



Effects of Different Adhesion Promoters and Deproteinizing Agents on the Shear Bond Strength of Orthodontic Brackets: An in Vitro Study

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ABSTRACT:

Aim: The present in-vitro study was undertaken to evaluate the effects of different adhesion promoters and deproteinizing agent.

Material and Methods: One hundred human maxillary premolars, without caries or fillings, were used. The teeth were divided into 4 groups of 25, Group 1 control (37% H₃PO₄), Group 2 (37% H₃PO₄ + Ortho Solo), Group 3 (37% H₃PO₄ + Assure Universal Bonding Resin), Group 4 (37% H₃PO₄ + Enhance LC).

Results: The Kruskal-Wallis test showed significant differences ($P = .00$) in shear bond strength. The Mann-Whitney test for 2 independent samples established the differences between the system of greater bond strength with respect to the 3 systems that showed lower average values of bond strength: ($P = .001$), ($P = .001$), and ($P = .002$)

Conclusion: It was concluded that adhesion promoters and deproteinizing agents can be used to enhance the shear bond strength of orthodontic brackets. Among all the groups Ortho Solo showed the highest bond strength when used with Transbond™ XT.

Introduction

In the past few years, great technological advances have brought numerous advantages in the field of dentistry and particularly to orthodontics. New materials and techniques help in simplifying the clinical procedures. For decades, orthodontists have approached successful, reliable orthodontic bonding in offices around the world replacing traditional bonding.¹

The words “adhesion promoters” were first used to designate molecules that adhered chemically to dental structures.² One of the first molecules tested was N-phenylglycine-glycidyl methacrylate, which was proposed by Bowen in 1965.³ The first dentin adhesive was created with this molecule,⁴ but commercial products showed poor clinical results.⁵ Adhesion to the dentin was unsuccessful until the introduction of hydrophilic resins,⁶ agents that promote adhesion to dentin.⁷



The incorporation of hydrophilic monomers to adhesive systems facilitates the infiltration of resin into the etched enamel, reducing interfacial porosity and therefore adhesive defects, achieving greater bond strength after polymerization.⁸ Based on these concepts, adhesion promoters have been introduced in orthodontics. They incorporate hydrophilic resins as a component and are intended to improve bond strength and integrity. However, an increase in bond strength could compromise the safety of debonding.⁹

One of the adhesion boosters is Enhance LC (Reliance, Itasca, Illinois, USA) which can improve the bond strength to a variety of surfaces including alloy, porcelain, irregular enamel surfaces as well as normal enamel. It consists of hydroxyethyl methacrylate (HEMA), tetrahydrofurfuryl, cyclohexane dimethacrylate, and ethanol. The HEMA molecule contains two functional, one hydrophobic, and another hydrophilic group.¹⁰

Recently, a product called Assure R Universal Bonding Resin (Reliance Orthodontic Products, Inc., Itasca, III) has been introduced to the orthodontic community. The manufacturer mentions that Assure R Universal Bonding Resin has the adhesion promotion capacity of Enhance LC, which improves bond strength to a variety of surfaces and, in addition, eliminates the need for the bonding agent.¹¹

Hence, the present in-vitro study was undertaken to evaluate the effects of different adhesion promoters and deproteinizing age.

Material and Methods

One hundred human maxillary premolars, without caries or fillings, were used. The teeth had been extracted for reasons unrelated to the objectives of this study and with the patients' informed consent.

The teeth were washed to remove any traces of blood and then placed in 0.1% thymol solution. They were stored in distilled water for up to 1 month; the water was changed periodically to prevent deterioration. Before testing, the teeth were set in a 4-cm long copper cylinder with an internal diameter of 3 cm, and the roots were set in type IV die stone.

The teeth were divided into 4 groups of 25, Group 1 control (37% H₃PO₄), Group 2 (37% H₃PO₄ + Ortho

Solo), Group 3 (37% H₃PO₄ + Assure Universal Bonding Resin), Group 4 (37% H₃PO₄ + Enhance LC), and metal maxillary premolar brackets (Victory Series, 3M Unitek) were bonded on their buccal surfaces, according to the manufacturers' instructions. The base area of each bracket was calculated (mean, 9.79 mm²) by using image analysis equipment and MIP 4 software (Microm Image Processing Software, Digital Image Systems, Barcelona, Spain) under 400 times magnification. For all groups, the buccal surfaces were polished with a rubber cup and polishing paste (Détartrine, Septodont, Saint-Maur, France); then the area where the bracket was to be placed was etched with 37% o-phosphoric acid gel (Total Etch, Ivoclar, Vivadent, Schaan, Liechtenstein) for 30 seconds and washed with water. After washing, for groups 1 and 3, the enamel surface was completely dried with compressed air; for groups 2 and 4, the enamel was air-dried, leaving the surface slightly moist.

