Original Article

A Comparison of the Shear Bond Strength of a Resin Cement and Two Orthodontic Resin Adhesive Systems

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Abstract: The object of this study was to compare the shear bond strength and the quantity of adhesive remaining on the tooth after the debonding of brackets bonded with two light-cured orthodontic resin adhesive systems (Transbond XT and Light-Bond) and a dual-cured resin cement (RelyX Unicem). Seventy-five premolars were divided into three groups. In each group, brackets were bonded with one of the adhesives according to the manufacturer's instructions. Shear bond strength was measured using a universal test machine at a crosshead speed of one mm/min, and adhesive remnant was quantified using image analysis equipment. Our results showed that the resin cement produced significantly lower bond strength than the two orthodontic resin adhesive systems. It was also observed that the bond strength produced by Light-Bond was significantly greater than that of Transbond XT. RelyX left significantly less remnant adhesive than Transbond XT and Light-Bond. Between the two orthodontic systems, Light-Bond left significantly less adhesive on the tooth than Transbond XT. (*Angle Orthod* 2004;75:109–113.)

Key Words: Orthodontic adhesives; Resin cements; Shear bond strength

INTRODUCTION

The term adhesion is used in different ways in different fields. Adhesion implies the existence of interatomic or intermolecular attraction.[1] In dentistry, we often use this term to refer to mechanical unions in which union is produced by microretention without any chemical interaction between substrata. By mechanical retention, we understand, for instance, the union produced on enamel etched with resin adhesive systems.

Buonocore[2] proved an increase in adhesion between tooth enamel and the acrylic materials in use at that time when he treated the enamel surface beforehand with a phosphoric acid solution. When phosphoric acid is applied to enamel, a selective dissolution of the hydroxyapatite crystals occurs. This dissolution produces microporosities into which a fluid monomer can penetrate.[3] The resin seeps into the porous enamel, and when polymerized, a micromechanical union between this and the enamel occurs.[4] The union between an orthodontic bracket and resin is also a mechanical union.

There are other materials, such as glass ionomer cements, which, thanks to their chemical composition, have an inherent adhesive capacity.[5,6] These adhere chemically to enamel, to dentine, to nonprecious metals, and to plastics.

Advances in the formulation of resins have led to the production of resin cements capable of forming chemical union with enamel, dentine, ceramic, metals, and composite materials.[7] The main advantage of materials that adhere chemically to enamel is that they do not require prior acid etching. Research is in general agreement that acid etching causes iatrogenic effects to the enamel surface including enamel loss.[8–11] It is estimated that the loss of enamel surface during etching is between 10 and 30 μm.[12]

Another problem is that resin tags remain on the enamel after debonding. In time, this can cause the retention of plaque, formation of caries, and changes to color.[11] Moreover, enamel surface loss, which is rich in fluoride, may make the enamel more susceptible to demineralization.[13]

The aim of this study was to compare shear bond strength and the amount of adhesive remaining on the enamel after debonding of brackets bonded with two light-

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cured orthodontic resin adhesive systems (Transbond XT and Light-Bond) and a dual-cured resin cement which requires no etching (RelyX Unicem).

MATERIALS AND METHODS

Teeth

A total of 75 human upper premolars that were free from caries and fillings were used. These teeth had been extracted for reasons unrelated to the objectives of this study and with the informed consent of the patients. The project had been approved by the Murcia University Bioethical Commission.

The teeth were washed in water to remove any traces of blood and placed in a 0.1% thymol solution. Afterward, they were stored in distilled water, which was changed periodically to avoid deterioration. In no case was a tooth stored for more than a month after extraction. The premolars were set in a four-cm-long copper cylinder with an internal diameter of three cm, and their roots were set in type IV plaster.

Brackets

Seventy-five metal upper premolar brackets were used (Victory Series, 3 M Unitek Dental Products, Monrovia, Calif). The base area of each bracket was calculated (mean = 9.79 mm^2) using image analysis equipment and MIP 4 software (Microm Image Processing Software, Digital Image Systems, Barcelona, Spain).

Bonding procedure

The upper premolar teeth were divided into three groups of 25 each, and brackets were bonded on the buccal surfaces according to the instructions supplied by the manufacturer of each product. For all groups, the buccal surfaces were polished with a rubber cup and polishing paste (Détartrine, Septodont, Saint-Maur, France). Afterward, for groups I and II, the area where the bracket was to be located was etched with a 37% *o*-phosphoric acid gel (Total Etch, Ivoclar, Vivadent, Schaan, Liechtenstein) for 30 seconds and then washed with water. After washing, the enamel surface was completely dried with compressed air.

