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Shear Bond Strength of Metal Brackets to Porcelain Using a Universal Adhesive

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ABSTRACT

Introduction: Bracket bonding to porcelain has high failure rate compared to bonding to enamel. **Aim**: This study aimed to assess the shear bond strength (SBS) of metal brackets to porcelain using a universal adhesive. **Material and Methods:** In this in vitro experimental study, 40 porcelain blocks (1x1x1 cm^3)were divided into four groups (n=10). The porcelain surfaces were etched with 10% hydrofluoric (HF) acid and bonded to metal brackets using Transbond XT composite and the following bonding protocols: Transbond XT bonding agent alone in group 1, silane plus Transbond XT bonding agent in group 2, silane plus universal adhesive (G-Premio bond) in group 3 and universal adhesive alone in group 4. The SBS was measured using a universal testing machine at a crosshead speed of 1 mm/minute. Fracture surfaces were evaluated under a stereo microscope, and the adhesive remnant index (ARI) scores were determined. **Results:** The highest and the lowest SBS values were noted in groups 3 (17.06±2.58 MPa) and 4 (9.85±4.76 MPa), respectively. Type of adhesive had no significant effect on SBS (P=0.611). However, the effect of application of silane on SBS was significant (P=0.000). Groups subjected to the application of silane showed higher SBS values than others. The mode of failure was mainly adhesive in groups 2 and 3, and adhesive and mixed in groups 1 and 4. The difference in ARI scores was statistically significant (P=0.016). **Conclusion:** Universal adhesive and Transbond XT were not significantly different in SBS. However, application of silane significantly increased the bond strength.

Keywords: Orthodontic brackets, Dental porcelain, Shear strength.

1. INTRODUCTION

By the increased demand for orthodontic treatment among adults, bonding of orthodontic brackets to dental restoration surfaces has become a common necessity in dentistry (1). Most adults have composite resin, amalgam, gold, acrylic resin or ceramic restorations in their mouth (2), which need to be bonded to brackets in case of fixed orthodontic treatment. In the recent years, demand for ceramic dental restorations especially in fixed partial dentures has greatly increased (3). Dental ceramics have many advantages such as biocompatibility, excellent aesthetics, insignificant plaque accumulation, low thermal expansion, resistance to abrasion and color stability (4). Ceramic crowns used in fixed partial dentures are made of feldspathic porcelain, lithium disilicate ceramic or zirconia ceramics (5, 6). Dental ceramics are mainly composed of metal oxides and some other conventional ceramic materials (7) while dental porcelain is a feldspathic glass containing crystalline silica (8). Since the bracket-resin interface is the weakest point in orthodontic bracket bonding, attempts are made to reinforce this area (9). Repeated debonding of orthodontic attachments is a major concern for orthodontists. It interrupts the smooth course of treatment, increases the treatment time and necessitates rebonding of debonded attachments, which is time consuming (10).

Although recent advances in adhesive systems have enabled the bonding of orthodontic brackets to materials other than the enamel, bracket bonding to some restorative materials such as ceramic crowns is still challenging for orthodontists (11, 12). Bracket bonding to porcelain has high failure rate compared to bonding to enamel. Rate of failure depends on the type of porcelain, surface conditioning, bracket material, type of bonding agent used and expertise of the clinician (13). Surface treatment is among the most important parameters affecting bracket bonding to restoration surfaces. Mechanical methods such as increasing the surface roughness by using a diamond bur and air abrasion with aluminum oxide or silica and chemical methods such as acid-etching with/without the application of silane can be used for ceramic surface preparation (2). An optimal bond should well tolerate orthodontic and masticatory forces applied to the bracket. Also, the bracket bond strength should not be too high to traumatize the enamel or the restoration surface during debonding (14). The manufacturers claim that universal adhesives have unique chemical properties and bonding mechanism, which allow bonding to different substrates (15). Universal adhesives are available in self-etch, etch and rinse and selective etching modes for dental purposes. They can bond to bis methacrylate, enamel, dentin, glass ionomer and indirect restorations made of metals, alumina, zirconia and other ceramics. They all contain acidic monomers (16). The conventional bonding systems are time-consuming and have high technical sensitivity. Moreover, risk of error is high since they have multiple application steps (17).

