

COMPARISON OF SHEAR BOND STRENGTHS OF METAL BRACKETS BONDED WITH A UNIVERSAL ADHESIVE CONTAINING A SILANE COUPLING AGENT

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ABSTRACT

Background and Aim: Certain recently developed universal adhesives contain a silane coupling agent, which would eliminate the need for the clinician to apply additional silane when bonding brackets to ceramic surfaces. The aim of this in vitro study was to compare the shear bond strength (SBS) of orthodontic brackets that were bonded with a universal adhesive against a control group that had brackets bonded with a separate silane on two different types of ceramic material.

Materials and Methods: Thirty hybrid and thirty feldspathic ceramic specimens were prepared. All samples were acid etched with hydrofluoric acid. In group 1, a silane and an adhesive primer (Transbond XT, 3M Unitek) were applied, and metal brackets were bonded to the hybrid ceramic surfaces using adhesive paste resin. In group 2, a universal adhesive (Clearfil Universal Bond, Kuraray) was applied, and brackets were bonded with the same adhesive paste. In groups 3 and 4, the same protocols were applied to feldspathic ceramic surfaces as were applied to the hybrid surfaces in groups 1 and 2, respectively. A two-way analysis of variance (ANOVA) was used to compare the groups.

Results: The mean SBS values were 10.7 ± 3.1 MPa for group 1, 11.6 ± 4.1 MPa for group 2, 5.7 ± 1.8 MPa for group 3, and 9.3 ± 3.4 MPa for group 4. There were also significant differences between the ARI scores of the groups.

Conclusion: Universal bonding showed adequate SBS values for clinical use during orthodontic bonding on ceramic surfaces.

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Clin Dent Res 2017; 41(2): 69-74

Keywords: Shear Bond Strength, Silane Coupling Agent, Universal Adhesive

Submitted for Publication: 01.26.2017

Accepted for Publication: 06.28.2017

SİLAN İÇEREN BİR UNIVERSAL ADEZİV İLE YAPIŞTIRILAN METAL BRACKETLERİN MAKASLAMA BAĞLANTI KUVVETLERİNİN KARŞILAŞTIRILMASI

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ÖZ

Amaç: Son geliştirilen universal adezivler, içerisinde yer alan silan sayesinde, seramik yüzeylere braket yapıştırırken klinisyenin ek bir silan uygulama ihtiyacını ortadan kaldırabilmektedirler. Bu çalışmanın amacı, iki farklı seramik materyal üzerine ortodontik braket yapıştırırken kullanılan bir universal adeziv ve bir kontrol materyalinin makaslama bağlantı kuvvetlerini (SBS) karşılaştırmaktır.

Gereç ve Yöntem: 30 hibrid ve 30 feldspathic seramik örnek hazırlandı. Bütün örnekler hidroflorik asit uygulandı. Birinci grupta silan ve adeziv primer (Transbond XT, 3M Unitek) uygulandı ve metal braketler hibrid seramik yüzeylere adeziv rezin ile yapıştırıldı. İkinci grupta bir universal adeziv (Clearfil Universal Bond, Kuraray) kullanıldı ve braketler aynı adeziv rezin ile yapıştırıldı. Üçüncü ve dördüncü gruplarda ise birinci ve ikinci gruplarda hibrid seramik yüzeylerde kullanılan aynı protokoller feldspathic seramik yüzeyler için uygulandı. Grupları karşılaştırmak için iki yönlü varyans analizi (ANOVA) kullanıldı.

Bulgular: Birinci grupta ortalama SBS değeri 10.7 ± 3.1 MPa, ikinci grupta 11.6 ± 4.1 MPa, üçüncü grupta 5.7 ± 1.8 MPa ve dördüncü grupta 9.3 ± 3.4 MPa olarak ölçüldü. Gruplar arasında ARI skorları arasında da anlamlı farklılık bulundu.

Sonuç: Universal adeziv, ortodontik braket yapıştırma sırasında klinik kullanım için yeterli SBS değerleri sağlamıştır.

