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# Influence of Light Source, Thermocycling and Silane on the Shear Bond Strength of Metallic Brackets to Ceramic

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The objective of this study was to evaluate the effects of different light sources, thermocycling and silane on the bond strength of metallic brackets to ceramic. Cylinders of feldspathic ceramic were etched with 10% hydrofluoric acid for 60 s. Half of the cylinders (Groups 1 to 4) received two layers of silane. Metallic brackets were bonded to the cylinders using Transbond XT and divided into 8 groups (n=20), according to light source (Radii Plus LED - 40 s; Groups 1, 2, 5 and 6 and XL 2500 halogen light - 40 s; Groups 3, 4, 7 and 8) and experimental conditions with (Groups 2, 4, 6 and 8) without thermocycling (Groups 1, 3, 5 and 7). Shear bond testing was carried out after 24 h of deionized water storage (Groups 1, 3, 5 and 7) and thermocycling (Groups 2, 4, 6 and 8; 7,000 cycles - 5°/55 °C). Data were submitted to three-way ANOVA and Tukey's post hoc test ( $\alpha=0.05$ ). The Adhesive Remnant Index (ARI) was evaluated at 8x magnification. The application of silane was effective in increasing the shear bond strength of the brackets to ceramic ( $p<0.05$ ). Significant difference ( $p<0.05$ ) on the bond strength was observed between light sources with or without thermocycling. The ARI showed a predominance of scores 0 for all groups, with an increase in scores 1, 2 and 3 for the silane groups. In conclusion, silane improved significantly the shear bond strength of the brackets to ceramic. The thermocycling and light sources influence on the bond strength.

Key Words: ceramic,  
orthodontic bracket, light  
source, silane, thermocycling,  
shear bond strength.

## Introduction

In the last years, the number of adult patients looking for orthodontic treatment has been increasing. Ceramic materials may serve as substrates for bonding of orthodontic brackets under clinical conditions. Bonding orthodontic brackets to ceramic surface present a higher degree of failure when compared to bonding to enamel (1). Etching procedure with hydrofluoric acid is responsible for creating a rough surface and increased contact surface area in the ceramic bonding area, improving the interaction between bonding material and ceramic (2). Bonding materials need sufficient wettability to infiltrate the irregularities of ceramic surface. The use of silane on the ceramic surface prior to applying bonding material may also increase the bonding strength between ceramic and orthodontic brackets. Silane is able to form chemical bonding with both organic and inorganic surfaces (3,4). Some studies have shown better durability and bonding strength (2,4,5)

After the treatment of ceramic surface, photo-activated resin is usually used for bonding. Some light-curing units (LCUs) are currently available for photo-activation (6,7). The traditional quartz-tungsten-halogen (QTH) and light-emitting diodes (LEDs) units have been used for photo-activation (8-10).

On the other hand, when orthodontic brackets are bonded to ceramic surface and exposed to the oral environment failure can occur during the treatment due to heavy forces produced by an archwire or thermal changes in the oral cavity. Thermocycling regimens between 500 and 6,000 cycles have been used to verify if temperature variations promoted stresses in the light-cured materials (11-13). However, the literature is still not conclusive about thermocycling, silane and effectiveness of different light-curing units.

Therefore, the purpose of this study was to evaluate the effects of different light sources, silane and thermocycling on the bond strength of metallic brackets to feldspathic ceramic. The hypotheses tested were as follows: 1) The light sources do not affect the shear bond strength; 2) The silane application does not influence the shear bond strength; and, 3) Thermocycling does not affect the shear bond strength.

## Material and Methods

### *Preparation of the specimens*

Eight feldspathic ceramic glazed cylinders (Certec Advanced Ceramics, Barueri, SP, Brazil) measurement 20 mm in height x 13 mm in diameter were used in this study