A study (18) reported that application of phosphoric acid can be used as an alternative of HFA for ceramic surfaces preparation for orthodontic bonding; however, a previous study showed that use of a self-etching primer created higher shear bond strength (SBS) of brackets to ceramic surfaces. It also showed that the most reliable technique for bracket bonding to ceramic surfaces was micro-etching by the hydrofluoric acid (HF) followed by the application of silane prior to bonding. However, this method significantly damages the porcelain surface (19). Therefore, it is imperative to find a bonding protocol that can provide a bond strong enough to resist orthodontic and masticatory forces with minimal damage to the surface of porcelain during debonding. This study aimed to assess the SBS of metal brackets to porcelain using a universal adhesive.

2. MATERIAL AND METHODS

This in vitro experimental study was performed on 40 cubic-shaped glazed feldspathic porcelain blocks measuring $1x1x1cm^3$. Minimum sample size was calculated to be 40 blocks (n=10 in each of the four groups) according to a previous study by Schmage et al. (6), assuming the standard deviation of SBS to be 3.3 and 3.4 in the HF acid and HF acid plus silane groups, respectively, accuracy (d) of 5, alpha=0.05 and power of 90%. Samples were randomly divided into four groups using a table of random numbers (n=10).

In group 1, 10% HF acid (3M Unitek, Monrovia, CA, USA) was applied on the porcelain surface for 2 minutes, rinsed and dried (19). Transbond XT bonding agent (3M Unitek, Monrovia, CA, USA) was then applied on the porcelain surface and cured for 10 seconds. Transbond XT composite (Monrovia-USA) was applied over the back of metal bracket of maxillary central incisor (Roth 18; Dentaurum, Springen, Germany) and the bracket was then positioned at the center of porcelain surface and manually compressed in order for the excess composite to leak out around the bracket base. Excess composite was removed by the tip of a dental explorer. The bracket was then light cured from each side for 10 seconds using a LED light curing unit (LED.D; Woodpecker, China) with a light intensity of 850-1000 mW/cm^2.

In group 2, 10% HF acid was applied on the porcelain block surface for 2 minutes, rinsed and dried. Silane (Angelus, Netherlands) was then applied and dried. Transbond XT bonding agent was applied on the surface and light cured for 10 seconds. Metal bracket was bonded to the porcelain surface as in group 1.

In group 3, 10% HF acid was applied on the porcelain surface for 2 minutes, rinsed and dried. Silane was also applied and dried. G-Premio BOND universal adhesive (GC America, IL, USA) was applied on the porcelain surface and light cured for 10 seconds. Metal bracket was bonded to the porcelain surface as in group 1.

In group 4, 10% HF acid was applied on the porcelain surface for 2 minutes, rinsed and dried. Universal adhesive was applied on the porcelain surface and light cured for 10 seconds. Metal bracket was bonded to the porcelain surface as in group 1.

The samples were stored in distilled water (20) at room temperature for 24 hours and were then subjected to thermo cycling between 5-55°C for 1000 cycles with a dwell time of 20 minutes and transfer time of 5 minutes (20). After thermo cycling, the samples were stored in distilled water at room temperature for 7 days (20). The samples were then transferred to a universal testing machine (STM 20; Santaam, Tehran, Iran). Load was applied at a crosshead speed of 1 mm/minute until bracket debonding. The load at bracket debonding was recorded in Newtons (N). The SBS in megapascals (MPa) was calculated by dividing the load in Newtons by the bracket base surface area in square millimeters (2x3.7 mm).

All samples were then inspected under a stereo microscope (SZM, Optika, Italy) at x40 magnification (Figure 1). The mode of failure was determined according to the amount of composite remaining on the porcelain surface using the adhesive remnant index (ARI). According to the ARI, score 0 indicates no adhesive remaining on the surface, score 1 indicates less than 50% of adhesive remaining on the surface, score 2 indicates over 50% of adhesive remaining on the surface and score 3 indicates all adhesive remaining on the surface (21).

