Adhesion promoters: Effects on the bond strength of brackets

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ABSTRACT: **Purpose:** To evaluate the effect of two adhesion promoters on shear bond strength and remnant adhesives of brackets cemented with a light-cured orthodontic adhesive resin system. **Methods:** The two adhesion promoters tested were OrthoSolo and All-Bond 2 Primer. Seventy-five upper premolars were divided into three groups of 25. A control group was established using Transbond-XT adhesive system and two experimental groups: Transbond-XT/OrthoSolo and Transbond-XT/All-Bond 2. Shear bond strength was measured using a universal testing machine and adhesive remnant was quantified using an image analysis equipment. **Results:** The application of Orthosolo significantly increased bond strength for Transbond-XT adhesive system (P< 0.017). All-Bond 2 primer did not significantly increase the bond strength of Transbond-XT (P> 0.017). The Adhesive Remnant Index results and the analysis of the percentage of area of tooth occupied by adhesive indicated that adhesive remnant after debonding did not increase significantly (P> 0.05) with the use of either of the promoters. (Am J Dent 2005;18:323-326).

**Clinical Significance:** The use of Orthosolo could be useful whenever increased bonding is required for orthodontic adhesives. This adhesion promoter did not produce significant increases in the quantity of adhesive remaining on the enamel after debonding brackets.

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Introduction

Orthodontic adhesive systems should provide sufficient bond strength to withstand the forces of mastication, the stress generated by dental arches, the abuses from the patient as well as allow the control of dental movement in the three spatial planes. These are factors which often test the bonding capacity of the products used to bond brackets to tooth enamel. The percentage of bracket failure is currently estimated to be between 5 and 7% of brackets bonded using light-cured or self-cured composite resins.

Various treatments of the metal bracket surface have been developed, such as micro-etching, silanization, etc., which seem to be effective in increasing bond strength on the bracket/adhesive interface. However, in clinical practice, their use is not practical and they have never been taken up as routine treatment methods.

Recently, adhesion promoters have been proposed as an alternative. These are chemical products which are easy to apply and which increase adhesion at the adhesive/enamel interface. They may be in greater general use in everyday practice than the methods mentioned above. Adhesion promoters incorporate hydrophilic resins in their compositions. It would appear that the incorporation of hydrophilic monomers in adhesive systems facilitate the infiltration of the resin into enamel etched to the level of the prisms, reducing interfacial porosity and consequently bonding defects. In this way greater bond strength is achieved after polymerization. However, it must be stressed that an increase in bond strength may compromise safe debonding.

On the basis of these concepts, a variety of orthodontic adhesives have been introduced in order to improve bond strength and interfacial integrity; two such products are All-Bond 2 and Orthosolo. All-Bond 2 is a fourth generation dentin adhesive. Hydrophilic priming resins have been used on dentin mainly in conservative dentistry. All-Bond 2 achieved successful bonding for composite to enamel, dentin, metal, composite or porcelain surfaces. The capacity to improve bonding with other surfaces, such as silver amalgam surfaces, etc. could be of interest for use with adult orthodontic patients who at times present amalgam restorations on the buccal surfaces of molars.

Orthosolo is an adhesion promoter, which was recently introduced for specific use in orthodontics. Its composition includes filler particles, which aid structural strength and compensate for the shrinkage of the material when polymerized.

This study determined the effects of OrthoSolo and All-Bond 2 primer on bond strength and quantity of adhesive remaining on the enamel after the debonding of brackets cemented using a light-cured resin orthodontic adhesive system, Transbond-XT.

Materials and Methods

**Teeth**

Seventy-five human upper premolars, free from caries and restorations were used. These had been extracted for reasons unrelated to the objectives of this study and with the subject’s informed consent. The project was approved by the Murcia University Bioethical Commission.

The teeth were washed in water to remove any traces of blood and then placed in a 0.1% thymol solution. Afterwards, 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 4 cm long copper cylinder with an internal diameter of 3 cm, their roots set in type IV plaster.

**Brackets**

Seventy five metal upper premolar brackets were used (Victory Series). The base area of each bracket was calculated (mean = 9.79 mm2) using an image analysis equipment and MIP 4 software.
Table 1. Shear bond strength (MPa) (n=25).