and had their surfaces cleaned using a rubber cup (KG Sorensen, Cotia, SP, Brazil) and nonfluoridated pumice-water slurry (S.S. White, Petropolis, RJ, Brazil) for 20 s, rinsed with air-water spray for 20 s and dried with air for 20 s before testing. The rubber cup was replaced after each cylinder. All cylinders were etched for 60 s with 10% hydrofluoric acid gel (Dentsply Caulk, Milford, DE, USA), rinsed with air-water spray for 30 s and dried with air for 30 s. Two layers of a silane RelyX Ceramic Primer (3M ESPE, St. Paul, MN, USA) were applied and dried for 60 s in half of the cylinders (Groups 1 to 4 - Table 1). After that, stainless steel, standard maxillary premolar brackets (Abzil; 3M do Brazil Ltda, São José do Rio Preto, SP, Brazil) were positioned and firmly bonded to the curved area of the ceramic cylinders surface using light-cured bonding resin (Transbond XT; 3M Unitek, Monrovia, CA, USA), following the manufacturers' instructions. Excess of resin was removed using a microbrush.

### Light-activation Procedures

The light-activation was carried out with 4 exposures (one in each side of the bracket). Total exposure time was 40 s using light-emitting diodes (LED) (Radii Plus; SDI Limited, Bayswater, Victoria, Australia; Groups 1, 2, 5 and 6) and Quartz-tungsten-halogen (QTH) (XL 2500; 3M ESPE, Saint Paul, MN, USA, Groups 3, 4, 7 and 8) having an irradiance of 1,200 and 800 mW/cm<sup>2</sup>, respectively measured by a power meter (Ophir Optonics Inc., Danvers, MA, USA) and a computer-controlled spectrometer (USB2000; Ocean Optics, Dunedin, FL, USA). The radiant exposure was 48 and 32 J/cm<sup>2</sup> for the LED and QTH, respectively.

Twenty brackets were bonded to each ceramic cylinder (n=20) for each light source, silane and thermocycling totalized 160 bonded brackets. A punch-holed strip of black adhesive tape was used to avoid light exposure to adjacent brackets, restricting the polymerization light to the specimen being bonded (2,7).

Table 1. Experimental groups according to light source, silane and thermocycling

| Groups | Light Source             | Silane | Thermocycling |
|--------|--------------------------|--------|---------------|
| 1      | Radii Plus LED           | Yes    | No            |
| 2      |                          |        | Yes           |
| 3      |                          |        | No            |
| 4      | Halogen Light<br>XL 2500 | No     | Yes           |
| 5      | Radii Plus LED           |        | No            |
| 6      |                          |        | Yes           |
| 7      | Halogen Light<br>XL 2500 |        | No            |
| 8      |                          |        | Yes           |

### Storage and Bonding Testing

All the specimens (groups 1 to 8) were stored in deionized water at 37 °C for 24 h. After this period, the specimens of groups (2, 4, 6 and 8) were submitted to a 7,000 thermal cycles in a thermal cycler (MSCT 3, Marnucci ME, São Carlos, SP, Brazil) with deionized water between 5 °C and 55 °C (dwell time of 30 s) and transfer time of 10 s between baths.

The shear bond test was performed in a universal mechanical testing machine (Model 4411; Instron, Canton, MA, USA) using a knife-edged rod at a crosshead speed of 1.0 mm/min until failure. A mounting jig was used to align the ceramic-bracket interface parallel to the testing device (2,7,14). The shear bond strength values were calculated in MPa. Data were submitted to two-way ANOVA and Tukey's post hoc test ( $\alpha=0.05$ ).

After debonding, the bracket and ceramic surfaces were observed under optical microscopy (Olympus Corp, Tokyo, Japan) at 8x magnification. The Adhesive Remnant Index (ARI) was used to classify the failure modes as follows (15): score 0: no resin was left on the ceramic; score 1: less than half of the resin was left on the ceramic; score 2: half of the resin was left on the ceramic; and score 3: all resin was left on the ceramic, with a clear impression of the bracket mesh.

### Results

Shear bond strength mean values are shown in Table 2. Significant differences between the light sources ( $p<0.0001$ ), thermocycling ( $p<0.0001$ ) and silane ( $p<0.0001$ ) were detected. The interaction between light sources and silane ( $p=0.63789$ ), silane and thermocycling ( $p=0.66022$ ), light sources and thermocycling ( $p=0.12462$ ), light sources and silane and thermocycling ( $p=0.74495$ ) factors were not significant. Figure 1 showed the results for ARI. A predominance of score 0 was observed in all groups.