Data were analyzed using SPSS version 16 (SPSS Inc., IL, USA) via descriptive and analytical statistics. The mean and standard deviation values were calculated and reported for descriptive data. For analytical data, normal distribution of data was first assessed using the Shapiro-Wilk test. Two-way ANOVA was used to compare the four groups in terms of SBS while the Kruskal-Wallis test was applied to compare the four groups in terms of mode of failure. Level of significance was set at 0.05.

3. RESULTS

According to the Shapiro-Wilk test, the SBS data were normally distributed in the four groups (P>0.05). Thus, two-way ANOVA (parametric test) was used to compare the SBS data among the four groups. Table 1 shows the mean SBS in the four groups. As shown, group 3 had

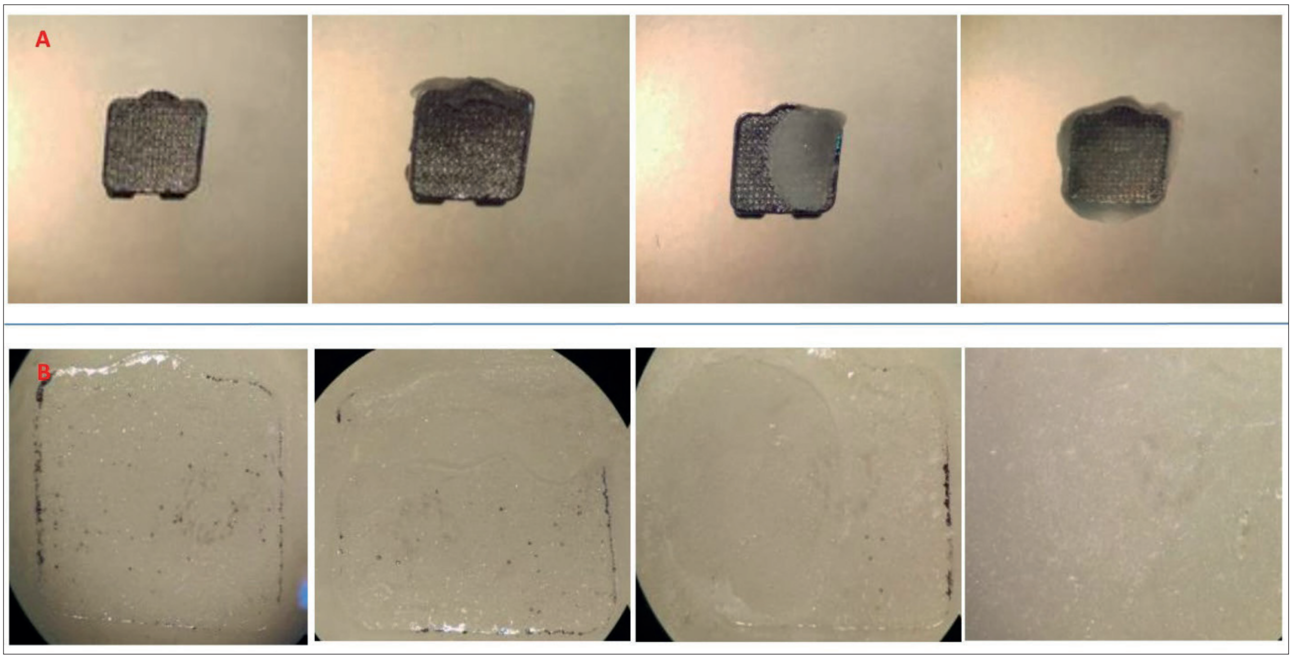

Figure 1. Mode of fracture and ARI scores [right to left: Scores 0, 1, 2, and 3] (A) bracket at x10magnification; (B) porcelain at x40 magnification

Group	Shear bond strength (MPa)		
	Mean	Maximum	Minimum
1	10.03±4.41	19.02	5.04
2	15.62±3.52	21.80	11.40
3	17.06±2.58	20.21	12.13
4	9.85±4.76	17.29	2.39

Table 1. Mean shear bond strength in the four groups (n=10)

