

Original Article

Shear Bond Strength of Orthodontic Brackets to Composite Restorations Using Universal Adhesive

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KEY WORDS

Adhesives;
Composite Resins;
Dental Bonding;
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ABSTRACT

Statement of the Problem: The dental adhesives may have the potential to increase the bond strength of orthodontic brackets to composite resin and it would be highly desirable if adequate bracket-composite bond strength could be yielded by using these adhesives without the need for surface roughening.

Purpose: The purpose of this study was to measure the shear bond strength (SBS) of metal brackets to composite restorations by use of a universal adhesive compared with a conventional adhesive.

Materials and Method: In this *in vitro*, experimental study, 45 composite discs measuring 6 mm in diameter and 4 mm in thickness were fabricated and assigned to three groups (n=15). In the group 1, discs were etched with 37% phosphoric acid for 15 seconds and Scotchbond Universal was then applied. Discs were roughened by diamond bur in the group 2 and were subjected to the application of Scotchbond Universal. In the group 3, conventional adhesive (Single Bond 2) was applied after roughening the discs by diamond bur. Metal brackets were then bonded to discs and after thermocycling, the SBS was measured by an Instron machine. The mode of failure and adhesive remnant index (ARI) score were determined using stereomicroscope. Data were analyzed by SPSS version 18, one-way ANOVA, and the Kruskal Wallis test.

Results: The surface roughening plus universal adhesive group showed the highest SBS (11.90 MPa) but according to one-way ANOVA, the difference in this regard among the three groups was not statistically significant ($p=0.94$). Most samples showed ARI score of 4.

Conclusion: Universal adhesive can provide sufficient bond strength as high as that provided by conventional adhesives for orthodontic bracket bonding to composite restorations even in absence of surface roughening by bur.

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Introduction

Considering the increased demand of adult patients for orthodontic treatment, orthodontic bracket bonding to composite resin restorations is commonly performed in

orthodontic clinics [1]. Obtaining a reliable bond to dental substrate other than the enamel is difficult [2]. Many techniques such as acid etching, micro-etching, surface roughening, and surface conditioning by chem-

ical agents have been recommended to increase the bond strength between the luting composite and the old composite restoration [1]. Mechanical surface preparation methods include sandblasting and surface roughening by diamond bur [3-4]. Chemical methods include prolonged phosphoric acid etching, hydrofluoric acid etching, and silanation. A previous study showed that the type of bracket is more important than the type of bonding agent to increase the bond strength of bracket to composite resin [4]. However, no consensus has been reached on a specific protocol for this purpose [3]. Recently, universal or multi-mode adhesives were introduced to the dental market. They can be used in both self-etch and etch and rinse modes [5]. The manufacturers claim that these new adhesives can bond to different substrates including the enamel, dentin, composite, amalgam, and porcelain [5].

Some modifications have been made in the chemical formulation of these adhesives compared to previous generations, which necessitate further studies on their bonding properties. These adhesives may have the potential to increase the bond strength of orthodontic brackets to composite resin and it would be highly desirable if we could obtain adequate bracket-composite bond strength by use of these adhesives without the need for roughening the surface by bur since roughening of anterior composite restorations may compromise esthetics. Thus, this study sought to assess the shear bond strength of orthodontic brackets using a universal adhesive to composite resin with and without surface roughening by bur in comparison with a conventional adhesive.

Materials and Method

A total of 45 composite discs measuring 6 mm in diameter and 4 mm in thickness were fabricated of Point 4 (Kerr, Italy) composite. The discs were assigned to three groups of 15 including group 1 with application of Scotchbond Universal(3M-ESPE, Seefeld, Germany) adhesive without surface preparation, group 2 with application of Scotchbond Universal adhesive following surface roughening by diamond bur, and group 3 with application of Single Bond 2(3M ESPE, Conway, USA) conventional adhesive following surface roughening by diamond bur.

The surface of the discs in groups 2 and 3 was ro-

ughened by a long fissure diamond bur (863 Grit, Drendell and Zweilling, Berlin, Germany). The surface of the discs was swiped by high-speed bur three times under water coolant. A new diamond bur was used for every five discs. The discs were then etched with 37% phosphoric acid for 15 seconds, rinsed with water spray for 30 seconds and dried with air spray for 30 seconds.