Group 1 (n = 25)

The surface of the enamel of premolars was etched with 37% phosphoric acid (3M ESPE Scotchbond etching gel, St Paul, MN) for 15 s, washed with water, and dehydrated with moisture-free squeezed air for 20 s followed by primer application. The orthodontic brackets were bonded using Transbond XT adhesive (3M/Unitek, Monrovia, Calif) followed by photopolymerization (LED, Woodpecker) for 40 s (10 s on each side).

Group 2 (n = 25)

One coat of Ortho Solo was applied to the etched enamel. No drying or curing step is necessary. Immediately the orthodontic brackets were bonded with Transbond XT followed by photopolymerization as in control/Group 1. Ortho Solo itself acts as primer.

Group 3 (n = 25)

Two layers of Assure Universal Bonding Resin were applied to the etched enamel. The surface was lightly air-dried to evaporate the solvent; the orthodontic bracket was bonded immediately with Transbond XT followed by photopolymerization as in control/Group 1.

Group 4 (n = 25)

Two coats of Enhance LC were applied to the etched enamel, after application of second coat the enamel



surface was completely air-dried until shiny. A thin layer of Transbond XT primer was applied directly to the Enhance LC coated layer and light-cured for 10 s. The orthodontic bracket was immediately bonded after application with Transbond XT followed by photopolymerization as in control/Group 1.

The specimens were immersed in distilled water at a temperature of 37°C for 24 hours.⁹

Shear bond strength was measured with a universal testing machine (Autograph AGS-1KND, Shimadzu, Japan) with a 1-kilonewton load cell connected to a metal rod with 1 end angled at 30°. The cross-head speed was 1 mm/minute.¹²

The teeth were set at the base of the machine so that the sharp end of the rod incised into the area between the base and the wings of the bracket, exerting a force parallel to the surface of the tooth in an occlusoapical direction. The force required to debond each bracket was registered in newtons (N), and converted into megapascals as a ratio of newtons to the bracket's surface area (MPa N/mm²).

After debonding, the percentage of the surface of the bracket base covered by adhesive was determined with image analysis equipment (video camera connected to a microscope) and MIP 4 software. The percentage of the area still covered by adhesive on the tooth was obtained by subtracting the area of adhesion covering the bracket base from 100%. Then each tooth was assigned an adhesive remnant index (ARI) value according to the following criteria¹⁰: 0, no adhesive left on the tooth; 1, less than half the adhesive left on the tooth; 2, more than half the adhesive left on the tooth; 3, all adhesive left on the tooth. Possible enamel fractures were also registered macroscopically.

Adhesive remnant index (ARI)

The enamel surfaces of all the test samples were examined after shear bond strength estimation under a stereomicroscope at 16× magnification to determine the amount of the adhesive resin remaining on the surface and then classified according to the ARI. The ARI scores were arranged according to the criteria given by Artun and Bergland¹² from 0 to 3, with 0 indicating no composite left on the enamel; 1, less than half of the composite left; 2, more than half of the composite left;

and 3 all of the composite remained on the tooth surface.

Statistical analysis

The Kolmogorov-Smirnov normality test and the Levene variance homogeneity test were applied to the bond strength data. Because the data were not normally distributed, significant difference was evaluated ($P \leq .05$) by using the Kruskal-Wallis test, finding groups that were significantly different with the Mann-Whitney test for 2 independent samples. To prevent an accumulation of errors from multiple comparisons, the significance level ($P \leq .05$) was modified by dividing it between the number of comparisons made (Bonferroni correction), and $P \leq .003$ was considered significant.

ARI values were analyzed by using the Pearson chi-square test and an analysis of corrected residuals.

Enamel fractures were evaluated with the Pearson chi-square test and an analysis of corrected residuals.

A significance level of $P \leq .05$ was set for both the Pearson chi-square test and the analysis of corrected residuals (residual ≥ 2 implies $P \leq .05$).

The Kolmogorov-Smirnov test and the Levene homogeneity test of variances were applied to the data for the percentage area of adhesive remaining on the tooth. Because there was neither homogeneity of variances nor normal distribution, they were also analyzed with the Kruskal-Wallis test and the Mann-Whitney test for 2 independent samples, taking the Bonferroni correction into account.

The statistical analysis was made with the statistical program SPSS 10.0 for Windows (SPSS, Chicago, Ill).

Results

Table I. Shear bond strength (MPa)

Groups	N	Mean	Median	SD	Minimum	Maximum
Group I	25	12.40	11.50	5.01	6.60	28.10
Group II	25	12.65	12.78	3.20	8.90	22.45
Group III	25	13.70	13.68	4.75	6.15	36.5



Group IV	25	16.60	14.52	5.50	6.36	32.1
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The Kruskal-Wallis test showed significant differences ($P = .00$) in shear bond strength. The Mann-Whitney test for 2 independent samples established the differences between the system of greater bond strength with respect to the 3 systems that showed lower average values of bond strength: ($P = .001$), ($P = .001$), and ($P = .002$) (Table I).