Groups	Number (%)			
	Score 0 No adhesive on enamel	Score 1 <50% adhesive on enamel	Score 2 >50% adhesive on enamel	Score 3 All adhesive on enamel
1	4 (40%)	2 (20%)	1 (10%)	3 (30%)
2	1 (10%)	1 (10%)	0	8 (80%)
3	1 (10%)	2 (20%)	1 (10%)	6 (60%)
4	3 (30%)	6 (60%)	0	1 (10%)

Table 2. Frequency of ARI scores in the four groups (n=10)

the highest (17.06±2.58 MPa) and group 4 had the lowest SBS value (9.85±4.76 MPa). However, according to ANOVA, the SBS data were not significantly different in terms of type of bonding agent used (P=0.611, df=1, F=0.263) while the difference among the groups was significant in terms of presence/absence of silane (P=0.000, df=1, F=27.26). Groups subjected to silane application showed significantly higher SBS compared to others.

Table 2 shows the frequency of ARI scores in the four groups. According to the Kruskal-Willis test, the four groups were significantly different in this respect. Groups 2 and 3 had the highest frequency of ARI score 3, which means that bond failure was adhesive type (debonding at the adhesive-bracket interface; almost all composite remained on the porcelain surface) while groups 1 and 4 had the highest frequency of ARI scores 0 and 1, which means adhesive failure (debonding at the adhesive-porcelain interface; almost no composite remained on the porcelain) and mixed failure (some of the composite remained on the porcelain and some on the bracket) [P=0.016, df=3, chi-square=10.296).

4. DISCUSSION

Several types of dental adhesives have been introduced to the market aiming to facilitate the process of bonding, shorten the chair time and minimize technical sensitivities. A new type of adhesive, known as universal adhesive or multipurpose adhesive is available in dental market, which can be used in two-step etch and rinse, or one step self-etch mode. This capability allows the dentists to select the most suitable protocol based on their priority and clinical status of patient. Universal adhesives can bond to dental structures, resin, stainless steel, ceramic and zirconia (15, 22, 23).

In orthodontic bracket bonding to the enamel, the bonding process depends on the penetration of adhesive into the etched enamel surface and formation of resin tags. However, resin tags do not form on the surface of ceramic crowns. Thus, ceramics require surface treatment prior to bonding (2). This study assessed the SBS of metal brackets to porcelain using a universal adhesive with and without silane compared to Transbond XT with and without silane. Transbond XT is a commonly used bonding agent for orthodontic brackets. It is the bonding agent of choice for bracket bonding to the enamel and is the gold standard for assessment of bond strength of new products (24).

Fox et al. (25) stated that after bonding, samples should be stored in distilled water at 37°C for 24 hours. Zachrisson et al. (26) recommended immersion in water at 37°C for 24 hours prior to thermo cycling. Eikenberg and Shurtleff (27) showed that thermo cycling alone is not sufficient for simulation of oral conditions before bond strength testing and the samples should be kept in 100% humidity for some time prior to thermo cycling to better simulate the clinical setting. Thus, in the current study, samples were stored in distilled water for 24 hours and were then subjected to thermo cycling (20). Moreover, they were stored in distilled water for 7 days after thermo cycling and prior to bond strength testing.

According to Karan et al. (28), 14 kg/cm² (equal to 1.5 MPa) is the maximum load that can be applied by orthodontic appliances to a tooth while Reynolds (29) reported that 50 kg/cm² load (equal to 5 MPa) was required for clinical success. Barcelo Santana et al. (30) reported that the ideal bracket bond strength is 6 to 10 MPa. The SBS values obtained in all four groups in our study were acceptable according to Karan et al. (28). However, considering the ideal bond strength of 6 to 8 MPa, two samples in group 1 (5.36 and 5.04 MPa) and two samples in group 4 (2.39 and 4.56) did not have the ideal bond strength.