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Median</th>
<th>Range</th>
<th>Standard deviation</th>
<th>95% C.I.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transbond *</td>
<td>12.27</td>
<td>11.13</td>
<td>21.30</td>
<td>5.01</td>
<td>10.20, 14.34</td>
</tr>
<tr>
<td>Transbond/OrthoSolo #</td>
<td>14.52</td>
<td>14.61</td>
<td>14.00</td>
<td>3.17</td>
<td>13.22, 15.83</td>
</tr>
<tr>
<td>Transbond/All-Bond 2</td>
<td>13.65</td>
<td>13.02</td>
<td>28.96</td>
<td>5.30</td>
<td>11.47, 15.84</td>
</tr>
</tbody>
</table>

Results were analyzed by means of the Kruskal-Wallis test and the Mann-Whitney test for two independent groups. Samples marked by different symbols showed significant differences with one another. The group unmarked did not show significant differences with any other (P<0.017).

**Bonding procedure**

The teeth were divided into three groups of 25 upper premolars and the brackets were bonded on the buccal surface. For all groups, the buccal surfaces were polished with a rubber cup and polishing paste (Détartrine®), and then the area to which the bracket was to be located was etched with a 37% orthophosphoric acid gel (Total Etch®) for 30 seconds, and then rinsed with water. After rinsing, for Groups 1 and 2 the enamel surface was completely dried with compressed air; for Group 3 the enamel surface was air-dried leaving the surface slightly moist.

**Group 1: Transbond-XT®** - A layer of Transbond-XT primer was applied onto the tooth. Transbond-XT paste was applied to the base of the bracket which was then placed to the tooth pressing firmly. Excess adhesive was removed from around the base of the bracket, the adhesive was light-cured positioning the light guide of an Ortholux XT® lamp on each interproximal side for 10 seconds. The instructions of the manufacturer of this product were followed.

**Group 2: Transbond-XT/OrthoSolo** - A layer of OrthoSolo was applied. No air drying or curing step was necessary. Immediately afterwards the bracket was bonded in place with Transbond-XT paste. According to the manufacturer, with light cure systems, OrthoSolo takes the place of the primer. Its composition includes hydrophilic monomers, monomers with phosphate groups, a fluoride release agent and filler particles. The instructions of the manufacturer of each product were followed.

**Group 3: Transbond-XT/All-Bond 2** - Five layers of All-Bond 2 primer were applied. The primer was obtained from the mixing of two components, one containing N-tolylglycine-glycidylmethacrylate (NTG-GMA), ethanol, water and acetone, and the other bisphenyl-dimethacrylate (BPDM), acetone and water. After the last layer was applied, the surface was completely dried with compressed air. The surface was left with a shiny appearance. Immediately afterwards the bracket was bonded in place with Transbond-XT adhesive system (primer and paste). The instructions of the manufacturer of this product were followed.

**Storage of test specimens**

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

**Bond strength test**

Shear bond strength was measured with a universal test machine (Autograph AGS-1KNED®) with a 1 KN load cell connected to a metal rod with one end angled at 30°. The cross-head speed was 1 mm/minute.⁹

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 occluso-apical direction.

The force required to debond each bracket was registered in Newtons (N), and converted into Mega-Pascals as a ratio of Newtons to surface area of the bracket (MPa = N/mm²). To properly compare different studies about bond tests in orthodontics, it is necessary to determine bond strength, because using only debonding force brackets with different geometries cannot be compared.

**Adhesive Remnant Index**

The percentage of the surface of the bracket base covered by adhesive was determined using an image analysis equipment (Sony DVC151-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%. Afterwards each tooth was assigned an Adhesive Remnant Index (A.R.I.) value according to the following criteria:a

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 the 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 data. As the data did not show a normal distribution, significant difference was evaluated (P< 0.05) using the Kruskal-Wallis test, finding those groups which were significantly different with the Mann-Whitney test for two independent samples. In order to avoid an accumulation of errors due to multiple comparisons, the significance level was modified dividing this (P< 0.05) between the number of comparisons made (Bonferroni Correction) and P< 0.017 was considered significant.

A.R.I. values were analyzed using the Pearson Chi-squared test and an analysis of corrected residuals. Both statistical tests were applied to evaluate enamel fractures. A significance level P< 0.05 was set for both Pearson's Chi-squared test and the analysis of corrected residuals (residual > 2 implies P< 0.05).