Table 2. Mean shear strength values (S.D.) in MPa

| Treatment       | Light source | Thermocycling |              |
|-----------------|--------------|---------------|--------------|
|                 |              | Without       | With         |
| With silane*    | LED          | 10.7 (1.2)A,a | 7.3 (1.3)B,a |
|                 | QTH          | 9.5 (1.1)A,b  | 6.0 (0.7)B,b |
| Without silane* | LED          | 8.4 (1.3)A,a  | 4,3 (0.9)B,a |
|                 | QTH          | 7.7 (1.0)A,b  | 3.0 (0.8)B,b |

Means followed by different uppercase letters in the same row and lowercase letters in the same column indicate statistically significant difference ( $p<0.05$ ). \*Indicate that groups with silane showed bond strength significantly higher than without silane groups ( $p<0.05$ ).

## Discussion

The first hypothesis, which stated that the light sources do not affect the shear bond strength was rejected. The results showed that significant differences were observed between LED and QTH regardless of the thermocycling and silane condition. These results are in line with those of previous studies, which also found significant differences between QTH and LED units (8-10). Other study showed that photo-activation is dependent on the radiant exposure (16). Radiant exposure is the product of irradiance and exposure time. In this study, LED ( $48 \text{ J/cm}^2$ ) presents higher radiant exposure during photo-activation than QTH ( $32 \text{ J/cm}^2$ ). Probably the differences in energy dose between LED and QTH were enough to influence the bond strengths. However, several studies showed no significant differences among different light sources (6,7,17,18). Other studies showed that the absence of differences probably might be explained by the fact that a very thin resin layer is necessary for bracket bonding and, thus, the differences in energy dose were probably not enough to influence the bond strengths (7,19).

In the current study, the influence of silane on the shear bond strength was evaluated. Silane agents are usually monomeric species in which silicon is linked to reactive organic radicals and hydrolyzable ester groups. Hydrolyzable monovalent groups bond chemically to silicon contained in the glass matrix and lithium disilicate (4,20). The results indicated that the second hypothesis was not accepted. All the groups that the silane was applied showed a significant increase in the shear bond strength,

independent of the light source and thermocycling. These results are in accordance with those of previous studies, which also found significant differences when silane was used (2,4,21,22). The reason is that silane forms a chemical bond with inorganic (silica layer on the ceramic) and organic (bonding materials) surfaces, which increase the bond strength.

The clinical success of the bond strength between orthodontic bracket/ceramic depends on the quality and durability of the bond between the bracket, bonding resin and ceramic. The quality of this bond is determined by the bonding mechanisms between bracket/bonding materials. Thermocycling has been used to determine if temperature variations might influence on the reduction of the bond strength. Several kinds of thermocycling methods, such as artificial ageing, have been used to determine the durability of bracket, however, have not employed long-term water storage (13). The reduction of mechanical properties of the bonding resin is probably a result of a continuous action of water on the interface of the orthodontic bracket/bonding resin. Thus, a reduction in the bond strength could be caused by hydrolytic degradation of the interface components (23) or by the differences of the coefficient of thermal expansion among brackets, bonding material and ceramic.

When thermocycling was analyzed, significant difference was found between thermocycling and water storage (24 h), regardless of the light source and silane. Thus, the third hypothesis was rejected. These findings are not in agreement with the previous studies, which

found no significant difference in bond strength after thermocycling (11-13). Probably, the absence of difference might be explained by the fact that these studies used a small number of cycles while in the current study was used a larger number of cycles. Another study showed that a larger number of cycles are necessary to permit accelerated simulation (12).

