Original Article

Rebonding of Orthodontic Brackets

Part I, a Laboratory and Clinical Study

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ABSTRACT

Objective: To compare rebonding of orthodontic brackets based on the hypothesis that no difference would be found between the adhesive systems with respect to shear bond strength, mode of failure, and clinical failure rates.

Materials and Methods: The three adhesive systems included two self-etch primers (Transbond and M-Bond) and a conventional phosphoric acid etch (Rely-a-Bond). The sample size was 20 premolars for each adhesive system. The shear bond strength was tested 24 hours after bracket bonding with the bonding/debonding procedures repeated two times after the first debonding. Bond strength, adhesive remnant index (ARI), and failure sites were evaluated for each debonding. Statistical analysis consisted of a two-way analysis of variance (ANOVA) followed by Scheffè analysis. The clinical portion evaluated 15 patients over a 12-month period.

Results: The mean shear bond strengths after the first, second, and third debondings for Rely-a-Bond were 8.4 ± 1.8, 10.3 ± 2.4, and 14.1 ± 3.3 MPa, respectively; for Transbond 11.1 ± 4.6, 13.6 ± 4.5, and 12.9 ± 4.4 MPa, respectively; and for M-Bond 8.7 ± 2.7, 10.4 ± 2.4, and 12.4 ± 3.4 MPa, respectively. After the three debondings the mean shear bond strength increased significantly from the first to the third debonding for Rely-a-Bond and M-bond ($P \leq .001$), but did not change for Transbond ($P = .199$).

Conclusions: The original hypothesis is not rejected. The two self-etching primers showing higher or comparable bond strength to the conventional phosphoric etch with less adhesive remnant on the enamel surface after the first debonding. With repeated bonding/debonding, the differences in the bond strength, ARI, and failure site were not significantly different. There was no difference in the clinical performance of the three adhesive systems ($P = .667$).

KEY WORDS: Rebonding; Bond strength; Adhesive remnant index

INTRODUCTION

Direct bonding is a significant development in dentistry that has been applied in all fields of dentistry including orthodontics,[1–4] since its introduction by Buonocore[5] in 1955. Conventional adhesive systems employ three different agents, ie, an enamel conditioner, a primer solution, and an adhesive resin. Self-etch systems, on the other hand, combine the conditioning and priming agents into a single acidic primer solution. Scanning electron microscopy studies indicate that the etching pattern of self-etch primers is less deep than phosphoric acid etching.[6,7] However, no correlation has been found between the morphological pattern of the etch and the bond strength.[8–11]

Bracket rebonding is a frequent and undesirable problem during orthodontic treatment which requires an understanding of which variable most affects the bond strength. The literature provides inconsistent findings regarding the shear bond strength of rebonded brackets with some reporting lower bond strength while others report comparable or higher bond strength.[12–16] Researchers stress the importance of clinical studies because of the inherent limitations of the laboratory studies.[17–20]

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The hypothesis of this study was that with repeated bonding, the bond strength, the adhesive remnant index scores (ARI), and the failure sites of adhesive systems, two self-etch primers and a phosphoric acid etch would show no significant differences for bonding orthodontic brackets. The study included a clinical component in an attempt to correlate the laboratory and the clinical performance of the bonding systems.

MATERIALS AND METHODS

The in vitro testing used 60 freshly extracted human upper premolars stored in an aqueous solution of thymol (0.1% weight/volume). The use of extracted human teeth has been exempted as research that does not involve human subjects as defined in 45 CFR 46.102(f) under research protocol 1995-0777 from IRB 1, Office for the Protection of Human Subjects, University of Illinois at Chicago. The teeth were embedded in self-curing acrylic resin placed in flexible molds (Buehler, Lake Bluff, Ill) with only the buccal surface exposed and oriented parallel to the bottom of the mold. The teeth were randomly divided into three equal groups.

