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The Effect of Universal Adhesives on Shear Bond Strength of Orthodontic Brackets

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ABSTRACT

Background and Objective: A proper bond between enamel and bracket is essential in orthodontic treatment. Recently, a new type of adhesive (universal adhesive) has been introduced, which has been claimed to present the ability to bond with metal surface. The aim of this study was to evaluate the effect of universal adhesives on shear bond strength (SBS) and adhesive remnant index (ARI) of orthodontic brackets to enamel surfaces.

Methods: In this experimental in-vitro study, 56 intact human premolars were randomly divided into four groups according to the adhesives used. All teeth were etched by 37% phosphoric acid. Then, in Group 1 (control), Transbond XT primer was only applied on the enamel surface. Group 2: Transbond XT primer applied on both enamel and bracket base. Group 3: Single Bond Universal adhesive was applied on both enamel and bracket base. Group 4: G-Permio Bond was applied on both enamel and bracket base. Then, the brackets were bonded to teeth with Transbond XT composite. After storing samples in water for 24 hours and thermocycling (2000 cycles), SBS was recorded using a Universal Testing Machine. The debonded samples were examined under the stereomicroscope at 10x magnification to check the amount of remaining adhesives on teeth (ARI).

Findings: Group 3 showed the highest SBS (25.4±8.7 Mpa) and group 2 showed the lowest SBS (16±5.3 Mpa). The SBS of group 3 was significantly more than group 2 (p=0.03) and there was no significant difference between the other groups. There was no significant differences among the four groups in term of ARI score.

Conclusion: The bond strength values of orthodontic brackets to enamel using universal adhesives (Single Bond Universal and G-Permio Bond) are similar to the conventional adhesive (Transbond XT).

Keywords: *Composite Resin, Adhesives, Orthodontic Brackets*.

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Introduction

A proper bond between the enamel and bracket is essential in orthodontic treatment. The adhesive that bonds brackets to the enamel must resist intraoral and orthodontic forces during the treatment and also allow bracket debonding at the end of the treatment without enamel damage (1, 2). Bracket debonding is a major problem in orthodontic treatment that leads to increased treatment period, poor patient satisfaction, increased risk of decalcification and increase in costs (3). Different studies have shown that the failure of brackets usually takes place at the cement-bracket base interface (4). The surface condition of the bracket base is one of the factors affecting the bracket-enamel bond strength. Much attempt has been made to increase the bracket base retention. The surface of the bracket can be modified by various mechanical and chemical methods, including sandblasting the bracket base, silanation, silica layer application, micro-etching and adhesives (5, 6).

It is generally accepted that orthodontic adhesives have no chemical affinity for metals or teeth, and their bonding is based on mechanical interlocking. As a result, if we can better moisturize the base surface with the use of a suitable primer, the penetration of the adhesive into the undercut of the base will improve and the bond strength will increase (7). Recently, a new type of dental adhesives have been introduced as universal adhesives, which are the latest generation of bonding systems and although they are one-step self-etch adhesives, they have a unique ability to be used in both self-etch and etch and rinse modes (8). The main advantage of universal adhesives is the presence of specific monomers, which could to bond to other materials than enamel, such as zirconia, composite, metals and silica-based ceramics (9, 10).

Shafiei et al. evaluated the bond strength of orthodontic brackets bonded with universal adhesive using different etching methods. In this study, the adhesive was applied only to the enamel. Their results showed that the bond strength of Single Bond Universal (SBU) was significantly more than Transbond XT (11). Proença et al. evaluated the bond strength of brackets bonded with universal adhesives containing 10-MDP (methacryloyloxy-decil-dihydrogen phosphate). In this study, the adhesives were used in self-etch mode and their results showed that the bond strength values of universal adhesives were similar to the Transbond Plus SEP (12).

In self-cured composites, in addition to the enamel, the surface of the bracket is primed for composite setting. However, when orthodontic light-cured composites are used, it is not necessary to apply the primer on the base of bracket for composite setting (13). Since the new universal adhesives have the ability to bond with metals, the use of adhesive on the base of bracket may improve the bond of bracket-to-enamel, and the review of previous literature found no studies applying universal adhesives to the bracket base in addition to the enamel surface and then measuring its effect on the bond strength. Therefore, the present study was conducted to evaluate the effect of applying universal adhesives on the shear bond strength and the adhesive remnant index of orthodontic brackets to enamel surface.

Methods

This in vitro experimental study, which was approved by the ethics committee of Kerman University of Medical Sciences under ethical code IR.KMU.REC.1398.006, was conducted on 56 intact human maxillary premolars, without cracks, developmental defects, caries or previous restorations. All teeth were immersed in 0.5% chloramine-T solution for one week and then stored in normal saline solution until the experiment. In all groups, the buccal surfaces of teeth were etched with 37% phosphoric acid gel (Spident, Korea) for 30 seconds, rinsed with water for 20 seconds, and dried with moisture-free air. The samples were then randomly divided into 4 groups (n=14):

Group 1 (control): A thin layer of Transbond XT primer (3M, ESPE, USA) was applied on the etched surface according to the manufacture instructions and light cured for 20 seconds using a light cure device with a minimum light intensity of 600 mW/cm^2 (Demetron, kerr), and then the Transbond XT composite was applied on the surface of stainless steel upper premolar bracket (Focus, USA). The bracket was placed on the mid buccal surface of tooth perpendicular to the long axis of the buccal surface of the tooth and pressed firmly. The excess composite was then removed using the Explorer and light cured for 20 seconds from the mesial side and for 20 seconds from the distal side.

