Evaluation of shear strength of lingual brackets bonded to ceramic surfaces

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Abstract

Objectives: The aim of this study was to evaluate the shear strength of lingual metal brackets (American Orthodontics) bonded to ceramic veneers. **Methods:** A total of 40 specimens were divided into four groups of 10, according to bonding material and ceramics preparation: Group I - Sondhi Rapid-Set resin and hydrofluoric acid, Group II - Sondhi Rapid-Set resin and aluminum oxide, Group III - Transbond XT resin and hydrofluoric acid, and Group IV - Transbond XT resin and aluminum oxide. Prior to bonding, the brackets were prepared with heavy-duty resin base (Z-250) and the ceramic veneers were treated with silane. The shear test was conducted with a Kratos testing machine at a speed of 0.5 mm/min. **Results:** The results were statistically analyzed by the Tukey test ($p<0.05$) and showed a statistically significant difference between groups I (2.77 MPa) and IV (6.00 MPa), and between groups III (3.33 MPa) and IV. **Conclusions:** In conclusion, the bonding of lingual brackets to ceramic surfaces exhibited greater shear strength when aluminum oxide was used in association with the two resins utilized in this study, although Transbond XT showed greater shear strength than Sondhi Rapid-Set.

Keywords: Bonding. Ceramic surface. Orthodontics. Lingual brackets.

INTRODUCTION

A few years ago orthodontic treatment was regarded as exclusively geared toward children and adolescents. As of the 1970's, the orthodontic industry sought to improve the aesthetic appearance of orthodontic appliances by introducing transparent brackets that could be bonded to the labial surface of the teeth in order to meet the aesthetic needs of adult patients.[9] In Europe, in the 1980's, studies began to be conducted on

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lingual orthodontics, which was indicated for those patients who value aesthetics and sometimes refuse traditional orthodontic treatment.[9]

Besides the concern with aesthetics, another important factor to be considered in adult patients is the presence of prosthetic ceramic crowns. This fact raises the need for studies on the bonding of orthodontic brackets to lingual ceramic surfaces.[15] Although the literature contains research on the bonding of brackets to ceramic surfaces, their results were based on techniques for bonding directly to the labial surface.[4,8,15]

It is noteworthy that lingual bonding differs from labial bonding in many respects. The first difference is the laboratory phase, which consists in positioning the brackets in a plaster model with the teeth properly positioned in a setup model of the patient's initial malocclusion. Each bracket receives a portion of filler resin on their base to regularize lingual surface anatomy and the buccolingual width of the teeth, thereby preventing the archwire from having inset/offset bends placed during orthodontic treatment. Thus, bracket bonding (in the patient) occurs by adhesion between the resin on the bracket base and the enamel or ceramic surface.[2]

Another difference is that the lingual surfaces of teeth exhibit different characteristics when compared to labial surfaces. The lingual surface of posterior teeth is narrower mesiodistally in the occlusocervical direction, showing a steep curvature relative to the labial surface. The upper incisors display concave surfaces with compromised visibility while the lower incisors are affected by tongue position, which requires a skilled professional.[3]

Thus, the lingual technique requires scientific studies to assess and reduce the rate of bracket debonding. It further requires the use of the best possible materials and bonding techniques for preparation of ceramic surfaces mainly due to the fact that ceramic surfaces exhibit lower adhesion than dental enamel.

OBJECTIVE

Based on the reviewed literature, this study intended to evaluate the shear strength of lingual brackets bonded to ceramic surfaces using two resins, i.e., Sondhi Rapid-Set A and B self-curing resin (3M-Unitek) and Transbond XT light-curing resin (3M-Unitek), in addition to two ceramic surface preparation materials, namely, hydrofluoric acid and aluminum oxide.

