation effects that interfere with stable resin-dentin bonds when compared with three-step etch-and-rinse systems.

TWO-STEP ETCH-AND-RINSE VERSUS TWO-STEP SELF-ETCH

Bekes *et al.*^[25] compared the clinical performance of the two-step self-etching AdheSE and the two-step etch and rinse Excite in class I and II composite restorations (Tetric Ceram HB, Vivadent, Schaan, Liechtenstein). The modified Ryge criteria were used to evaluate the restorations at 2 years. The study reported that both systems performed well. However, although statistically insignificant, AdheSE showed double the cases of marginal discoloration and marginal defects at 2 years compared to Excite.

Table 1: Summary of materials mentioned in the studies

Adhesive agent	Manufacturer
Three-step etch and rinse	
OptiBond™ FL	Kerr
Gluma Solid Bond	Heraeus Kulzer
Two-step etch and rinse	
Excite	Ivoclar Vivadent
Adper Single Bond	3M ESPE
Adper™ Single Bond Plus	3M ESPE
Optibond Solo Plus	Kerr
Prime and Bond NT	Dentsply/Caulk
One-Step Plus	Bisco
Gluma Comfort Bond	Heraeus Kulzer
Two-step self-etching	
AdheSE	Ivoclar Vivadent
Clearfil SE Bond	Kuraray
OptiBond XTR	Kerr
Adper Scotchbond SE	3M ESPE
One-step self-etch	
Xeno III*	Dentsply DeTrey
Adper Scotchbond SE plus	3M ESPE
Clearfil S3 Bond	Kuraray
iBond	Heraeus Kulzer
Xeno® V+	Dentsply
OptiBond All-In-One	Kerr
G-bond	GC
Adper Prompt L-Pop*	3M ESPE
Universal bond	
All-bond Universal	Bisco
Scotchbond Universal	3M ESPE
Prime&Bond Elect Universal	Dentsply
Single Bond Universal	3M ESPE
Clearfil Universal Bond	Kuraray
Gluma Bond Universal	Heraeus Kulzer

*One-step self-etch adhesive which requires mixing before application in one step

Ermes *et al.*^[26] investigated the clinical performance of a two-step etch and rinse (Adper Single Bond) and two-step self-etch (Clearfil SE) adhesive system in class II restorations (Filtek Z250, 3M ESPE, St Paul, MN, USA). The restorations were examined by using the modified Ryge criteria (USPHS). Adper Single Bond restorations revealed more retention failures and Clearfil SE restorations exhibited more small marginal enamel defects. However, the study reported these problems not to be critical for the overall clinical performance of these adhesives and no significant differences between the clinical performances of these adhesive systems were found. Sundfeld *et al.*^[27] evaluated the clinical performance of direct class I resin composite restorations (Filtek™ Supreme Plus, 3M ESPE, St. Paul, MN, USA) after 3 years. The restorations were performed using two types of adhesive systems: Adper™ Single Bond Plus, which is a two-step etch-and-rinse system, and Adper Scotchbond™ SE, which is a two-step self-etching system. The restorations were examined by using the modified Ryge criteria (USPHS). Statistically significant differences when comparing the baseline and the 3-year values for marginal discoloration with both systems; however, no statistically significant difference was observed for marginal integrity with both adhesive systems after 3 years. The results demonstrated no statistically significant differences between the teeth restored with the two-step etch-and-rinse and two-step self-etching adhesive system. Both demonstrated similar and satisfactory clinical performance after 3 years. Sundfeld *et al.*^[28] assessed the performance of posterior composite resins (Filtek Supreme Plus 3M ESPE Dental Products, St Paul, MN, USA) applied with the two-step etch and rinse (Adper Single Bond Plus) and a two-step self-etch (Adper Scotchbond SE) adhesive systems using modified USPHS criteria. It was observed that both adhesives presented good clinical performance and no differences between restorations applied with either adhesive system in the variables of marginal discoloration, or marginal adaptation after 1 year.

TWO-STEP ETCH-AND-RINSE VERSUS ONE-STEP SELF-ETCH

Swift *et al.*^[29] compared the clinical performance of a one-step self-etch (Xeno III) adhesive with that of a two-step etch and rinse (Optibond Solo Plus) adhesive after 3 years of clinical service. The restorations were evaluated at baseline, 6, 12, 18, and 36 months. The quality of the restoration margins, particularly as indicated by marginal discoloration, tended to decline with time for both groups. At 36 months, there was slightly more marginal discoloration in the self-etch group (27% of the restorations) than in the etch-and-rinse control group (16%

of the restorations). However, the difference was not statistically significant. The study concluded slightly more marginal discoloration and marginal deterioration were observed in the self-etch group at 36 months, but the difference between the two tested materials was not statistically significant. Another study by Dijken and Pallesen^[30] evaluated the clinical performance of a two-step etch and rinse (Excite) and a one-step self-etch (Xeno III) adhesive system in Class II restorations (Ceram X Dentsply/DeTrey, Konstanz, Germany). The one-step self-etch adhesive had a higher percentage of marginal deterioration at 4 years as compared to Excite. However, it was not statistically significant. The study concluded that the restorations evaluated showed good clinical effectiveness during the 4-year period for both adhesive systems, and no significant differences were observed in the overall clinical effectiveness between the two adhesives.