Clin Dent Res 2017; 41(2): 69-74

Anahtar Kelimeler: Makaslama Bağlantı Dayanıklılığı, Silan Ajanı, Universal Adeziv

Yayın Başvuru Tarihi : 26.01.2017

Yayına Kabul Tarihi : 28.06.2017

INTRODUCTION

Adult orthodontic care has been growing in popularity in recent decades. Thus, orthodontists encounter various types of ceramic restorations, such as crowns and fixed partial dentures, during adult orthodontic treatment. However, bonding of orthodontic attachments to those ceramic surfaces requires specific surface treatment techniques to ensure adequate bond strength.^{1,2} Etching with either hydrofluoric or phosphoric acid, roughening with diamond burs, and air particle abrasion with aluminum trioxide are examples of those techniques.³ Etching ceramic surfaces with hydrofluoric acid followed by the application of silane coupling agents is the most popular and clinically recommended procedure.^{4,5}

The most recent generation of new adhesives are known as “universal” adhesives, some of which contain a silane coupling agent.⁶ Inclusion of a silane in an adhesive eliminates the need for the clinician to apply a separate silane solution after the surface treatment of a ceramic material. The presence of a Bis-GMA monomer in a silane solution decreases the contact angle and reduces surface wettability.⁷ A recent study showed that, although separate silane application provided the highest bonding strength, universal bond application to lithium disilicate ceramic surfaces after both 5% and 9.5% hydrofluoric acid treatments without any separate silane yielded an adequate SBS for orthodontic bonding.⁸

Manufacturers produce novel materials to enhance the clinical availability of dental products. Recently, a dental hybrid ceramic material was developed that combines the properties of both a polymer and a ceramic. A polymer network reinforces the dominant ceramic network of this material, with each network penetrating the other to create a hybrid material. This polymer-infiltrated ceramic can be acid etched to allow for adhesive bonding.⁹

Therefore, the aim of this study was to assess the effects of universal bonding on the SBS of metal brackets when bonded to either hybrid or routinely used feldspathic ceramic surfaces. The null hypothesis was as follows: There are no significant differences between the SBS values of metal brackets when bonded with a universal bonding agent versus a separate silane coupling agent on ceramic materials.

MATERIALS AND METHODS

Thirty feldspathic pressed ceramic specimens (Ceramco 3, Dentsply, Burlington, New Jersey, USA) were prepared, each with a diameter of 5 mm and a thickness of 3 mm. The feldspathic specimens were glazed according to the

manufacturer's instructions. Thirty CAD/CAM hybrid ceramic specimens (VITA ENAMIC, Vita Zahnfabrick, Bad Säckingen, Germany) were cut from ENAMIC blocks using a diamond blade, each with the same diameter and thickness. The surfaces of the samples were polished according to the manufacturer's instructions. All samples were placed in autopolymerizing acrylic blocks (Meliodent, Heraeus Kulzer Ltd., Newbury, Berkshire, UK) with their polished and glazed surfaces facing upward.

The samples were divided into four groups (n=15). The specifications of the groups are detailed in Figure 1. The surfaces of the samples in each group were acid etched with 9.6% hydrofluoric acid gel (Porcelain Etch Gel, Pulpdent, Watertown, MA) for 2 minutes. After chemical surface roughening, the surfaces were washed and rinsed to remove the debris and dried with oil-free air. In group 1, a silane (Pulpdent, Watertown, MA) and an adhesive primer (Transbond XT, 3M Unitek, Monrovia, CA) were applied prior to the bonding of upper central metal brackets (Gemini 3M-Unitek, Monrovia, CA) to hybrid ceramic surfaces using Transbond XT light cure adhesive paste resin according to the manufacturer's instructions. In group 2, a universal adhesive (Clearfil Universal Bond, Kuraray) was applied after acid etching with hydrofluoric acid gel, and brackets were bonded with the same adhesive paste. In groups 3 and 4, the same protocols were applied to feldspathic ceramic surfaces as in groups 1 and 2, respectively. Excess adhesive was removed prior to light curing. The samples were cured for 20 seconds with an LED unit (Elipar™ S10, 3M Unitek, Monrovia, CA). All samples were prepared by the same operator (S.C.). Samples were stored in distilled water at 37°C for 24 hours. After 24 hours, thermocycling was performed 500 times between 5°C and 55°C with a custom-made device. Bond strength (MPa) was tested using a Lloyd LRX testing machine (Lloyd Instruments Plc, Fareham, Hampshire, UK), which was set at a crosshead speed of 1 mm/minute. The measurements were made in Newtons and converted into megapascals (MPa) via the following equation: shear force (MPa) = debonding force (N) / (w/l) (mm²), where w = width of the bracket base, l = height of the bracket base, and 1 MPa = 1 N/mm².