MATERIAL AND METHODS

For this experiment 40 lingual premolar metal brackets of the Stealth brand (American Orthodontics, Lot No.: 395-0023B) were prepared and had their shear strength tested as follows:

Bracket base resin preparation

For this research a maxillary arch model in ideal occlusion was selected. The model was duplicated with dental plaster and the lingual brackets were bonded using resin Z-250 (3M, Lot No.: 5BX) to the maxillary right first molars and premolars.

To determine the exact position of the forty brackets on the second premolars a rectangular 0.017x0.025-in stainless steel archwire (American Orthodontics) was adapted to the bonded brackets bypassing the distal side of the second molars, resting on the occlusal surface of the molars and stabilized with self-curing acrylic resin (Ortho Cril yellow, Dental Vip). The mesiodistal position of the brackets was standardized with a red mark on the wire which coincided with the mesial bracket tie wing (Fig 1). The surface of the second premolars received an insulation layer (Cel-lac) to prevent the brackets from adhering to the plaster.

Single Bond 2 (3M) was applied to the second premolar bracket bases prior to Z-250 resin

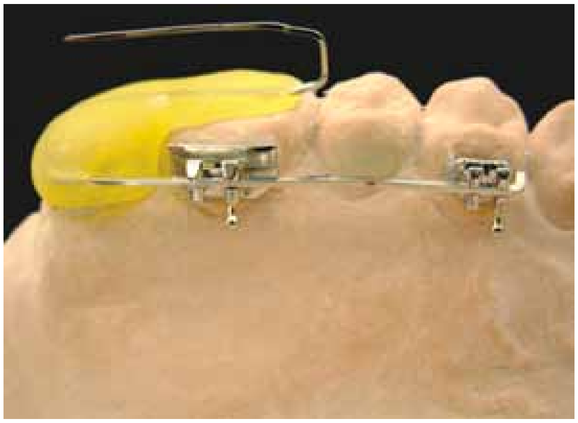

FIGURE 1 - Model with brackets bonded and 0.017x 0.025-in stainless steel adapted with acrylic resin.

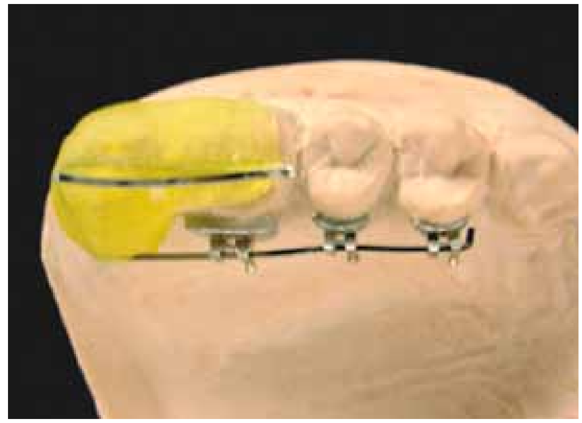

FIGURE 2 - Occlusal view of model with bracket positioned on second premolar and stabilized with occlusal support during resin base Z-250 preparation.

application. After placing the brackets in the model all excesses was removed and the resin was cured for 20 seconds (Fig 2).

The resin bases of the 40 brackets received a jet of aluminum oxide (Bio-art, Lot No.: 156,957) for 5 to 10 seconds at a distance of 10 mm until they turned white and opaque. Subsequently, the resin was cleaned with a brush and a solution of ether at 50% (Removex), followed by acetone solution (5, Lutex AP at 58%, Lot No. 11256208), for removal of any oily resin layer from the bracket bases.

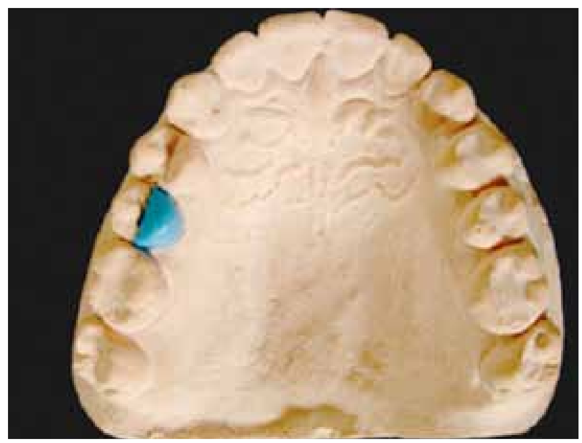

FIGURE 3 - Plaster model with wax added to half of second premolar.