Group I: Transbond XT. A layer of Transbond XT (3 M Unitek) primer was applied on the tooth. Transbond XT paste was applied to the base of the bracket and pressed firmly onto the tooth. Excess adhesive was removed from around the base of the bracket and the adhesive was light-cured, positioning the light guide of an Ortholux XT lamp (3 M Unitek) on each interproximal side for 10 seconds.

Group II: Light-Bond. A layer of Light-Bond (Reliance, Itasca, Ill) liquid resin was applied on the tooth. Light-Bond paste was applied to the base of the bracket and pressed firmly onto the tooth. Excess adhesive was removed from around the base of the bracket, and it was light-cured, positioning the light guide on the incisal side of the bracket for 20 seconds and on the mesial side for 10 seconds.

Group III: RelyX Unicem Aplicap. The RelyX Unicem Capsule was activated in the Aplicap Activator (3 M ESPE AG Dental Products, Seefeld, Germany), after which the capsule was mixed for 15 seconds in a high-frequency mixing unit (Capmix, 3 M ESPE). Afterward, the capsule was inserted in the Aplicap Applier (3 M ESPE), and the cement was applied to the base of the bracket and pressed firmly onto the tooth. Excess adhesive was removed from around the base of the bracket, and the adhesive was light-cured by positioning the light guide on each interproximal side for 10 seconds.

The specimens were immersed in distilled water at a temperature of 37°C for 24 hours.[14]

Bond strength test

Shear bond strength was measured with a universal test machine (Autograph AGS-1KND, Shimadzu, Kyoto, Japan) with a one-KN load cell connected to a metal rod with one end angled at 30°. The crosshead speed was one mm/min.[14]

The teeth were set at the base of the machine so that the sharp end of the rod incised in the area between the base and the wings of the bracket, exerting a force parallel to the tooth surface in an occlusal-apical direction.

The force required to debond each bracket was registered in newtons and converted into megapascals as a ratio of newtons to surface area of the bracket (MPa = N/mm^2). To appropriately compare different bond test studies in orthodontics, it is necessary to determine bond strength because using the force of debonding only does not permit comparisons of brackets with different geometries.

Adhesive remnant index

The percentage of the surface of the bracket base covered by adhesive was determined using an image analysis equipment (Sony dxc 151-ap video camera, connected to an Olympus SZ11 microscope) and MIP software. The percentage of the area still occupied by adhesive remaining on the tooth after debonding was obtained by subtracting the area of adhesive covering the bracket base from 100%. Afterward, each tooth was assigned an Adhesive Remnant Index (ARI) value according to the following criteria:[15]

- 0, no adhesive left on the tooth.
- 1, less than half of the adhesive left on the tooth.
- 2, more than half of the adhesive left on the tooth.
- 3, all adhesive left on the tooth.

Possible enamel fractures were also registered macroscopically.

Statistical analysis

The Kolmogorov-Smirnov normality test and the Levene variance homogeneity test were applied to the bond strength

TABLE 1. Shear Bond Strength (MPa)[a]

Group	n	Mean	Median	Standard Deviation	Minimum	Maximum
Transbond XT[1]	25	12.27	11.30	5.01	6.79	28.01
Light-Bond[2]	25	14.93	14.27	4.73	6.13	27.50
RelyX[3]	25	8.16	7.66	2.62	4.14	14.50

[a] Results were analyzed using the Kruskal-Wallis test and the Mann-Whitney *U*-test for two independent samples. Groups marked by different superscribed numbers showed significant differences with one another. $P < .017$.

data. Because the data did not show a normal distribution, a significant difference was evaluated ($P < .05$) using the Kruskal-Wallis test, finding those groups which were significantly different with the Mann-Whitney *U*-test for two independent samples. To avoid an accumulation of errors due to multiple comparisons, the significance level was modified dividing this ($P < .05$) between the number of comparisons made (Bonferroni Correction). Any value where $P < .017$ was considered significant.

Bond strength data were also analyzed with Kaplan-Meier survival analysis using Breslow statistic ($P < .05$). This finds those groups that were significantly different and compares them by pairs with the same test, taking the Bonferroni correction into account ($P < .017$).