The bracket base and ceramic surfaces of the samples were examined with a stereomicroscope (Nikon SMZ 1500, Nikon, Tokyo, Japan) at a magnification of 10×, and the amounts of remnant adhesives were scored. A 4-step adhesive remnant index was used, as described by Årtun and Bergland¹⁰, as follows: 0, all adhesive on the bracket base; 1, more than

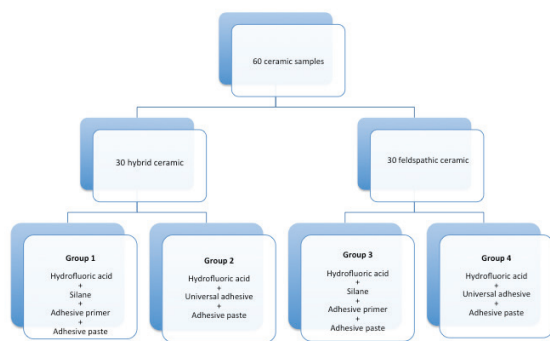


Figure 1. Flow chart of the study

half of the adhesive on the bracket base; 2, less than half of the adhesive on the bracket base; and 3, no adhesive on the bracket base. Statistical analysis was performed using SPSS for Mac version 20.0. A two-way ANOVA was performed to determine the differences among the ceramic materials and bonding adhesives as well as their interactions. All treatment combinations for bond strength were compared using the Bonferroni test. In vitro ARI scores were assessed using the chi-squared test. The level of significance was set at $p < 0.05$.

RESULTS

According to the results of the two-way ANOVA, the main effects on SBS values were significant for ceramic materials and bonding adhesives (silane+adhesive or universal adhesive). However, the interaction between the ceramic materials and bonding adhesives was not significant (Table 1). Bonferroni correction was used to compare the main effects.

The mean SBSs of the groups are presented in Table 2. SBS values for each group are presented in Figure 2. The mean SBS values were 10.7 ± 3.1 MPa for group 1, 11.6 ± 4.1 MPa for group 2, 5.7 ± 1.8 MPa for group 3, and 9.3 ± 3.4 MPa for group 4. Feldspathic samples bonded with silane (group 3) showed the lowest SBS value between the groups. The

mean SBS values were $11.2 (\pm 3.6)$ MPa for hybrid ceramics and $7.5 (\pm 3.2)$ MPa for feldspathic ceramics. There was a statistical difference between the SBS values of ceramic materials. Hybrid ceramics showed statistically more SBS than feldspathic ceramics. There was also a significant difference between the silane + adhesive application and the universal adhesive only application. The universal adhesive only application groups showed higher SBS values than the silane + adhesive application groups. The adhesive remnant index scores are detailed in Table 3. There was also a significant difference in ARI scores between the groups.

DISCUSSION

Various ceramic materials are used in restorations, such as glass-filtered alumina, feldspathic, and leucite-reinforced ceramics, due to their superior esthetic appearance. Silane coupling agents are mainly used for adhesion in such restorations. The repair of these ceramics with resin composites also includes silane application.^{5,11,12} Silane coupling agents usually increase the bond strength of orthodontic brackets.¹³ During bonding of an adhesive resin on silane, the reactive organic radical groups in the silane coupling agent become chemically bonded to resin molecules, and hydrolyzable monovalent groups bond chemically to silicon contained in the glass matrix and crystals. Then, a chemical bond is formed between the silica layer on ceramic surfaces and the silane coupling agent.¹⁴ Silanes also improve surface wettability, which results in better contact and infiltration of the adhesive into irregularities on treated ceramic surfaces.^{7,14} The results of this in vitro study indicated that using a silane coupling agent and an adhesive primer application to hybrid ceramic surfaces after acid etching with 9.6% hydrofluoric acid gel yielded similar results to those from universal bond only applications after surface treatments. Reynolds suggested that adequate bond strength for clinical orthodontics is between six and eight MPa.¹⁵ The mean SBS values were adequate in both groups 1 and 2 for orthodontic bonding. In group 4, when orthodontic metal brackets were bonded to

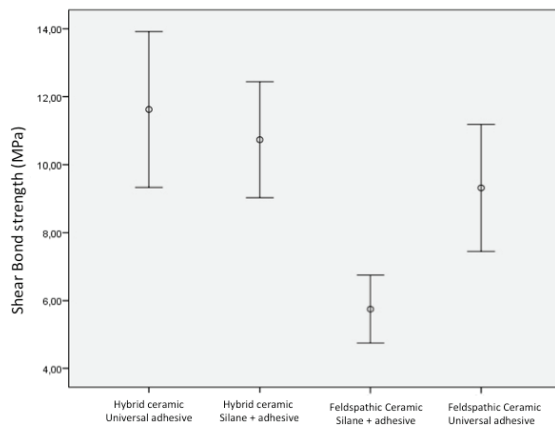
Table 1. Two-way analysis of variance of force (Megapascals) required to debond metal brackets from dental ceramic.