Fabrication of ceramic specimens

The second premolars in the model received a coat of waxing wax in order to compensate for any shrinkage in the ceramics caused by oven heat (Fig 3). An impression of the model was then made with heavy condensation silicone (Zetalabor). On top of this new impression the ceramic body was applied to the lingual half of the crown impression and subsequently dried with an electric dryer to remove moisture from the ceramic.

The ceramic body was placed in a vacuum oven at a temperature of 925°C for 1 minute. Finishing was accomplished with fine-grained diamond stone and polishing was completed with a special rubber made especially for this procedure. The piece was glazed and surface imperfections corrected. The ceramic body was placed in a non-vacuum oven at a temperature of 880°C for 1 minute.

Acrylic cylinder preparation

A cylinder of Jet acrylic resin was fabricated using a silicone impression tray with 11.0 mm diameter and 8.0 mm thickness to match the

FIGURE 4 - Acrylic cylinder with ceramic specimen adapted with acrylic resin.

FIGURE 5 - Specimen bonded to ceramic veneer attached to acrylic resin cylinder with bracket base parallel to cylinder surface (lateral distal view of bracket).

size of the metal support on the KRATOS testing machine. The ceramic specimen — in the shape of the second premolar — was attached to the cylinder in such a manner as to allow the metal base of the bracket to be positioned parallel to the acrylic surface after bonding (Fig 4).

Ceramics preparation and bracket bonding

Twenty ceramic pieces, which had already been inserted in the acrylic cylinder, were prepared with a jet of aluminum oxide (Bio-art, Lot No. 156,057) for 5 seconds at a distance of 5 to 10 mm, rinsed thoroughly and dried with air. The other part of the sample was prepared with 10% hydrofluoric acid (Dentsply, Lot No. 579861) for 4 minutes, rinsed and dried for 15 seconds as described by the manufacturer.

All ceramic veneers received an application of silane (Dentsply, Lot No. 209,071) in a 1:1 ratio, mixed for 10 seconds, with a 5-minute rest.

On twenty specimens (10 prepared with aluminum oxide and 10 with hydrofluoric acid) brackets were bonded with Sondhi Rapid-Set A (3M-Unitek, Lot: 051219), applied to the ceramic surface; and Sondhi Rapid-Set B (3M-Unitek, Lot: 0511114), applied to the resin base of the bracket.

On the other twenty specimens (10 prepared with aluminum oxide and 10 with hydrofluoric acid) brackets were bonded using Transbond XT adhesive (3M-Unitek, Lot: 6 CP) (Fig 5).

Thus, taking into account ceramics preparation and bonding system, the samples were divided into four groups with 10 brackets each, as follows:

» Group I - Sondhi and hydrofluoric acid.
» Group II - Sondhi and aluminum oxide.
» Group III - Transbond XT and hydrofluoric acid.
» Group IV - Transbond XT and aluminum oxide.

Specimen storage for shear strength test

The specimens were stored for seven days prior to shear test in plastic containers with lids and water at room temperature. The containers were kept in a thermal bag to maintain the temperature.

Shear strength test

Tensile shear strength tests were performed with a KRATOS Universal Testing Machine at the Department of Prosthodontics, Bauru School of Dentistry, University of São Paulo (Fig 6), by applying 50 Kgf of force at 0.5 mm/min. The values initially obtained in kgf were converted into MPa, a measure used for pressure evaluation.