Table II. ARI and enamel fractures

ARI						
Groups	N	0	1	2	3	Enamel Fracture
Group I	25	0	7	18	0	4
Group II	25	0	4	20	0	2
Group III	25	1	9	19	0	4
Group IV	25	0	12	12	0	3

The ARI values and enamel fractures are shown in Table II. The Pearson chi-square test indicated significant differences ($P = .00$) in ARI values. Enamel fractures occurred in all groups. Analysis of these fractures with the Pearson chi-square test did not show significant differences between the groups ($P = 0.4$). However, the analysis of corrected residues indicated a significant association between Transbond XT (residue =2) and the absence of fractures.

Discussion

The benefits of successful orthodontic treatment are well known today. While orthodontic bonding is generally successful, orthodontic bond failure occurs at 4.7–6.0% (O'Brien et al. 1989)¹⁴ for a variety of reasons such as poor operator technique, moisture contamination, and excessive masticatory forces. For effective orthodontic bonding, SBS values between 5.9 MPa and 7.8 MPa are suggested to be sufficient.

Noncompliant patients, fluoresced and hypocalcified teeth, debonded and recycled brackets also require additional bond strength. To achieve good bond strength, proper enamel conditioning is a must. Buonocore,¹⁵ was the first to demonstrate that acrylic resin adhesion was more when H₃PO₄ of 85% concentration was used on the tooth. Since then phosphoric acid has been in routine use for etching the enamel to receive the adhesive resin.

It has been suggested that bond strength values between 5.9 and 7.8 MPa are sufficient for a clinically effective orthodontic bonding.¹⁶ Greater bond strengths are sometimes required with uncooperative patients or fluoridated teeth, or when humidity control is difficult. Enhance L.C. is an adhesion promoter for specific use in orthodontics. The manufacturer recommends application with adhesive systems from its product range. Thus, Enhance L.C. was used with a recommended system, Light-Bond, and a light-cured composite resin adhesive from another manufacturer (Transbond XT).

The bond strength provided by the Light Bond system was greater than the strength achieved with Transbond XT, but no significant differences were found between the systems.

Our results showed that Enhance L.C. produced a greater increase in bond strength for Light Bond but the increase was not significant for either adhesive. Recent research has shown no significant increase in bond strength when Enhance L.C. was used with Light Bond on new brackets, but, when used on rebonded brackets, a reduction (although not significant) in bond strength occurred.¹⁷ Enhance L.C. was already evaluated by applying it to the base of rebonded brackets, but this application produced no improvement in bond strength.¹⁸

The results from the ARI and the analysis of the percentage of tooth area with remnant adhesive showed that Enhance L.C. did not produce significant increases in the amount of adhesive remaining on the enamel. These results concur with previous research.¹⁷ It was also observed that Light Bond left significantly less adhesive on the enamel than Transbond XT after debonding, whether either system was used with Enhance L.C. This is an advantage because cleaning



adhesive off teeth after debonding always causes some loss of enamel.¹⁹

The standard deviations and ranges for the bond strength values were wide in all groups (Table I). This variation might reflect the diversity in proper fit between the bracket base and the anatomically variable buccal curvature of the crowns.¹⁷

There is wide disparity among the various in-vitro studies (ie, types of teeth used, sample storage conditions before testing, machine head speed) that made it difficult to compare the bond strength values obtained for the different systems. The use of different units for bond strength measurements adds to the difficulty of comparing results. The force required to debond each bracket in our study was registered in newtons and converted into megapascals as a ratio of newtons to surface area of the bracket (MPa N/mm²). We think that, to properly compare different studies about bond tests in orthodontics, it is necessary to determine bond strength, because, when we use force of debond, we cannot compare brackets with different geometries. Clinical significance between bonding systems will be found only when oral strength conditions are between the corresponding values for the different systems evaluated. Obviously, if these oral strength conditions were usually above any of the adhesive systems, no clinical significance will be found regardless of the statistical significance among them. Therefore, in-vivo research must be carried out to confirm laboratory results.

Conclusion

All the adhesion promoters and deproteinizing agents used in this study provide a significant increase in shear bond strength with Ortho Solo and Enhance LC, having statistically significant increase in Shear bond strength as compared with the conventional method of bonding. An increase in the ARI scores of all the experimental groups demonstrates better adhesion of composite to the enamel surface, leading to a safer debonding after treatment as the fracture interface shifts from enamel adhesive to the adhesive bracket interface thus preventing enamel micro fractures. Therefore, the use of these agents gains importance where extra bond strength is required like in fluoresced, hypocalcified, and premature enamel. Hence, in vitro studies give only a hint about the optimal bonding procedure.

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