Group 2 (Transbond XT): A thin layer of Transbond XT primer (3M, ESPE, USA) was applied to the enamel surface according to the manufacture instructions and light cured for 20 seconds. Then a layer of Transbond XT primer was also applied to the bracket base, the excess was removed by a microbrush and the Transbond XT composite was placed on the bracket surface according to the first group and cured.

Group 3 (G-Permio Bond): A layer of G-Permio Bond (GC Corporatian, Japan) was applied to the enamel surface according to the manufacture instructions and cured for 20 seconds. Then, a layer of G-Permio Bond was also applied to the bracket base and the excess was removed with a microbrush, and the Transbond XT composite was placed on the bracket surface according to the first group and cured.

Group 4 (Single Bond Universal): A layer of Single Bond Universal (3M, ESPE, USA) was applied on the enamel surface according to the manufacture instructions and light cured for 20 seconds. Then a layer of Single Bond Universal bonding was also applied to the bracket base, the excess was removed with a microbrush, and the Transbond XT composite was placed on the bracket base according to the first group and cured.

All samples were immersed in distilled water at 37 ºC for 24 hours, and then were subjected to 2000 thermal cycles (at temperatures of 5 and 55 ºC with a time interval of 20 seconds for each bathing) (Vafaei Industrial, TC-300).

All teeth were mounted in self-curing acrylic resin (Acropars, Iran) to 1mm below the cemento-enamel junction, in a way that the buccal surfaces of teeth were parallel to the shear blade.

The shear bond strength of the samples was evaluated using a universal testing machine (Testometric M350-10 CT, England). To measure the shear bond strength, the samples were placed in the jig attached to the base plate of the device and the force was applied vertically to the tooth-composite interface with a blade at a crosshead speed of 0.5 mm/min until debonding occurred. The maximum force before bracket debonding was recorded in Newton and the shear bond strength was calculated in MPa by dividing the maximum force to the cross section area of the bracket base (12 mm).

The debonded samples were examined under the stereomicroscope at 10x magnification to check the amount of remaining adhesive on teeth (ARI). The results of the remaining adhesive index were evaluated using the Bishara ranking (14):

Rank 1: Entire composite remaining on the tooth.

Rank 2: More than 90% of the composite remaining.

Rank 3: 10% - 90% of the composite remaining.

Rank 4: Less than 10% of composite remaining.

Rank 5: No composite remaining.

The results related to shear band strength in the studied groups were statistically analyzed using One Way ANOVA and Tukey's post hoc test using SPSS 20. The data related to the remaining adhesive index were also statistically analyzed using the Chi-square test, and $p<0.05$ was considered significant.

Results

Group 3 (Single Bond Universal) showed the highest bond strength (25.4±8.7 MPa) and group 2 (Transbond XT) showed the lowest bond strength (16±5.3 MPa). The results of statistical analysis showed that the shear bond strength of group 3 (Single Bond Universal) was significantly higher than group 2 (Transbond XT) (p=0.03) and the difference between the other groups was not statistically significant (Table 1).

The ARI results showed that the highest debonding in the adhesive layer and adhesive-enamel interface occurred in the SBU and Transbond XT groups, respectively. Statistical analysis of ARI scores showed no significant difference among the different groups (p=0.756). The ARI results are shown in Table 2.

Table1. Two-by-two comparison of groups based on Tukey's post hoc test

Adhesive type	p-value
Control group	
Single Bond Universal	0.68
Transbond XT	0.31
G-Permio Bond	0.89
Transbond XT	
Single Bond Universal	0.034
G-Permio Bond	0.71
Single Bond Universal	
G-Permio Bond	0.272

Table 2. ARI ranking of different groups

Groups	**ARI ranking**				
	Rank 1 Number(%)	**Rank 2 Number(%)**	**Rank 3 Number(%)**	**Rank 4 Number(%)**	**Rank 5 Number(%)**
1st group (control)	0(0)	2(14.3)	7(50.0)	2(14.3)	3(21.4)
2nd group (Transbond XT)	0(0)	2(16.7)	5(35.7)	2(16.7)	5(35.7)
3rd group (G-Premio Bond)	1(7.1)	2(14.3)	7(50.0)	2(14.3)	2(14.3)
4th group (Single Bond Universal)	0(0)	2(28.6)	8(57.1)	0(0)	2(14.3)

Discussion

The results of the present study showed that the highest bond strength was observed in the Single Bond Universal and the lowest bond strength was related to Transbond XTgroup; statistically, only the difference between Single Bond Universal and Transbond XT was significant.