The three adhesive systems were Rely-a-Bond fluoride releasing no mix adhesive system with 37% liquid phosphoric acid for etching (Reliance Orthodontics Products Inc, Itasca, Ill), Transbond XT light cure adhesive and Transbond Plus Self-Etching Primer (3M Unitek, Monrovia, Calif), and M-Bond self-cured, two-part, powder/liquid resin cement with a self-etching primer (Tokuyama Dental Corporation, Tokyo, Japan). The first two systems are bis-phenol-A-diglycidyl-methacrylate (Bis-GMA) resin based, and the third is 4-methacryloxy ethyl trimellitate anhydride (4-META) resin based.

Premolar stainless steel brackets (Mini twin, American Orthodontics, Sheboygan, Wis) were used. The buccal surface of each tooth was cleaned with non-fluoride oil-free pumice paste using a nylon brush attached to a slow-speed hand piece for 5 seconds, and then the tooth was rinsed with water for 10 seconds and dried with an oil-free air spray. Brackets were bonded to the teeth according to the manufacturer's instructions for each adhesive system and stored in distilled water at 37°C until testing.

Bracket debonding was performed 24 hours after bonding in a universal testing machine (LLOYD Instruments; Segensworth, Fareham, England) with an occlusal-gingival load applied to the bracket, producing a shear force at the bracket tooth interface. The cross-head speed was 2.0 mm/min, and the failure load in Newtons was divided by 10.26 mm^2 (bracket bonding surface as provided by the manufacturer and confirmed by measurement) to determine the shear bonding strength in MPa.

After debonding, all visible residual adhesive was removed with a sharp scaler. The removal of the composite was considered complete when the tooth surface felt smooth and appeared free of composite to the naked eye under an operatory lamp. The bonding/debonding procedures were repeated two additional times using new brackets each time. The same order of the teeth was kept from the first to the third bonding.

The ARI and failure site assessment was completed immediately after each shear bond strength debonding test under 10× magnification. The ARI evaluation used the 4-point scale of Artun and Bergland[21] where 0 indicates no adhesive left on the tooth surface, implying bond fracture occurred at the resin/enamel interface; 1 indicates less than half the resin left on the tooth surface, implying bond fracture occurred predominantly at the resin/enamel interface; 2 indicates more than half the resin left on the tooth surface, implying bond fracture occurred predominantly at the bracket/resin interface; and 3 indicates all resin left on the tooth surface, with a distinct impression of the bracket base, implying bond fracture occurred at the bracket/resin interface.

The in vivo testing was done on 15 female patients between 12 and 14 years of age who required comprehensive orthodontic treatment with full fixed appliances at Mansoura University, Faculty of Dentistry, Orthodontic Department. The study followed the guidelines for clinical studies for the protection of human subjects as approved by the Faculty of Dentistry, Mansoura University, Mansoura, Egypt.

The research design adopted a randomized clinical trial with patients divided randomly into three equal groups. For the first group Transbond and Rely-a-Bond adhesive systems were used; for the second group M-Bond and Rely-a-Bond adhesive systems were used; and for the third group M-Bond and Transbond adhesive systems were used. Brackets were bonded with a split-mouth design; the right or left side application of one material in either arch was alternated. The same type of bracket used in the in vitro testing was used. The date of placement of each bracket and the dates of bond failures were recorded in the patients' records. Patients were given strict instructions to record accurately when a bracket failure was discovered and to contact the clinic immediately. Failures were recorded when the initial arch wires were ligated and then on a monthly basis for 12 months. A similar arch wire sequence and approach to treatment mechanics were adopted for each case.

Descriptive statistics, including the mean, standard deviation, and minimum and maximum values of the shear bond strength were calculated for each of the

Table 1. Descriptive Statistics of the In Vitro Shear Bond Strengths for First, Second, and Third Debondings of the Three Adhesive Systems