Then, in groups 1 and 2, Scotchbond Universal adhesive was applied in one layer on the surface by a micro-brush and rubbed for 20 seconds, air sprayed for 5 seconds and light cured for 10 seconds using a light curing unit (Optilux 50; Kerr, Danbury, CT, USA) with a light intensity of 650 mW/cm².

In the group 3, Single Bond 2 conventional adhesive was applied in two layers on the surface by a micro-brush and rubbed for 20 seconds, air sprayed for 5 seconds and light cured for 10 seconds using the same light curing unit with a light intensity of 650 mW/cm².

Mandibular central incisor brackets (American Orthodontics, California, USA) were bonded to the surface of the discs by the same operator. Transbond XT Light Cure Adhesive (3M Unitek, Monrovia, California, USA) was used for this purpose with 5 N pressure with the help of a Correx gauge (Haag Streit, Berne, Switzerland). It was then light cured for 40 seconds with a light intensity of 650 mW/cm². The discs were then mounted in auto-polymerizing acrylic resin (Pars Dental, Tehran, Iran) such that the bracket slot was parallel to the horizon. The discs were immersed in distilled water for 24 hours and were then subjected to 500 thermal cycles between 5-55°C for 24 hours. Shear bond strength testing was then performed using an Instron universal testing machine (Z020; Zwick/Roell, Ulm, Germany) with a crosshead speed of 0.5 mm/minute.

The shear bond strength was then calculated using the equation below:

$$\text{Shear bond strength} = \text{Load at debonding (in Newtons)} / \text{bracket base surface area (mm}^2\text{)}$$

To assess the mode of failure, the discs were evaluated under a stereomicroscope (ZSX9; Olympus, Tokyo, Japan) and the adhesive remnant index (ARI) score was determined according to the method suggested by Bergland and Artun [6]. The scores, defined in this method, include score 0 (no adhesive remaining

on the surface), score 1 (less than 50% of adhesive remaining on the surface), score 2 (more than 50% of adhesive remaining on the surface), score 3 (the entire surface coated with adhesive and score), and score 4 (surface fracture) [6].

Statistical analysis

Data were analyzed using SPSS version 18. One-way ANOVA was applied to compare the shear-bond strength values among the three groups. The Kruskal Wallis test was applied to compare the mode of failure and ARI scores among the three groups.

Results

This study assessed the bracket bond strength to composite restorations in use of a conventional and a universal adhesive. The effect of surface roughening by bur on bond strength of universal adhesive to composite was also evaluated.

Table 1 shows the descriptive statistics of shear bond strength obtained from the three groups.

Table 1: Mean and standard deviation of SBS (MPa) in different groups (Std=standard)

	N	Mean	Std. Deviation
Universal adhesive	15	11.2440	6.31591
Universal adhesive+ surface treatment	15	11.9093	5.68762
Conventional adhesive+ surface treatment	15	11.5187	3.69475
Total	45	11.5573	5.23500

Since the shear bond strength values in the three groups had normal distribution ($p > 0.05$), the assumption of homogeneity of variances was met ($p = 0.24$). One-way ANOVA was applied to compare the mean bond strength among the three groups and showed that the three groups were not significantly different in this respect ($p = 0.94$). Table 2 shows the ARI scores in the three groups. The Kruskal Wallis test showed that the three groups were not significantly different in ARI scores

($p = 0.71$).

Discussion

In contemporary orthodontics, clinicians may need to bond the brackets not only to the enamel, but also to different restorative materials such as composite resins, amalgam, and porcelain as the result of the increasing demand of adult patients for orthodontic treatment [1]. Thus, increasing the bracket bond strength to composite surfaces with minimal surface modifications has been among the main research topics in the recent years.

Viwattanatipa *et al.* [7] assessed the bond strength of orthodontic appliances to five different composite resin restorations including flowable, packable, hybrid, and nanofilled composite resins and found that the same bonding protocol resulted in significant differences in bond strength, ranging from 6.9 MPa for nanofilled to 12.99 MPa for hybrid composite resin restorations. Crumpler *et al.* [8] also reported that different composite resins yielded different bond strength values in restoration repair. However, no studies demonstrated any association between the bond strength and filler particle size or viscosity. The restorative composite resin used in the present study was Point 4 (Kerr, Italy), which is an optimized particle, light-cure, resin-based composite that contains approximately 76wt% (57v%) inorganic filler with an average particle size of 0.4 μ . It is commonly used for restoration of anterior teeth.