In a study by Hellak et al. on the bond strength of three orthodontic adhesive systems (SBU, iBond and Transbond XT) to enamel and restorative materials (composite, metal and ceramic) that were self-etched and only on the enamel, the highest bond strength to the metal was provided by the SBU (15). Proença et al. evaluated the bond strength of brackets bonded with universal adhesives containing 10-MDP. In this study, the adhesives were used in self-etch mode. Their results showed that the bond strength values of universal adhesives were similar to the Transbond Plus SEP (12).

Shafiei et al. evaluated the bond strength of orthodontic brackets bonded with universal adhesive (SBU) using different etching methods. In this study, the bonding was applied only to the enamel and not to brackets. Their results showed that the bond strength of SBU was significantly more than Transbond XT (11) that is due to the low viscosity of Single Bond Universal Bonding, which has the ability to better moisturize roughness and surface irregularities.

The SBU contains a functional monomer (10-MDP) that can be bonded to metal or ceramic (15). Moreover, the nanofillers in the SBU and the formed thick adhesive layer have a positive effect in term of bond strength via stress relief and preventing crack propagation (11).

In the comparison of universal adhesives investigated in the present study, the results showed that the bond strength of SBU was higher than that of G-Permio Bond, although this difference was not significant.

Nowadays, the primers containing monomers derived from carboxylic acid (such as 4-META [4-methacryloxyethyl trimellitate anhydride]) or phosphoric acid or thiophosphoric acid (such as MDP) are used to enhance bonding to metals. Studies have shown that carboxylic acid-derived monomers, such as 4-META, have lower bond strength than phosphoric acid-derived monomers and among the phosphoric acid-derived monomers, 10-MDP is more suitable for non-precious alloys and create higher bond strength (16).

The functional monomer of SBU is 10-MDP, while the G-Permio Bond contains MEPS, MDP and 4-MET monomers. Studies have shown that the purity of 10-MDP and its concentration in adhesives affect their chemical bonding potential. As a result, the difference in bond strength of two studied universal adhesives may be due to the different purity and concentration of MDP in the two adhesives (17-19).

In the literature review, no similar study was found to evaluate the bond strength of orthodontic brackets when universal adhesives were applied on the bracket surface. The results of the present study showed that the highest debonding in the adhesive layer and adhesive-enamel interface occurred in the SBU and Transbond XT groups, respectively.

Some studies have shown that higher bond strength is associated with higher amount of adhesive remnant on the enamel surface (11, 20, 21). In the present study, the SBU had the highest strength and the highest debonding was reported in the adhesive layer, but the highest failure in the adhesive-enamel interface was observed in the Transbond XT group, which had the lowest bond strength.

ARI is one of the most common methods to assess the quality of adhesion between bracket base and composite and also composite and tooth. However, the efficiency of ARI to reflect the bond strength is debatable (22, 23).

Brauchli et al. evaluated the ARI values of brackets bonded with silorane compared with Transbond XT in cow teeth and showed that the highest debonding in Transbond XT is in the bracket-adhesive interface (24). However, in the present study, it occurred in the adhesive layer, which is due to the different samples (cow teeth) and different methods.

It is concluded that the ARI score and crack occurrence seems to be dependent not only on the bond strength but also on many factors such as type and design of bracket base, adhesive composition, and surface characteristics of prepared enamel (11, 25). Shearing and tension are the most common methods for testing the bond strength of brackets (26, 27). In this study, the shear bond strength test was used because it provides the force similar to those that frequently causes bracket debonding in orthodontic treatment (5).

The use of 37% phosphoric acid with Transbond XT is the most common protocol used by orthodontists in experimental studies (28) and is the gold standard for bracket bonding to enamel (14). In the present study, the Transbond XT composite was used with various adhesives (Single Bond Universal, G-Permio and Transbond XT Primer).

In the present study, to simulate the oral environment, the samples were subjected to thermal cycles of 5-55ºC and this temperature is comparable to the condition that can be tolerated in a short time in the mouth environment. However, it is noticeable that in-vitro tests cannot replace in-vivo studies even by thermocycling, and the results of shear bond strength will be much higher than in-vivo studies because the appliance in the mouth, in addition to thermal changes, undergoes pH and enzymatic changes as well as fatigue caused by occlusal forces (29, 30). Moreover, some factors, such as the composition of the enamel, saliva contamination, and the difference between the force applied by the testometric device and the intraoral force (which is a combination of shear, tensile and torsion forces) affect the results in clinical conditions (1, 11). As a result, clinical trials are the gold standard, and it is suggested that subsequent studies evaluate the effect of adhesives containing metal-bonding agents under real clinical conditions.

According to the results of this study, it was concluded that the bond strength values of orthodontic brackets to enamel using universal adhesives (Single Bond Universal and G-Permio Bond) are similar to the conventional adhesive (Transbond XT).

Conflicts of Interest: The authors declare no conflict of interest.

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