	Shear Bond Strength					
	Rely-a-Bond, MPa		Transbond, MPa		M-Bond, MPa	
	Mean	Range	Mean	Range	Mean	Range
First debonding	8.4 ± 1.8	4.9–12.1	11.1 ± 4.6	4.4–18.8	8.7 ± 2.7	2.7–13.9
Second debonding	10.3 ± 2.4	6.7–14.7	13.6 ± 4.5	6.3–20.8	10.4 ± 2.4	6.7–16.2
Third debonding	14.1 ± 3.3	7.6–18.2	12.9 ± 4.4	6.3–22.9	12.4 ± 3.4	6.4–20.6

adhesive systems tested. A two-way analysis of variance (ANOVA) was performed with the two variables, the adhesive system, and the bonding sequence. Because the two-way ANOVA showed significant interaction between the two variables, a subsequent analysis using a one-way ANOVA followed by a Scheffè post-hoc multi means comparison test when needed was performed. A Kruskal-Wallis test was used in conjunction with a Mann-Whitney test to compare the differences in the ARI scores, the failure sites, and the clinical failure rate between the three adhesive systems. For analysis of the failure site, the ARI scores 1 and 2 were combined to indicate mixed type failure. Significance for all statistical tests was at $P \leq .05$.

RESULTS

Descriptive statistics of the shear bond strengths for the three adhesive systems at each debonding are shown in Table 1. The two-way ANOVA, Table 2, indicated a significant difference of the shear bond strength between the adhesive systems ($P = .003$), between the debonding sequences ($P < .001$), and the interaction ($P = .036$) between these two variables. The one-way ANOVA, Table 3A, indicated after repeated debonding that the mean shear bond strength did not change for Transbond ($P = .199$), but changed significantly for Rely-a-Bond ($P < .001$) and M-Bond ($P = .001$). The Scheffè post-hoc test showed that the bond strength increased significantly from the first to the third debonding for Rely-a-Bond ($P < .001$) and for M-bond ($P = .001$) groups. A significant difference in the bond strength, Table 3B, was observed between the three adhesive systems for the first debonding ($P = .020$) and second debonding ($P = .002$) only. The Scheffè analysis showed that Transbond had a significantly higher bond strength after the first ($P = .036$) and the second debonding ($P = .009$) than Rely-a-Bond; the bond strength was not significantly different between Rely-a-Bond and M-Bond after the first ($P = .946$) and second ($P = .999$) debondings.

The results of the Kruskal-Wallis analysis demonstrated that the ARI scores, Table 4, after the first debonding of the three adhesive systems were significantly different ($P = .001$). The Mann-Whitney test showed a significantly higher ARI score for Rely-a-Bond than either Transbond ($P = .011$) or M-Bond ($P = .001$). The ARI scores were not significantly different between the two self-etching groups ($P = .383$). The ARI scores were not significantly different after the second ($P = .098$) or third debondings ($P = .662$) for the three adhesive systems.

The failure site after the first debonding for the three adhesive systems was significantly different ($P = .006$) between Rely-a-Bond and both Transbond ($P = .046$) and M-Bond ($P = .009$), with no difference between Transbond and M-Bond ($P = .495$). The two self-etching adhesive systems (Transbond and M-Bond) showed a higher number of failures between the adhesive and the enamel than Rely-a-Bond, which showed a higher number of mixed failures. There was no difference in the failure site between the three adhesive systems after the second ($P = .206$) and third debonding ($P = .319$).

The distribution of the clinical failures for the three adhesive systems, Table 5, showed no difference in the overall clinical failure rate ($P = .627$) between the three adhesive systems. There was also no difference in the clinical failure rate in the maxillary arch ($P =$

Table 2. Results of Two-Way ANOVA of the Shear Bond Strength for the Variables Adhesive Systems, and the Interaction Between the Two Variables

	Two-Way ANOVA of Shear Bond Strength			
	Sum of Squares	Degree of Freedom	F	*P* Value
Adhesive systems	138.86	2	5.92	.003*
Debonding	423.78	2	18.06	<.001*
Adhesive systems × debonding	123.15	4	2.62	.036*

* Significant at $P \leq .05$

Table 3. Results of One-Way ANOVA Comparing the Shear Bond Strength for (A) Each of the Three Adhesive Systems After the Three Debonding Sequences and (B) Each of the Debonding Sequences for the Three Adhesive Systems

ANOVA of the Adhesive Systems and Debonding		
(A) Adhesive Systems		
	F	*P* Value
Rely-a-Bond	25.27	<.001*
Transbond	1.66	.199
M-Bond	8.59	.001*
(B) Debonding		
	F	*P* Value
First debonding	4.19	.020*
Second debonding	6.78	.002*
Third debonding	1.05	.358

* Significant at $P \leq .05$

.990) and in the mandibular arch ($P = .469$) between the three groups.