Lai *et al.* [4] evaluated the role of type of bracket in increasing the bond strength of orthodontic brackets to composite resin and concluded that type of bracket was more imperative than type of adhesive in this respect. Eslamian *et al.* [9] reported that the shear bond strength of ceramic brackets is significantly higher than that of metal brackets. In the current study, we us-

Table 2: Adhesive remnant index (ARI) in experimental groups

		ARI			Total	
		2.00	3.00	4.00		
Group	Universal adhesive	Count	0	6	9	15
		% within Group	0.0%	40.0%	60.0%	100.0%
	Universal adhesive+ surface treatment	Count	2	1	12	15
		% within Group	13.3%	6.7%	80.0%	100.0%
Conventional adhesive+ surface treatment	Count	3	1	11	15	
	% within Group	20.0%	6.7%	73.3%	100.0%	
Total	Count	5	8	32	45	
	% within Group	11.1%	17.8%	71.1%	100.0%	

ed stainless steel brackets due to their more common use by clinicians in the clinical setting compared to other types so that our results could be more generalizable to the clinical setting.

Unlike a freshly applied composite resin, an existing, old composite restoration no longer possesses the reactive layer of unpolymerized methacrylate groups on its surface. Thus, chemical bond between the orthodontic adhesive and the restoration surface would be impossible to achieve [10-11]. Therefore, several techniques were suggested to increase the bond strength of orthodontic brackets to the existing composite restorations [12].

Mechanical surface preparation methods include sandblasting and surface roughening by diamond bur [3, 13]. Evidence shows that diamond bur and air abrasion are both effective for increasing the bond strength [3, 9, 12, 14-16]. Bayram *et al.* [14] reported that the use of a diamond bur and air abrasion provided mean shear bond strength of 10.6 and 10.3 MPa, respectively, compared to only 2.8 MPa when no surface preparation was performed. Similarly, Bishara *et al.* [15] reported mean shear bond strength value of 9.4 and 7.8 MPa when using diamond bur and air abrasion, respectively compared to 6.1 MPa with no surface preparation. Viwattanatipa *et al.* [12] reported mean shear bond strength values of 17.1 MPa and 15.0 MPa when using diamond bur and air abrasion, respectively compared to only 6.5 MPa when no mechanical surface preparation was performed.

Riberio *et al.* [17] concluded that surface roughening of composite is the most efficient method for increasing the bracket bond strength. Eslamian *et al.* [3] measured the bond strength of metal brackets to composite surfaces in three groups with different surface treatments. They concluded that composite surface roughening by bur is the most efficient and cost-effective modality for increasing the bond strength. In the current study, composite surface roughening by diamond bur was performed to increase the bond strength in two groups.

Although effective, surface preparation by diamond bur or air abrasion has disadvantages as well. Mechanical roughening by use of a diamond bur or air abrasion may not be suitable in situations where the clinician does not wish to abrade a highly polished es-

thetic composite resin surface. Hence, in one group in our study, the mechanical surface preparation was not performed in order to evaluate the sole effect of universal bonding.

Several chemical methods have also been recommended such as prolonged exposure to phosphoric acid, etching with hydrofluoric acid, silanation, and application of a variety of bonding resins or adhesion promoters. Unlike the tooth enamel, the conventional phosphoric acid etching has no effect on composite restoration surfaces; therefore, creating micromechanical retention is difficult in such surfaces [2]. Some studies have shown that hydrofluoric acid etching is effective for producing clinically acceptable bond strength values [3, 9, 12, 14]. Bayram *et al.* [14] and Viwattanatipa *et al.* [12] both reported mean shear bond strength values of 7.2 MPa and 13.0 MPa, following hydrofluoric acid etching, compared to 2.8 MPa and 6.5 MPa when no surface preparation was performed. However, these values were less than those values achieved following diamond bur preparation or air abrasion. In contrast, Brosh *et al.* [18] reported that the lowest bond strength was noted following the use of hydrofluoric acid. Hydrofluoric acid is a highly caustic substance and can cause severe damage if it inadvertently contacts the soft tissue. It also increases the chairside time since its use requires placement of a soft tissue barrier. Considering these shortcomings and the controversy regarding its positive effect on bond strength, hydrofluoric acid was not used in our study. It is also believed that silanation is an effective adhesion promoter for bonding to porcelain surfaces. However, its efficacy for effective bonding to old composite resin restorations is still a matter of debate [19].