In our study, the highest SBS was noted in group 3 (17.06±2.58 MPa) while the lowest SBS was recorded in group 4 (9.85±4.76 MPa). Type of adhesive had no significant effect on SBS (P=0.611). However, the effect of application of silane on SBS was significant (P=0.000) such that groups subjected to the application of silane showed higher SBS values than others. Similarly, Eslami-Amirabadi et al. (20) reported the highest bond strength in no glaze group subjected to HF acid etching and silane application (25.16±10.66 MPa); the lowest bond strength was noted in the group subjected to phosphoric acid etching alone (0.67±0.54 MPa). Kalavacharla et al. (31) assessed the bond strength of Single Bond universal adhesive with/without silane to lithium disilicate ceramic and reported that bond strength was significantly higher when silane was applied prior to the universal adhesive. Also, Bishara et al. (32) indicated that use of Transbond XT adhesive and composite after micro-etching with HF acid and silane application on porcelain surface resulted in the highest SBS; however, this method significantly damaged the porcelain. Thurmond et al. (33) evaluated the effect of porcelain surface treatment on bond strength of composite resin to porcelain and showed that bond strength in HF acid plus silane group was higher than that in phosphoric acid plus silane group. However, Thurmond et al. (33) mentioned that considering the fact that bond strength higher than 13 MPa would greatly damage the ceramic during debonding, phosphoric acid can be used instead of HF acid to eliminate the potential risks of application of HF acid in the oral environment and decrease the possibility of ceramic damage during debonding.

In contrast to our study, Kim et al. (17) showed that application of universal adhesive increased the bond strength of resin to HF acid etched ceramic surfaces. They stated that use of silane plus universal adhesive is preferred for simple procedures. The difference between the results of the two studies may be attributed to the fact that they aimed to compare All Bond and Single Bond universal adhesives for bonding to ceramic and found no significant difference between the two adhesives in this respect. However, they showed that application of universal adhesives was superior to the use of no adhesive or RelyXceramic adhesive.

Regarding the ARI score, the four groups were significantly different in this respect. Groups 2 and 3 had the highest frequency of ARI score 3, which means that bond failure was adhesive type (debonding at the adhesive-bracket interface; almost all composite remained on the porcelain surface) while groups 1 and 4 had the highest frequency of ARI scores 0 and 1, which means adhesive failure (debonding at the adhesive-porcelain interface; almost no composite remained on the porcelain) and mixed failure (some of the composite remained on the porcelain and some on the bracket). During bracket debonding, bond failure at the adhesive-tooth interface results in no composite remnants on the enamel surface, which is an advantage in the clinical setting. However, debonding at the bracket-adhesive interface results in adhesive remnants on the tooth surface. This is important to prevent enamel fracture or damage to porcelain surface (34). Since the bond strength >13 MPa is associated with the risk of porcelain damage, as well as the fact that the bond strength in groups 2 and 3 was higher than 13 MPa in our study, we expected porcelain damage during debonding. However, the ARI scores showed that the bond failure in these two groups mainly occurred at the bracket-composite interface. Thus, it may be concluded that application of silane not only significantly increases the SBS, but also enables safe debonding with no porcelain damage.

In the current study, universal adhesive used with saline yielded higher bond strength than universal adhesive alone, which may indicate that universal adhesive does not contain adequate amount of silane. However, since bond strength between 6 to 10 MPa is ideal for bracket bonding (30), and use of universal adhesive provides adequately high bond strength for this purpose, we can accept the manufacturer's claim stating that use of universal adhesive alone without silane would suffice for bracket bonding; but, this decision would be based on our in vitro findings only and further in vivo studies are required to further scrutinize this topic by comparing the failure or survival rates.

Not having a force-meter to standardize the pressure applied during placement of brackets on the porcelain surface (to standardize the adhesive thickness) was a limitation of this study. Also, the effect of different surface treatment protocols on bond strength of universal adhesives should be evaluated in further studies. To better simulate the clinical setting, immersion of samples in artificial saliva, instead of distilled water, is recommended in future studies.

5. CONCLUSIONS

Within the limitations of this in vitro study, the results showed that application of silane after etching with HF acid significantly increased the SBS. Use of universal adhesive did not cause a significant change in SBS compared to Transbond XT. The mode of failure was mainly adhesive in groups where silane was used. As the result, almost all composite remained on the porcelain, which is favorable for porcelain protection but removal of this much composite from the porcelain surface would be time consuming.

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