DISCUSSION

This study demonstrated a significant difference in the bond strength between the three adhesive systems and the debonding sequences. The bond strength of the self-etch Transbond after the first debonding was significantly higher than M-Bond and Rely-a-Bond, which were equivalent. This is in agreement with the findings of other in vitro studies.[22–26] The high bond strength with the use of self-etch primers has been attributed to nanoretentive interlocking between the enamel crystallites and the resin, potential resin-to-enamel bonding, and chemical bonding.[11,27] After the third debonding, the bond strength was not different among the three adhesive systems. Transbond demonstrated no change in bond strength from rebonding, but the other two adhesive systems demonstrated an increase in bond strength. This contradicts reported inconsistent, but generally weaker, bond strength after repeated bonding with a conventional adhesive system.[15,16] However, in these studies the bond strength was tested a half hour after bonding vs 24 hours in this study, molars instead of premolars, and the residual adhesive was removed with a carbide bur. Numerous sources of variability in the bonding protocol can affect the bond strength within individual specimen including premolar/molar crown contour variations, the quantitative aspects of adhesive and force utilization during bonding, the distance of the point of force application from the bracket base surface, the method of adhesive removal, and interfacial characteristics of the bracket adhesive complex.[28]

The frequency of lower ARI scores after the first debonding was significantly higher in Transbond and M-Bond than in Rely-a-Bond. In agreement with other studies,[29,30] the ARI scores of the failure site after the first debonding showed that the two self-etching adhesive systems had a higher number of failures between the adhesive and the enamel than in Rely-a-Bond, which had a higher number of mixed type failures. High ARI values observed with conventional phosphoric etch systems have been attributed to the improved mechanical union between the composite and enamel.[24,26,29,30] The ARI assessment is subjective and can be affected with the mode of observation; however, previous studies found the system of value and found that interobserver and intraobserver variability was low.[21,30]

Scarring of the enamel after resin removal is well-documented for the different methods of resin removal[31,32] and may partially explain the increase in bond strength and ARI scores that were observed in this study after the second and third debondings. These increases may also be attributed to the presence of residual adhesive on the surface to which the adhesive used in the second or third bonding can be mechanically or chemically bonded.

Asgari et al[33] evaluated the clinical failure rate of Transbond Plus Self Etching Primer in comparison with 37% phosphoric acid for bonding orthodontic brackets and found a failure rate of 0.57% in the self-etching group versus 4.60% in the conventional phosphoric acid etch group. On the other hand, in a 6-month study by Ireland et al[34] the percentage of in vivo bond failures was 10.99% in the self-etching group (Transbond Plus Self Etching Primer) and 4.95% in the conventional phosphoric acid etch group. In this study the overall clinical failure rates among the

Table 4. Frequency Distribution of Adhesive Remnant Index (ARI) Scores for the Three Adhesive Systems after First, Second, and Third Debondings

	Frequency Distribution of Adhesive Remnant Index Scores												
		Rely-a-Bond ARI Scores				Transbond ARI Scores				M-Bond ARI Scores			
	N	0	1	2	3	0	1	2	3	0	1	2	3
First debonding	20	2	10	7	1	9	9	1	1	12	7	1	0
Second debonding	20	1	4	15	0	1	6	10	3	0	13	6	1
Third debonding	20	0	1	16	3	0	7	8	5	1	4	9	6

Table 5. Distribution of Clinical Failure Rates by Tooth Type for the Three Adhesive Systems