ARI values were analyzed using the Pearson Chi-squared test and an analysis of corrected residues. Both statistical tests were repeated, grouping the cases in categories with 0 and 1 index points or 2 and 3 points, with the aim of avoiding categories showing an expected frequency lower than 5. Enamel fractures were evaluated with the Pearson Chi-squared test and an analysis of corrected residues. A significance level $P < .05$ was set for both Pearson Chi-squared test and the analysis of corrected residues (residue > 2 implies $P < .05$).

The Kolmogorov-Smirnov test and the Levene homogeneity test of variances were applied to the data for percentage of area of adhesive remaining on tooth. Because there was no homogeneity of variances in the groups, they were also analyzed using the Kruskal-Wallis test and the Mann-Whitney *U*-test for two independent samples, taking the Bonferroni correction into account.

RESULTS

The Kruskal-Wallis test revealed significant differences ($P = .00$) in shear bond strength, and the Mann-Whitney *U*-test for two independent samples established these differences between Transbond XT and Light-Bond ($P = .008$), Transbond XT and RelyX ($P = .000$), and between Light-Bond and RelyX ($P = .000$) (Table 1).

Kaplan-Meier survival analysis detected significant differences in bond strength for the different groups ($P = .00$). The significant differences between groups were the same as when the Mann-Whitney *U* test was applied (Figure 1).

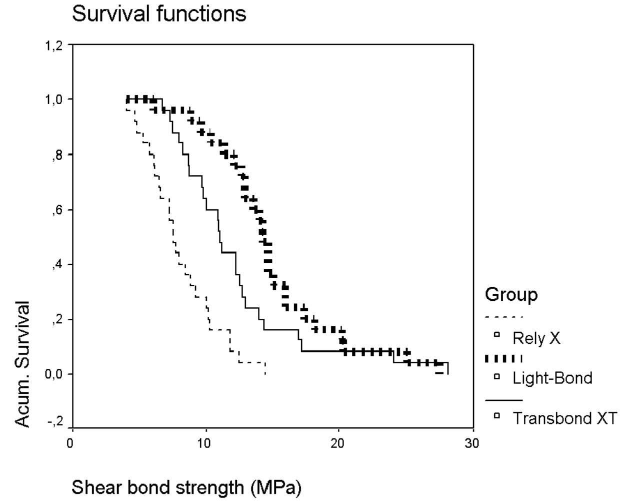

FIGURE 1. Probability of failure of the different bonding systems at particular shear stress values.

TABLE 2. Adhesive Remnant Index (ARI) and Enamel Fractures[a]

Group	Sample	ARI 0	ARI 1	ARI 2	ARI 3	Enamel Fracture
Transbond XT	25	0	7	18[1]	0	0
Light-Bond	25	1	20[1]	1	0	3[2]
RelyX	25	2	23[1]	0	0	0

[a] ARI values were analyzed using the Pearson Chi-squared test (obtaining significant differences) and an analysis of corrected residue. [1] indicates the ARI value to which each group is associated significantly according to the residue analysis. Enamel fractures were evaluated using the Pearson Chi-squared test obtaining significant differences, the residue analysis showed a significant association for Light-Bond to the production of fractures[2]. $P < .05$.

Values for the ARI and enamel fractures are shown in Table 2. The Pearson Chi-squared test indicated significant differences ($P = .00$) in the ARI, and corrected residues analysis showed that whereas Light-Bond and RelyX were significantly associated (residue = 2.6 and 3, respectively) with value 1 on the ARI, Transbond XT was associated with value 2 on the ARI (residue = 6.4) (Table 2).

Both tests were repeated, grouping the cases in categories with 0 and 1 index points or 2 and 3 index points, also showing significant differences when the Chi-squared test was applied ($P = .00$), and a significant association for Light-Bond and RelyX (residue = 2.8 and 3.7, respectively) to the ''0 + 1'' category, and Transbond XT to the ''2 + 3'' category (residue = 6.4) (Table 3).

Only Light-Bond produced enamel fractures. When enamel fractures were analyzed using the Pearson Chi-squared test, significant differences were found between the groups ($P = .04$). Corrected residues analysis indicated a significant association between Light-Bond (residue = 2.5) and enamel fracture (Table 2).