Eslamian *et al.* [1] evaluated the effect of composite surface preparation with and without silane and found that use of silane had no positive effect on bond strength of bracket to composite resin. Similarly, Brosh *et al.* [18] found no significant difference in use and no use of silane. Therefore, no silanation was performed in the present study.

Thermocycling is often performed *in vitro* to simulate aging [20]. Thermocycling simulates the thermal changes that occur in the oral environment. Intraoral temperature may fluctuate from 0 to 65°C [21]. Buonocore [22] reported that if thermocycling is not

performed, the obtained results could not correctly indicate oral conditions. This was also emphasized by study of Fox *et al.* [23] on bond strength testing in orthodontics. Tezvergil *et al.* [24] compared the repair bond strength of three different adhesives and found that higher mean bond strength values were obtained when thermocycling was not performed comparing when it was performed prior to debonding.

We performed 500 thermal cycles between 5 to 55°C after bracket bonding according to the recommendations of the international organization for standardization (IOS) for testing of bond strength to tooth structure [25]. The same protocol has been used in many previous studies [7, 9, 12, 16].

Orthodontic literature on the effectiveness of bonding resins for increasing the bond strength of orthodontic brackets to an existing composite resin restoration is scarce. Bonding resins serve as an intermediate layer and unify the orthodontic adhesive and the substrate surface to which the bracket is bonded. These unfilled, low-viscosity liquid monomer bonding resins can better penetrate deep into the microporosities present on the substrate surface compared to highly filled, viscous orthodontic adhesives [26].

Studies on composite repair provide information on the use of bonding resins for the bonding of new to old composite resins. Operative dentists often encounter the same problem when trying to obtain a reliable bond for repair of an old composite restoration.

Tezvergil *et al.* [24] reported significantly higher mean bond strength (35.7 MPa) when a bonding resin was used to repair an existing composite resin surface with new composite, compared to when no bonding resin was used (bond strength of 17.8 MPa). Similarly, Papacchini *et al.* [27] report significantly higher bond strength (38.2 MPa) when a bonding resin was used for composite repair, compared to no use of bonding resin (24.5 MPa). In a recent study, Staxrud *et al.* [10] reported a composite-composite bond strength value of 26 MPa when a bonding resin was used, compared to 9.9 MPa when bonding resin was not applied. It is therefore plausible that a bonding resin may effectively increase the bond strength of orthodontic brackets to existing composite restorations. The conventional bonding resin utilized in the present study was Single Bond 2 that is a total etch, visible-light activated dental

bonding agent containing 10wt% of 5nm diameter silica fillers. This adhesive is suitable for direct light-cure restorative materials and for treatment of cervical hypersensitivity.

Scotchbond Universal is a restorative bonding resin, marketed as a universal restorative bonding resin for application on all surfaces including enamel, dentin, composite resin, amalgam, and porcelain. Although it has been manufactured for use in restorative dentistry, we tested the possibility of its use as a multi-purpose restorative bonding resin to increase the bond strength of orthodontic brackets to an existing composite restoration effectively.

The highest mean bond strength among all groups was found in use of Scotchbond plus surface preparation (11.9 MPa). Although higher, this value had no significant difference with that in the other two groups. Isolan *et al.* [28] in their study on shear bond strength of new composite to old composite restorations reported that the bond strength of Single Bond 2 and Universal adhesive was similar.

Hellak *et al.* [29] evaluated the shear bond strength and ARI score of two self-etch no-mix adhesives (iBond and Scotchbond) when applied on different prosthetic surfaces (composite, porcelain, metal) and enamel, compared to the Transbond XT commonly used total etch system. In their study, Transbond XT showed the highest shear bond strength to the human enamel but Scotchbond Universal provided the highest shear bond strength to all other surfaces (metal, composite, and porcelain) without requiring additional primers. A noteworthy issue is that in the study by Hellak *et al.* [29], all surfaces had been sandblasted while in our study, the bond strength of universal adhesive was also measured to surfaces with no preparation, which showed no significant difference with the bond strength to prepared surfaces.