	Distribution of Clinical Failure Rates								
	Rely-a-Bond			Transbond			M-Bond		
		Failed			Failed			Failed	
Tooth	Placed	N	%	Placed	N	%	Placed	N	%
Overall	80	7	8.8	80	4	5.0	80	5	6.3
Maxilla	40	2	5.0	40	2	5.0	40	2	5.0
Mandible	40	5	12.5	40	2	5.0	40	3	7.5

three tested adhesive systems, 8.75%, 5.00%, and 6.25% for Rely-a-Bond, Transbond, and M-Bond, respectively, were not significantly different. This may be explained by the in vitro shear bond strengths of the three adhesive systems being within the range (6–8 MPa) considered adequate for routine clinical use.[35] To control the confounders, strict criteria for patient selection were necessary, which made the number of patients low; however, the number of brackets evaluated was 240. A larger patient sample would be beneficial; however, the observed statistical analysis for the overall failure rate ($P = .627$) would probably not be affected by an increase in sample size. The fact that the patients were all female is not expected to impact the clinical portion, due to the increase in female participation in organized athletics activities, a possible source of bracket failure.

CONCLUSIONS

- The original hypothesis was essentially confirmed with the self-etch primers showing comparable or higher bond strength, a slightly lower ARI, and a higher failure rate between the enamel and the adhesive than the conventional phosphoric etch after the first debonding.
- However, after repeated bonding/debonding, especially in the third bonding/debonding sequence, there was no difference in the three variables among the three adhesive systems.
- There was no difference in the clinical performance of the three adhesive systems.

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REFERENCES

1. Newman GV. Adhesion and orthodontic plastic attachments. *Am J Orthod.* 1969;56:573–88.
2. Barbosa VL, Almeida MA, Chevitarese O, Keith O. Direct bonding to porcelain. *Am J Orthod Dentofacial Orthop.* 1995;107:159–164.
3. Surmont P, Dermaut L, Martens L, Moors M. Comparison in shear bond strength of orthodontic brackets between five bonding systems related to different etching times: an in vitro study. *Am J Orthod Dentofacial Orthop.* 1992;101:414–419.
4. Britton JC, McInnes P, Weinberg R, Ledoux WR, Retief DH. Shear bond strength of ceramic orthodontic brackets to enamel. *Am J Orthod Dentofacial Orthop.* 1990;98:348–353.
5. Buonocore MG. A simple method of increasing the adhesion of acrylic filling materials to enamel surfaces. *J Dent Res.* 1955;34:849–853.
6. Hayakawa T, Kikutake K, Nemoto K. Influence of self etching primer treatment on the adhesion of resin composite to polished dentin and enamel. *Dent Mater.* 1998;14:99–105.
7. Hanning M, Reinhardt KJ, Bott B. Self-etching primer vs. phosphoric acid: an alternative concept for composite-to-enamel bonding. *Oper Dent.* 1999;24:172–180.
8. Di Hipólito V, Fernando de Goes M, Rocha de Oliveira Carrilho M, Chan DCN, Daronch M, Sinhoreti MAC. SEM evaluation of contemporary self-etching primers applied to ground and unground enamel. *J Adhes Dent.* 2005;7:203–211.
9. Pashley DH, Tay FR. Aggressiveness of contemporary self etching adhesives. Part II: etching effects on unground enamel. *Dent Mater.* 2001;17:430–444.
10. 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;28:215–235.
11. Yoshida Y, Nagakane K, Fukuda R, et al. Comparative study on adhesive performance of functional monomers. *J Dent Res.* 2004;83:454–458.
12. Wright WI, Powers JM. In vitro tensile bond strength of reconditioned brackets. *Am J Orthod.* 1985;87:247–252.
13. Jassem HA, Retief DH, Jamison HC. Tensile and shear strengths of bonded and rebonded orthodontic attachments. *Am J Orthod.* 1981;79:661–668.
14. Leas TJ, Hondrum S. The effect of rebonding on the shear bond strength of orthodontic brackets—a comparison of two clinical techniques. *Am J Orthod Dentofacial Orthop.* 1993;103:200–201.
15. Bishara SE, Vonwald L, Laffoon JF, Warren JJ. The effect of repeated bonding on the shear bond strength of a composite resin orthodontic adhesive. *Angle Orthod.* 2000;70:435–441.
16. Bishara SE, Laffoon JF, Vonwald L, Warren JJ. The effect of repeated bonding on the shear bond strength of different orthodontic adhesives. *Am J Orthod Dentofacial Orthop.* 2002;121:521–525.
17. Miller JR. Commentary: basic concepts concerning bracket failure research. *Angle Orthod.* 1997;67:167–168.
18. Eminkahyagil N, Korkmaz Y, Gokalp S, Baseren M. Shear bond strength of orthodontic brackets with newly developed antibacterial self-etch adhesive. *Angle Orthod.* 2005;75:843–848.
19. Sunna S, Rock WR. Clinical performance of orthodontic brackets and adhesive systems: a randomized clinical trial. *Br J Orthod.* 1998;25:283–287.
20. Eliades T, Brantley WA. The inappropriateness of conventional orthodontic bond strength assessment protocols. *Eur J Orthod.* 2000;22:13–23.
21. Artun J, Bergland S. Clinical trials with crystal growth conditioning as an alternative to acid-etch enamel pretreatment. *Am J Orthod.* 1984;85:333–340.
22. Arnold RW, Combe EC, Warford JH. Bonding of stainless

