

“Bond strength and adhesive remnant index of experimental brackets bonded with self-adhesive resin cement”

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Summary

Aim: To evaluate the shear bond strength (SBS) and adhesive remnant index (ARI) of experimental brackets bonded with self-adhesive resin cement. Ninety bovine teeth were randomly distributed ($n = 15$) according to the groups: G1 - metal brackets bonded with Transbond™ XT; G2 – APC metal brackets bonded without additional adhesive system; G3 - APC metal brackets bonded with self-etching adhesive system; G4 - metal brackets bonded with RelyXU200; G5 - experimental brackets bonded with Transbond™ XT; G6 - experimental brackets bonded with RelyXU200. Shear bond strength test of the brackets was carried out and after their removal, the ARI was observed.

Results: The highest mean value of SBS was found in group 1 (14.33 MPa) and lower mean SBS has been in group 4 (2.36 MPa). The mean values of SBS found in the experimental groups were higher compared to the non-modified brackets. The ARI analysis demonstrated that groups that received the phosphoric acid or self-etching primer (G1,G2,G3andG5) showed adhesive partially and fully adhered to the tooth. Greater amounts of remnants were adhered to the bracket in the experimental brackets, this minimizes the risk of damage to the tooth enamel since it requires minimal finishing. These results suggest that the experimental brackets are interesting options for future use in orthodontics, since it has sufficient adhesive strength to the orthodontic treatment, and less risk of damage to the enamel at the time of removal of the brackets, and is a simple and inexpensive alternative.

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Keywords:Orthodontic brackets; Dental cements; Shear strength.

Objetivo: Evaluar la resistencia al cizallamiento (SBS) y el índice de adhesivo remanente (ARI) de “brackets experimentales” unidos con cemento de resina autoadhesiva. Noventa dientes bovinos fueron distribuidos al azar (n=15) de acuerdo a los siguientes grupos: G1 - brackets de metal unidos con Transbond™ XT; G2 : APC brackets de metal unidos sin sistema adhesivo adicional; G3: Brackets APC de metal unidos con sistema adhesivo de autograbado; G4: Brackets de metal unidos con RelyXU200 ; G5:Brackets experimentales unidos con Transbond ™ XT; G6:Brackets experimentales unidos con RelyXU200. La prueba de resistencia al cizallamiento de los brackets se llevó a cabo y después de su fractura, el ARI se valoró.

Resultados: El valor medio más alto de la SBS se encontró en el grupo 1 (14,33 MPa) y más baja media de SBS fue en el grupo 4 (2,36 MPa). Los valores medios de SBS de los grupos experimentales fueron más altos en comparación con los brackets no modificados. El análisis demostró que ARI en grupos que fueron acondicionados con ácido fosfórico o imprimación de autograbado (G1,G2,G3yG5) mostraron adhesivo en forma parcial y/o totalmente adherido al diente . Mayores cantidades de restos se adhirieron al bracket en los brackets experimentales. Estos resultados sugieren que los brackets experimentales son opciones interesantes para su uso futuro en la ortodoncia, debido a que logran suficiente fuerza adhesiva para el tratamiento de ortodoncia, y generan menos riesgo de daños en el esmalte

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en el momento de la eliminación de los brackets, y es una alternativa simple y barata.

Palabras clave: brackets de ortodoncia; cementos dentales; Resistencia al cizallamiento.

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Bond strength and adhesive remnant index of experimental brackets bonded with self-adhesive resin cement

INTRODUCTION

The bonding of brackets represents one of the most significant challenge in the assembly of orthodontic devices⁹. The development of new techniques for bracket bonding brought significant changes in clinical orthodontics, representing technical simplification and less chair-side time⁷. This procedure has advantages compared to conventional banding presenting more aesthetic, less discomfort, more precise positioning, simplicity, speed, and ease of cleaning⁷.

Although bonding has various advantages for both the patient and dentist, the adhesive procedure is a sensitive technique. The resins have become the most used material by orthodontists for bracket bonding since adhesion has been proved in several studies^{1,24}.

The main difference from the traditional composites in comparison to orthodontic composites is the filler percentage and size particles. Orthodontic resins have a lower amount of filler particles, which allows higher material flow, filling of the bracket base and porosities in the enamel surface.

Low viscosity resins with similar characteristics, either flow or flowable resins, presents low cost and elasticity modulus and high fluidity, allowing better bracket adaptation in the areas of anchoring and demineralized region of the enamel^{16,26}. The effectiveness of the flow composite in bonding brackets are controversial, as some studies show its clinical viability^{5,12,27}, while others do not recommend its use because they have lower results of bond strength^{21,28}. This

limitation can occur due to polymerization shrinkage that can lead to the rupture of the adhesive layer⁶.

The self-adhesive resin cement allows less technical error and reduction of times. These simplifications occur parallel in orthodontics, where we can cite the APC or pre-coated system. This system contains composite incorporated into the bracket base, referred to APC I, APC II and APC Plus (3M Unitek, Monrovia, USA). The composite in this base is similar to Transbond composite (3M Unitek, Monrovia, USA), but with slight changes in proportion of the components and should be cured at the time of use. Furthermore, this system is used with self-etching adhesive system (Transbond Plus Self-etching Primer, 3M Unitek, Monrovia, USA)¹⁴.

The experimental protocol was developed in order to create a more stable union between enamel and bracket. In this case, modification of the bracket base was performed from traditional metal brackets in which was added a layer of composite resin over the metal mesh. To analyze the effectiveness of bonding on tooth enamel with experimental brackets this in vitro study evaluates the bond strength of experimental brackets bonded with self-adhesive resin cement on tooth enamel.