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. As there was neither homogeneity of variances nor a normal distribution, they were analyzed using the Kruskal Wallis test (P< 0.05).
Table 3. Percentage of tooth area occupied by adhesive.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Median</th>
<th>Range</th>
<th>Standard deviation</th>
<th>95% C.I</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transbond</td>
<td>59.88</td>
<td>60.82</td>
<td>71.79</td>
<td>19.2</td>
<td>51.95, 67.80</td>
</tr>
<tr>
<td>Transbond/OrthoSolo</td>
<td>59.75</td>
<td>63.92</td>
<td>59.52</td>
<td>13.83</td>
<td>53.62, 65.88</td>
</tr>
<tr>
<td>Transbond/All-Bond 2</td>
<td>50.82</td>
<td>58.68</td>
<td>65.78</td>
<td>24.24</td>
<td>39.78, 61.85</td>
</tr>
</tbody>
</table>

Kruskal-Wallis test did not show significant differences between groups (P < 0.05).

Results

The Kruskal-Wallis test revealed significant differences (P=0.01) in shear bond strength, and the Mann-Whitney test for two independent samples established differences between Transbond-XT and Transbond-XT/OrthoSolo (P=0.00) (Table 1).

Adhesive Remnant Index values and enamel fractures are shown in Table 2. The Pearson Chi-squared test indicated that there were no significant differences (P=0.18) in the Adhesive Remnant Index, and the analysis of corrected residues did not detect any significant association (residues < 2).

Enamel fractures analysis using the Pearson Chi-squared test did not show significant differences (P = 0.11) between the groups, nor did the corrected residues analysis indicate any significant association for any group to produce fractures or not (residues < 2).

Values for the percentage of area of the tooth occupied by remaining adhesive after debonding are shown in Table 3. The Kruskal-Wallis test detected that there were no significant differences between the different groups (P = 0.62).

Discussion

Adhesion promoters have been recently introduced into orthodontic practice. Data dealing with them is scarce and at times confusing. Our results did not show a significant improvement in bond strength for Transbond-XT as a result of the prior application of All-Bond 2. A previous study did not find a significant increase in bond strength with the application of All-Bond 2 in the case of new brackets, but it did significantly improve bond strength when rebonded brackets were used with Light-Bond system.

One study also observed that the application of All-Bond 2 did not significantly affect bond strength for resin composites on etched enamel.

The application of Orthosolo significantly increased bond strength for Transbond-XT system. With regard to adhesive remnant on the tooth surface, neither All-Bond 2, nor Orthosolo produced an increase and in fact they reduced it slightly although not significantly.

In this way, of the two adhesion promoters evaluated, Orthosolo displayed better results, with the added advantage that its application was simpler and required less time than that of All-Bond 2. For these reasons, Orthosolo could be useful whenever increased bonding is required for orthodontic adhesives, for example, with non-cooperative patients or in areas where humidity control is difficult.

Enamel fractures after bond strength test was noted on two samples of the Transbond-XT/OrthoSolo group, and four in the Transbond-XT/All-Bond 2 group. Therefore they were produced in all groups except with Transbond-XT. These results tend to show that enamel fractures begin to occur when the threshold of the bond strength marked by Transbond-XT is exceeded. Because of the irreversible nature of such fractures, this is not an unimportant issue, although in order to reach a valid conclusion, a study with a larger sample would be required.

Other studies have detected enamel fractures with the use of All-Bond 2. Therefore, it is recommended that when adhesion promoters are to be used, the debonding procedures for brackets should be carried out very carefully.

It must be stated that in vitro studies for the evaluation of adhesive systems have their limitations. One of these limitations is that the optimum conditions for bracket bonding and the isolation of humidity can only occur in an in vitro environment. Moreover, there are a series of parameters with regard to oral conditions which cannot be reproduced in testing such as the stress generated by the arches against occlusal forces, wide pH and temperature variations, and the existence of a microflora complex and its products. Studies have shown that microflora and its products may produce substantial irregularities in the structure and surface properties of orthodontic adhesive systems which may lead to bond failure.

In spite of these limitations, in vitro studies of bond strength are useful and necessary. There are many adhesive systems available for orthodontics and these are constantly being improved, so in vitro testing of the bond strength of such materials is of great importance and interest for the evaluation of such improvements.

a. Bisco, Schaumburg, IL, USA.
b. Ormco, Sybron, Tokyo, Japan.
c. 3M Unitek, Monrovia, CA, USA.
e. Septodont, Saint-Maur, France.
f. Ivoclar-Vivadent, Schaan, Liechtenstein.
g. Shimadzu, Tokyo, Japan.
h. Sony, Tokyo, Japan.
i. Olympus, Tokyo, Japan.

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References


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