Values for the percentage of area occupied by adhesive on the teeth are shown in Table 4. The Kruskal-Wallis test

TABLE 3. Adhesive Remnant Index (ARI) Values Grouped into Classes[a]

Group	Sample	ARI	
		0+1	2+3
Transbond XT	25	7	18[1]
Light-Bond	22	21[1]	1
RelyX	25	25[1]	0

[a] ARI values were grouped into classes and evaluated using the Pearson Chi-squared test (obtaining significant differences) and an analysis of corrected residue. [1] indicates the category to which each group is associated significantly according to the residue analysis. $P < .05$.

TABLE 4. Percentage of Tooth Area Occupied by Adhesive[a]

Group	n	Mean	Median	Standard Deviation	Minimum	Maximum
Transbond XT[1]	25	59.88	60.82	19.20	17	89
Light-Bond[2]	22	26.49	26.67	12.42	0	50
RelyX[3]	25	7.73	7.14	3.93	0.43	15

[a] Results were analyzed using the Kruskal-Wallis test and the Mann-Whitney *U*-test for two independent samples. Groups marked by different superscribed numbers showed significant differences with one another. $P < .017$.

detected significant differences between different groups ($P = .00$). The Mann-Whitney *U*-test established these differences between Transbond XT and Light-Bond ($P = .000$), Transbond XT and RelyX ($P = .000$), and between Light-Bond and RelyX ($P = .000$).

DISCUSSION

The results of our research showed that RelyX, a dual-cured resin cement that requires no etching, produced a bond strength that was significantly less than with the two orthodontic resin adhesive systems tested (Transbond XT and Light-Bond). It was also observed that bond strength produced by Light-Bond was significantly greater than that achieved with Transbond XT.

The standard deviation for bond strength for Transbond XT and Light-Bond were very similar. However, RelyX showed a lesser standard deviation. This might have been because resin cement technique is less sensitive than the technique of the two orthodontic adhesive systems and because of its inherent capacity for bonding to the dental structure.

No data exists for RelyX regarding bracket bonding. However, other resin cements such as Panavia have been evaluated. Rux et al[16] observed that bond strength values obtained with Panavia were not as high as with an orthodontic resin adhesive system. However, other research shows that there are no significant differences in bond strength between Panavia and a conventional orthodontic adhesive.[17]

The comparison of results between different studies of adhesives is difficult as there is no consensus as to the materials and method used to carry out bond strength tests. After reviewing a series of studies in which, similar to ours, Transbond XT[12,18–23] and Light-Bond[24,25] were tested, we have noted a wide disparity between the studies regarding the type of tooth, sample storage conditions before testing, crosshead speed, etc, which makes it impossible to compare the bond strength values obtained with the two systems.

Reynolds[26] suggested that bond strength values of between 5.9 and 7.8 MPa are sufficient for a clinically effective orthodontic bond, although clinically valid bond strengths have been registered as resisting in vitro forces of 4.9 MPa. If this is so, then the bond strengths of the three systems tested would be clinically acceptable. However, the relation between bond strength values in vitro and bond failure values in vivo is complex.[27]

ARI values and percentage of tooth surface area occupied by adhesive indicated that RelyX was the system that left less adhesive on the dental structure after debonding, being significantly less than that left by Transbond XT and Light-Bond. This might be because RelyX does not require acid etching of the enamel surface. It was also observed that Light-Bond left significantly less adhesive remnant than Transbond XT.

In orthodontics, it is desirable that bond failure occurs in the enamel-adhesive interface so that the subsequent replacement of adhesive is simpler and quicker.[28] Moreover, the cleaning procedures to remove adhesive remnant are always accompanied by a degree of enamel loss.[12]

Enamel fractures were only produced with Light-Bond. Residue analysis showed a significant association for Light-Bond to produce fractures. These results lead us to think that fractures begin to occur when a bond strength passes a certain threshold which in this study is that marked by Transbond XT. However, the results obtained for enamel fractures analysis must be interpreted with caution given that, to make an adequate evaluation of such lesions, further research with a larger sample would be necessary to collate conclusive results.

CONCLUSIONS

- Bond strength for RelyX was significantly less than that with Transbond XT and Light-Bond.
- Bond strength produced by Light-Bond was significantly greater than that achieved by Transbond XT.
- RelyX was the system to leave least adhesive on the tooth. It was significantly less than the adhesive left on the tooth with Transbond XT and Light-Bond.
- Light-Bond left significantly less adhesive on the enamel than Transbond XT.

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