FIGURE 6 - KRATOS Universal Testing Machine, Department of Prosthodontics, Bauru School of Dentistry, University of São Paulo.

Statistical Analysis

The test results were analyzed statistically. In order to check whether or not the data had normal distribution, the Kolmogorov-Smirnov test was used, and to test for homogeneity of variance among groups, the Bartlett test was used.[21] To compare differences between groups, one-criterion variance analysis (ANOVA) was performed. When ANOVA showed a significant difference, the Tukey test for multiple comparisons was applied. In all tests, a significance level of 5% was adopted.[21] The tests were performed using the program Statistics for Windows v. 5.1 (StatSoft Inc., USA).

RESULTS

Based on the methodology used in this study comparative results were obtained for the four groups. Table 1 shows the results of means and standard deviations for the four groups.

In checking the normal distribution of data, the Kolmogorov-Smirnov test showed no statistically significant difference ($p>0.05$). The Bartlett test, which was used to check homoscedasticity (homogeneity of variance) between groups showed no statistically significant difference between variances ($p = 0.127$). After the criteria of normality and homoscedasticity had been applied, one-criterion variance analysis was used to compare groups, disclosing a statistically significant difference between groups (Table 2).

Tukey's test for multiple comparisons only showed statistically significant differences between Group I and Group IV, and between Group III and Group IV (Table 3).

TABLE 1 - Shear strength means and standard deviations for the four groups, in Mpa.

Group	Strength	
	mean	SD
I	2.77	0.93
II	4.30	1.74
III	3.33	1.35
IV	6.00	2.17

TABLE 2 - One-criterion variance analysis (ANOVA) for comparing the four groups.

GL effect	QM effect	GL error	QM error	F	p
3	19.444	35	2.663	7.302	0.001*

*Statistically significant difference ($p < 0.05$).

TABLE 3 - Tukey's test for multiple comparisons among the four groups.

Comparison	p
I x II	0.212ns
I x III	0.886 ns
I x IV	0.001*
II x III	0.552 ns
II x IV	0.110 ns
III x IV	0.004*

* Statistically significant difference ($p < 0.05$).
ns = no statistically significant difference.

DISCUSSION

The bonding of lingual brackets to a ceramic surface was evaluated in this study by comparing two kinds of ceramics preparation and two bonding resins.

The decision to use silane in this study was based on data from the literature that prove its effectiveness in the bonding of labial brackets.[11,15,16,22] When applied to ceramic surfaces, silane increased the shear strength, regardless of how the ceramics was prepared.[15,16] Although the use of silane is considered optional by some authors[1,20] — due to difficulties inherent in lingual bonding combined with the inadequate bond strength shown by ceramic surfaces — the silane used on all ceramic surfaces in this research was considered an important element.

Although no research has hitherto been conducted on the bonding of lingual brackets to ceramic surfaces, Wiechmann,[18] in a recent investigation recommended the use of aluminum oxide and hydrofluoric acid prior to bonding ceramic brackets.

The bonding of lingual brackets, which consists of two stages (clinical and laboratory), often with indirect bonding, prompted the need to evaluate the difference in strength between a chemically activated (self-curing) bonding resin (Sondhi Rapid-set A and B) and a light-cured resin (Transbond XT).

The self-curing resin brand commonly found in the literature is Concise which, when combined with hydrofluoric acid showed, respectively, mean values of 17.38 MPa,[15] 9.52 MPa,[8] and 4.17 MPa.[11] In this study, when preparation was carried out using hydrofluoric acid and bonding performed with the self-curing resin (Sondhi) the mean value found was 2.77 MPa.

Cochran et al[1] obtained a mean value of 39.10 MPa when evaluating the shear bond strength of Concise on a ceramic surface previously prepared with aluminum oxide and silane, while Gillis and Redlich[5] found a mean value of 17.90 MPa. Sant'Anna et al[15] used a primer (Scotchprime - 3M) after the aluminum oxide and found a mean value of 18.64 MPa. Literature values were found to be higher than those reported in this paper. Group II (Sondhi resin and aluminum oxide) showed shear strength of 4.30 MPa. However, the self-curing resin used was different from those reported in the literature.