THREE-STEP ETCH AND RINSE VERSUS ONE-STEP SELF-ETCH

Manchorova-Veleva *et al.*^[31] compared the clinical performance of a one-step self-etch (Adper Prompt L-pop) and three-step etch and rinse (Scotchbond MP) adhesives. The composite restorations (Filtek Supreme, 3M ESPE, St. Paul, MN, USA) with Scotchbond MP exceeded the restorations with Adper Prompt L-Pop with regard to the marginal adaptation and marginal discoloration during 6-, 12-, and 36-month evaluations.

TWO-STEP SELF-ETCH VERSUS ONE-STEP SELF-ETCH

Perdigão *et al.*^[32] evaluated the 2-year clinical performance of three self-etching adhesives (Adper Prompt L-Pop, Clearfil S3 Bond and iBond) and one etch-and-rinse adhesive (One-Step Plus) in posterior composite restorations (Filtek Supreme, 3M ESPE). The restorations were evaluated using the USPHS modified criteria at baseline, 6 months, 1 year, and 2 years. The number of alpha ratings decreased significantly from baseline to 2 years for Adper Prompt L-Pop, Clearfil S3 Bond, and iBond in the categories color match, marginal staining, and marginal adaptation. For One-Step Plus, only marginal staining was significantly worse at 2 years than at baseline. The study concluded that only One-Step Plus, the etch-and-rinse adhesive, resulted in good marginal adaptation at 2 years and that one of the self-etching adhesives, iBond, resulted in unacceptable clinical performance. Similar results were reported by Vinagre *et al.*^[33] who evaluated the efficacy of five different adhesive systems in class I composite restorations (Esthet X HD, Dentsply DeTrey, Konstanz, Germany) after 1 year of function. They assessed the

performance of a three-step etch and rinse (Optibond™ FL) a two-step etch-and-rinse (Prime&Bond® NI™) and three self-etch (Clearfil™ SE, Xeno® III, Xeno® V+) adhesive systems using the FDI criteria at baseline, 6 months and 1 year. Their study reported that both etch-and-rinse adhesives revealed the similar performance and were superior to any of the self-etch adhesives tested. The self-etch adhesives tested in this study presented statistically significant worse marginal adaptation than adhesives that employed the etch-and-rinse approach with a considerable percentage of the margin perimeter deteriorated, particularly for the more simplified one, Xeno®V+. Nevertheless, those were clinically still acceptable and did not require any restorative intervention. Other studies, Delbous *et al.*^[34] evaluated the 18-month clinical performance of four adhesive strategies [the adhesives OptiBond FL (three-step etch-and-rinse), OptiBond SOLO Plus (two-step etch-and-rinse), OptiBond XTR (two-step self-etch), and OptiBond All-in-One (one-step self-etch)] in posterior composite restorations (Filtek Z350XT, 3M ESPE, St. Paul, MN, USA). Restorations were evaluated at baseline and at 18 months using USPHS-modified criteria. There were no significant differences when the adhesives were compared at 18 months. For each adhesive, there were no significant differences from baseline to 18 months. The study concluded that the bonding strategy did not influence the clinical performance of posterior composite restorations.

UNIVERSAL BONDING ADHESIVES

As with any recently introduced material, there is a relative paucity of evidence relating to universal adhesive agents. Çakır *et al.*^[35] evaluated the 2-year clinical behavior of five different universal adhesives (Gluma bond Universal, Clearfil Universal, Prime&Bond Elect, All-Bond Universal and Single Bond Universal). The adhesive agents were evaluated in the etch-and-rinse and self-etch modes in the case of Class I composite restorations (Filtek Z550 3M ESPE, St. Paul, MN, USA). The restorations were evaluated at baseline and during a 24-month recall using FDI and USPHS criteria. The results of the study showed that no difference was observed between the etch-and-rinse and the self-etch modes with regard to universal adhesives when evaluated in terms of all criteria. However, Gluma Bond Universal, Single Bond Universal, and Prime Bond Universal showed marginal discrepancies in self-etch mode according to FDI criteria. Gluma Bond Universal also showed marginal discoloration in self-etch mode according to FDI criteria. The results of the study showed that all adhesives were found to be clinically successful despite minor differences between them at the 24-month

recall. Van Dijken and Pallesen^[36] evaluated the clinical performance of a universal bonding agent (All-bond universal) applied with selective enamel etching, compared with a two-step self-etch adhesive. They observed that although statistically insignificant, the universal adhesive had a slightly lower percentage of marginal deterioration at 3 years as compared to the two-step self-etch adhesive. Carvalho *et al.*^[14] evaluated the clinical behavior of class I and class II composite resin restorations performed with a universal adhesive system (Scotchbond Universal adhesive) used in different application protocols (etch and rinse, self-etch, selective enamel etch) using the adapted FDI and adapted USPHS criteria. They concluded that the different application protocols of the universal adhesive resulted in clinically “acceptable” restorations after 15.8 ± 2.7 months of follow-up.

Dental restorative materials have improved to the point that early failures are rare. Practitioners should be aware about the long-term performance or longevity (patency) of their bonding agent in actual clinical performance. The current data may not be sufficient to evaluate the longevity of restorative material and long-term clinical studies are essential to evaluate tooth-colored restorative materials. Hence, to distinguish between materials, longer trials are absolutely required.^[23]

Finally, it should be noted that the adhesive restoration is a technique-sensitive procedure and that the success of these restorations is determined by the ability of the dentists and excellence of the technique employed, beyond the performance of the material.

CONCLUSION

The current review found that simplification in the adhesive technique so far seems to affect the clinical performance. There is a relative paucity of evidence relating to the performance of universal adhesive agents in posterior restorations. Further long-term clinical studies are needed to evaluate the clinical performance of adhesive agents.

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There are no conflicts of interest.

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