Other study suggests that bond strength values in the range of 6 to 8 MPa are necessary for orthodontic forces in the oral environment (24). In this study, bond strength values lower than 6 MPa were obtained for groups where silane was not applied after thermocycling. Thus, care should be taken when silane is not used because it has not been acceptable clinically bond strengths

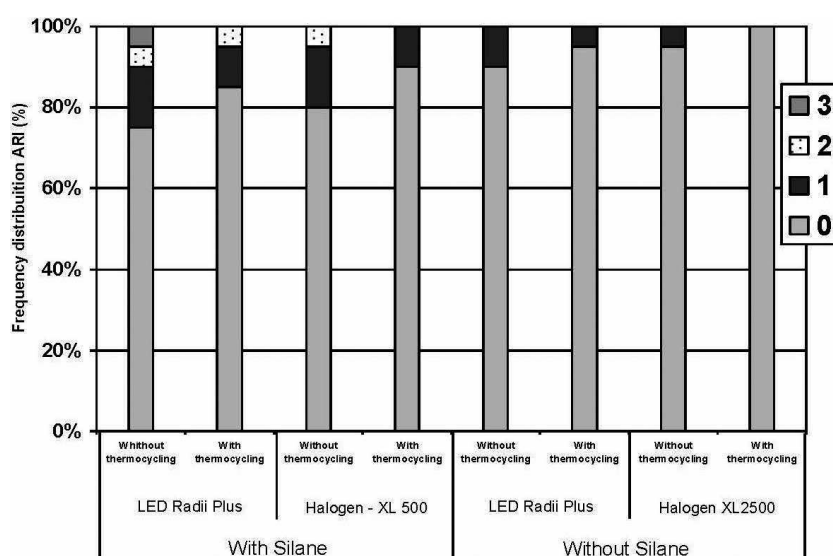


Figure 1. Frequency distributions (%) of the Adhesive Remnant Index (ARI) scores for all groups. Score 0: indicates that no bonding resin on the ceramic; Score 1: indicates that less than half of the bonding resin on the ceramic; Score 2: indicates that more than half of the bonding resin; and Score 3: indicates that all bonding resin on the ceramic, along with a clear impression of the bracket mesh.

to resist forces during orthodontic treatment.

The ARI scores indicated that most failures after debonding were scored 0, with no bonding resin on the ceramic surface, but there was an increase in scores 1, 2 and 3 for groups where silane was applied. A predominance of score 0 observed in all groups is clinically advantageous because there is less bonding material to remove from the ceramic surface after debonding.

In summary, the present results showed that light source, silane and thermocycling are decisive factors for the bond strength of orthodontic brackets to ceramic surfaces. The use of high-intensity light-curing units and silane application are necessary to obtain effectiveness of polymerization of the bonding resin and care should be taken during bonding procedures, irrespective of the silane and light source used. Future studies should be carried out to investigate other possible factors affecting the clinical performance of bracket bonding to ceramic.

## Resumo

O objetivo neste estudo foi avaliar o efeito de diferentes fontes de luz, termociclagem e silano na resistência de união de bráquetes metálicos a cerâmica feldspática. Cilindros de cerâmica feldspática foram condicionados com ácido fluorídrico a 10% por 60 s. Metade dos cilindros (Grupos 1 a 4) recebeu duas camadas de silano. Bráquetes metálicos foram colados aos cilindros usando Transbond XT (3M Unitek), formando 8 grupos (n=20), dependendo das fontes de luz usadas para fotoativação (Radii Plus LED - 40s; Grupos 1, 2, 5 e 6 e XL 2500 halógena - 40 s; Grupos 3, 4, 7 e 8), nas condições experimentais com (Grupos 2, 4, 6 e 8) e sem ciclagem térmica (Grupos 1, 3, 5 e 7). O ensaio de resistência ao cisalhamento foi realizado após armazenagem por 24 h em água deionizada (Grupos 1, 3, 5 e 7) ou armazenados e submetidos a ciclagem térmica (Grupos 2, 4, 6 e 8; 7.000 ciclos - 5° e 55° C). Os dados foram submetidos à Análise de Variância de três fatores e teste de Tukey ( $\alpha=0,05$ ). O Índice de Remanescente Adesivo (IRA) foi avaliado com aumento de 8x. O uso do silano foi efetivo no aumento da resistência de união ao cisalhamento de bráquetes à cerâmica. Diferença significativa na resistência de união foi observada entre as fontes de luz, e com ou sem ciclagem térmica. O IRA mostrou predominância de escore 0 para todos os grupos, com aumento de escores 1, 2 e 3 para os grupos com silano. Em conclusão, a aplicação do silano melhorou significativamente a resistência de união ao cisalhamento de bráquete à cerâmica. A ciclagem térmica e as fontes de luz influenciaram a resistência da união.

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