The lower values of Groups I and II compared to those observed in the literature may have occurred due to differences between labial and lingual bonding techniques. In the lingual technique, adhesion between brackets and ceramic surfaces occurs between the resin on the base (Z-250) and the bonding material, but in the labial technique adhesion takes place between the metal bracket base and the bonding material.

Transbond XT is the most widely used self-curing resin in the literature and was also selected for this research. Nebbe and Stein[12] also used this resin but prepared the ceramic surface with 37% phosphoric acid and silane, obtaining a mean value of 6.03 MPa. This result was higher than the one found in this study, which yielded a mean value of 3.33 MPa in Group III. However, the acid used in this study was 10% hydrofluoric acid. The choice of acid also differs from the one used by Moreira et al,[11] who applied 35% phosphoric acid with silane to the ceramic surface and found a mean value of 4.27 MPa, also higher than the results of this study.

Based on the methodology, the results showed that the values of Groups I, II and III were lower than would be clinically acceptable, i.e., between 6 and 8 MPa.[19] Group IV showed the best result, with values near those indicated for clinical use.

Group IV (Transbond XT + aluminum oxide) yielded a mean value of 6.00 MPa. This group showed the best overall results, demonstrating superior shear bond strength. Nebbe and Stein[12] concluded that bonding with Transbond XT combined with silane achieves a bonding strength comparable to bonding to enamel. Although the literature reports the effectiveness of Transbond XT and aluminum oxide, no association was found with ceramics bonding.

When the groups were subjected to analysis of variance a statistically significant difference was found between groups (Table 2). Tukey's test showed that this difference was found between Groups I and IV, and III and IV.

The difference between Groups I and IV involved all the factors studied in this research. The resin and preparation used in Group IV (Transbond XT aluminum oxide) showed greater shear strength than in Group I (hydrofluoric acid + Sondhi) (Table 3). Based on the methodology used in this work, light-curing resin proved superior to chemically activated resin. This result differs from other studies in the literature, which did not use Sondhi resin.[4,10]

Groups III and IV, which were also statistically different, showed that aluminum oxide is superior to hydrofluoric acid when bonding to ceramic surfaces (Table 3). This result is in agreement with Cochran et al,[1] who noted that when ceramics is treated with silane, aluminum oxide affords greater strength than hydrofluoric acid. Some authors contradict the results reported above. Gillis and Redlich[5] conducted an electron microscopy analysis and revealed that erosion caused by a diamond bur or jet of aluminum oxide produced superficial wear while hydrofluoric acid produced deep wear. In a literature review, Vieira et al[16] concluded that hydrofluoric acid appears more effective than aluminum oxide for roughening the ceramic surface.

Wiechmann[18] described the influence of a jet of aluminum oxide prior to etching with phosphoric acid. The author concluded that the adhesive strength between enamel and bonding material can be significantly increased with a jet of aluminum oxide prior to etching. He recommended the same procedure when bonding to ceramic surfaces.

Due to difficulties involved in bonding lingual brackets, an effective method has been sought to ensure a low debonding rate. The combination of hydrofluoric acid and aluminum oxide applied to the ceramic surface can increase shear strength. In this study, the best result was obtained with Transbond XT light-curing resin. Some professionals, however, still prefer self-curing resins. It is therefore suggested that other chemically activated resins also be evaluated to meet this market demand.

CONCLUSIONS

Based on the methodology used and results achieved in this study, it can be concluded that:

The bonding of lingual brackets to ceramic surfaces exhibited greater shear strength when aluminum oxide was used in association with either of the two resins utilized in this study, although Transbond XT showed greater shear strength than Sondhi Rapid-Set.

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