steel brackets to enamel with a new self-etching primer. *Am J Orthod Dentofacial Orthop.* 2002;122:274–276.
23. Rajagopal R, Padmanabhan S, Gnanamani J. A comparison of shear bond strength and debonding characteristics of conventional, moisture-insensitive, and self-etching primers in vitro. *Angle Orthod.* 2004;74:264–268.
24. Cacciafesta V, Sfondrini MF, De Angelis M, Scribante A, Klersy C. Effect of water and saliva contamination on shear bond strength of brackets bonded with conventional, hydrophilic, and self-etching primers. *Am J Orthod Dentofacial Orthop.* 2003;123:633–640.
25. Turk T, Elekdag-Turk S, Isci D. Effects of self-etching primer on shear bond strength of orthodontic brackets at different debond times. *Angle Orthod.* 2007;77:108–112.
26. Zeppieri IL, Chung CH, Mante FK. Effect of saliva on shear bond strength of an orthodontic adhesive used with moisture-insensitive and self-etching primers. *Am J Orthod Dentofacial Orthop.* 2003;124:414–419.
27. Hanning M, Bock H, Bott B, Hoth-Hanning W. Inter-crystallite nanoretention of self-etching adhesives at enamel imaged by transmission electron microscopy. *Eur J Oral Sci.* 2002;110:464–470.
28. Bishara SE, Gordan VV, VonWald L, Olson ME. Effect of an acidic primer on shear bond strength of orthodontic brackets. *Am J Orthod Dentofacial Orthop.* 1998;114:243–247.
29. Buyukyilmaz T, Usumez S, Karaman AL. Effect of self-etching primer on bond strength—are they reliable? *Angle Orthod.* 2003;73:64–70.
30. Oliver RG. Bond strength of orthodontic attachments to enamel from unerupted and erupted young permanent teeth. *Eur J Orthod.* 1986;8:123–126.
31. Eminkahyagil N, Arman A, Çetinsahin A, Karabulut E. Effect of resin-removal methods on enamel and shear bond strength of rebonded brackets. *Angle Orthod.* 2006;76:314–321.
32. Hosein I, Sherrieff M, Ireland AJ. Enamel loss during bonding, debonding, and cleanup with use of a self-etching primer. *Am J Orthod Dentofacial Orthop.* 2004;126:717–724.
33. Asgari S, Salas A, English J, Powers J. Clinical evaluation of bond failure rates with a new self-etching primer. *J Clin Orthod.* 2002;36:687–689.
34. Ireland AJ, Knight H, Sherriff M. An in vivo investigation into bond failure rates with a new self-etching primer system. *Am J Orthod Dentofacial Orthop.* 2003;124:323–326.
35. Bishara SE, Ostby AW, Laffoon JF, Warren JJ. The effect of modifying the self-etchant bonding protocol on the shear bond strength of orthodontic brackets. *Angle Orthod.* 2007;77:504–508.