	Sum of Squares	df	Mean Square	F	p
Ceramic	199.7	1	199.7	19.4	<0.001
Surface conditioning	74.5	1	74.5	7.2	0.009
Ceramic X Surface conditioning	26.9	1	26.9	2.6	0.112

(Surface conditioning= Silane + adhesive or only Universal adhesive)

Table 2. Descriptive statistics and mean SBS values of the groups.

	Hybrid ceramic	Feldspathic Ceramic	General
Silane + adhesive	10.7 ± 3.1	5.7 ± 1.8	8.2 ± 3.5
Universal adhesive	11.6 ± 4.1	9.3 ± 3.4	10.5 ± 3.9
General	11.2 ± 3.6	7.5 ± 3.2	

**Figure 2.** Shear bond strengths values of hybrid and ceramic feldspathic samples bonded with silane + adhesive and universal adhesive

feldspathic ceramic surfaces with a universal bonding agent yet without a separate silane application, the shear bond test values exhibited adequate bond strength. However, in group 3, the orthodontic metal brackets showed lower SBS than the other groups, and the mean bond strength of group 3 was below the adequate value.

The micromechanical retention of a ceramic surface plays an important role in SBS.¹⁴ A previous study compared the effect of different surface conditioning methods of all ceramic materials and found that feldspathic ceramics treated with hydrofluoric acid and silane showed inadequate bond strengths for orthodontic bracket bonding.⁴ The results of the present study support that previously published study. Other surface conditioning methods in past studies, including air abrasion with aluminum trioxide and roughening with diamond burs, gave higher bond strength values than hydrofluoric acid.^{3,16} Different surface conditioning methods could change the results of this study. Although the same surface treatment method was used in groups 3 and 4, universal bonding without any separate silane gave significantly higher values than a silane and transbond adhesive primer application.

Some recent studies have investigated the effects of using a silane coupling agent in universal adhesives. Yoshihara et al.¹⁷ concluded that Scotchbond Universal showed less effective results than a separate silane. However, Siqueira et al.¹⁸ found a wide variability in SBSs of different universal adhesives when applied to several CAD/CAM materials. The universal adhesive used in our in vitro study showed effective results for orthodontic bracket bonding to feldspathic and CAD/CAM hybrid ceramic surfaces.

There was also a significant difference between the ARI scores of the groups. It was observed that the type of ceramic material used in this in vitro study affected the ARI scores. The majority of the specimens in groups 3 and 4 presented scores of 0 (adhesive failure between ceramic and composite). This finding showed that bond strength between the composite and ceramic surfaces was lower than that between the composite and bracket surfaces and the cohesive strength of the composite. Some previous studies that used feldspathic ceramics showed similar results.¹⁶ Hybrid ceramic materials combine polymers and ceramics, and surface micro-roughening becomes easier due to the polymer matrix. Therefore, those increased micro retention areas could affect the remnant adhesive. Chemical bonding between a hybrid ceramic surface and resin cement can be achieved easily because of the polymer matrix; by contrast, although this connection can be achieved in feldspathic ceramics by forming a silane layer, the bond is weak.

CONCLUSIONS

This in vitro study evaluated the SBS of metal orthodontic brackets when bonded with a universal adhesive that contains a silane coupling agent versus conventional adhesive after application of a separate silane coupling agent on hybrid CAD/CAM and feldspathic ceramic surfaces. The following conclusions were drawn:

- The universal adhesive showed adequate SBS when used on both hybrid and feldspathic ceramic surfaces. The application of a separate silane coupling agent on

Table 3. The adhesive remnant index scores of the groups.

Groups	ARI scores	
	0	1
Group 1	7	8
Group 2	6	9
Group 3	13	2
Group 4	12	3

$\chi^2 = 10.622$ and $P = 0.014$

hybrid ceramics provided a higher SBS than when it was applied to feldspathic ceramics. However, different surface conditioning methods could yield different results.

- Universal adhesives could simplify the bonding process for the clinician when placing brackets on ceramic surfaces, and they showed adequate SBS values for clinical use.

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