Moreover, Tse *et al.* [30] assessed the mean bond strength value and mode of failure of five bonding systems (MIP1, Plastic Conditioner2, Assure2, Scotchbond3 and Transbond XT1) when bonding orthodontic brackets to artificially aged composite restorations, with and without mechanical surface preparation with a diamond bur *in vitro*. They concluded that mechanically roughening the surface of composite restorations with diamond bur provided significantly

greater bond strength values, regardless of the bonding resin used. However, Assure and Scotchbond, which were universal orthodontic and restorative bonding resins, without diamond bur preparation, provided similar bond strength to that of Transbond, MIP, and Plastic Conditioner, with diamond bur preparation. This confirms our results and shows that Scotchbond Universal can provide adequately higher bond strength even without surface preparation.

In our study, the obtained bond strength values in all groups was higher than the minimum required range of bond strength in the clinical setting (5.9 to 7.8 MPa) suggested by Reynolds [31]. Moreover, no significant difference was noted in bond strength among the groups. In other words, universal adhesive provides comparable bond strength to Single Bond 2 and can serve as a suitable alternative for bracket bonding to composite surfaces. Of particular interest is that in contrast to conventional bonding resins, surface roughening by bur does not significantly change the bond strength of universal adhesive to composite. Since clinicians prefer not to perform surface roughening in the clinical setting, because of esthetic considerations, use of Scotchbond Universal adhesive without composite surface roughening by bur can be recommended.

The chemical composition of orthodontic and restorative bonding resins is under constant development. Their exact composition remains proprietary. A recent systematic review on contemporary dental adhesives attempted to provide a list of all chemical ingredients used in the composition of the current bonding resins [32]. As reported by van Landuyt *et al.* [32], detailed information about the chemical composition of these bonding resins is not available, since many of the chemical compounds are proprietary and remain protected. The clinical performance of bonding resins can be changed by simply altering the proportion of monomers used, and van Landuyt *et al.* [32] reported that manufacturers commonly use this strategy to develop new bonding resins. However, the ability of universal bonding resins, such as Scotchbond, to provide high bond strength values without surface preparation, cannot be easily explained since the specific chemical composition of these products remains unknown. They may contain proprietary compounds with functional

groups that chemically bond to the organic resin matrix or inorganic filler particles; or they may have higher penetration ability into the irregularities present on the composite surface. It is not known whether it is because of their lower viscosity as the result of using lower molecular weight monomers, use of water-chasing solvents such as alcohol or acetone rather than water, or ideal proportion of the above-mentioned components.

The ARI is used to classify the location of the bond failure [6]. This can determine the risk of damage to the composite surface during debonding. Bond failure at the bracket-adhesive interface (scores 3) requires more adhesive removal following bracket debonding, whereas, bond failure at the restoration-adhesive interface (score 0) requires less adhesive removal. Some authors prefer adhesive failure at the bracket-adhesive interface, since it minimizes the risk of tooth or restoration surface fracture [33].

Regardless of the mode of failure, incidence of fracture of the composite resin restoration surface upon bracket removal is highly important since fracture of the restoration surface is undesirable.

The most common mode of bond failure in all groups in our study was found to be surface fracture (score 4). It should be noted that this significantly high incidence of fracture of the restoration surface is probably because Scotchbond and Single Bond 2 are restorative bonding resins. They have been formulated to achieve a permanent bond of the highest strength in restorative applications, whereas, orthodontic bonding resins are formulated to create a temporary bond and to allow for ultimate removal of orthodontic appliances.

This finding is in agreement with the results of Tse *et al.* [30] who showed higher incidence of surface fracture in Scotchbond group when compared to orthodontic bonding resins such as Transbond XT.

Conclusion

The bond strength of Scotchbond Universal adhesive was not significantly different from the bond strength provided by Single Bond 2 conventional adhesive. The bond strength of Scotchbond Universal adhesive was not significantly different with and without composite surface roughening by diamond bur.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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