MATERIALS AND METHODS

Specimens preparation

Ninety bovine teeth were selected, cleaned and stored in thymol solution (0.1%) no longer than two months until the time of use. The roots were cut and the teeth were embedded in chemically activated acrylic resin (Vipi Flash, DentalVipi,

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Pirassununga, Brazil) into cylindrical PVC (Tigre, Brazil) with a 20 mm internal diameter and height. Buccal portion of the specimen was parallel to a flat surface.

Prophylaxis was performed with rubber cup, pumice (SS White, Petrópolis, Brazil) and water for 10 seconds, followed by washing and drying at the same time with a triple syringe.

The teeth were randomly assigned (n = 15) according to the groups described in table1.

Experimental brackets

Modification of the bracket base was performed from traditional metal brackets (Victory Series TM 3M Unitek) in which the metal mesh was altered. Composite resin Z 350XT (3M ESPE TM) was evenly placed over the mesh with a single increment to fill the space in the fabric, making a smooth and uniform base. Then, the composite base was polymerized during 20 seconds (Radii Plus - SDI). This modification allows the self-adhesive resin cement to be placed in contact with the base composite and tooth enamel since the self-adhesive resin cement in contact with the bracket metal mesh proved to be inefficient^{3,9}. This modification on the bracket is necessary for possible improvement in the values of union.

Adhesive procedure

Group 01

Bovine enamel was conditioned for 30 seconds with 37% phosphoric acid on the buccal surface center, with the conditioning area corresponding to the bracket base area. And after 30 seconds, the acid was washed with water and dried for 15

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seconds. Transbond XT primer followed by a single 2 seconds air jet were applied to the etched surface and the metal bracket was (Victory Series™ 3M Unitek) bonded with Transbond™ XT (3M Unitek, Monrovia, Calif, USA).

Group 02

No additional adhesive procedure was performed. The brackets were bonded with the APC's system composite (3M Unitek, Monrovia, Calif, USA).

Group 03

Transbond™ Plus Self-Etching Primer was applied actively for 5 seconds on the labial surface of the enamel, a single air jet was applied for two seconds and the APC brackets was bonded (3M Unitek, Monrovia, Calif, USA).

Group 04

No prior treatment was performed on enamel. The resin cement RelyX U100 self-adhesive (3M ESPE, Seefeld, Germany) was manipulated and applied only to the area corresponding to the bracket base and the metal brackets Victory™ (3M Unitek, Monrovia, Calif., USA) were bonded.

Group 05

The same procedure was carried out in group 01.

Group 06

The same procedure was carried out in the group 04.

Brackets bonding

Central incisor brackets according to each group were used and were positioned on the tooth buccal surface with the aid of grasping forceps for bonding (Ortoply, Philadelphia, USA). All bonding procedures were performed by the same calibrated to procedure operator. After positioning the bracket, it was pressed [Escriba aquí]

against the tooth enamel in order to decrease the thickness of the composite between the bracket and the enamel. Excess composite was removed respecting the external limits of the bracket base and the polymerization was carried out for 10 seconds on each side (mesial, distal, incisal and gingival) with the unit LED (Radii-plus, SDI, Au) with 1100 mW/cm². The polymerization was performed with the light tip positioned 2 mm distant from the surface of the specimen.

Shear bond strength

Shear bond strength test of the brackets was performed in the universal testing machine (EMIC - DL 2000, São José dos Pinhais, Brazil), regulated to a compression speed of 0.5 mm / min. The cylinder containing the acrylic resin tooth was placed on the lower jaw of the machine and the bracket base was parallel to shear force direction according to protocol.

The values of SBS were recorded in kgf and transformed in kgf / cm², using the following formula:

$$E = \text{Kgf} \cdot A$$

E = Mechanical Tests

Kgf = Strength needed to remove the bracket

A= Bracket area

Subsequently, the values of SBS in kgf / cm² were converted into MPa.

Adhesive remnant index (ARI) adhered to the tooth after bracket debonding

After brackets removal, the ARI was observed in a stereomicroscope (Carl Zeiss, Brazil) by and blinded and calibrated to procedure examiner, with 30X of magnification. The amount of adhesive material in the enamel after debonding was evaluated according to the scores proposed by *Artun & Bergland (1984)*³: Score 0 - [Escriba aquí]

no adhesive in the tooth; score 1 - less than half the adhesive left in the tooth; score 2 - more than half of the adhesive left in the tooth; and score 3 - all adhesive was present in the tooth.

RESULTS

Table 2 presents the results of the SBS test. Higher values of SBS were found in groups 1 (20.60 MPa) and 3 (20.59 MPa). The lowest resistance was found in group 4 (0.98 MPa). Group 1 had the highest average (14,33 MPa) and group 4 the lowest (2.36 MPa). Data were subjected to one-way analysis of variance - ANOVA followed by Tukey post-test ($p = 0.05$) (Figure 1).

Tukey test showed that groups 2 and 4 were similar, presenting statistically lower values of SBS. Group 6 showed a statistically significant difference from group 4, with the highest average. Group 1 had higher mean values and statistically significant difference in all groups.

By analyzing the ARI on dental enamel the frequency of scores was evaluated and it could be seen that groups 4 and 6 do not showed scores 2 and 3, where more material was bonded to the tooth. However, the group that used the phosphoric acid or self-etching primer (groups 1, 2, 3 and 5) showed adhesive partially and fully adhered to the tooth (Table 3).

DISCUSSION

The self-adhesive resin cement consists of modified monomers in methacrylate phosphoric acid that forms cross-links in cement matrix during the polymerization process²⁰. Whereas the phosphoric acid contributes to the self-adhesion, double carbon bonds cause a high reactivity of methacrylate monomers with each other. Thus, the cement shows a high degree of monomer particles [Escriba aquí]

interrelated and good mechanical properties of this cement can be achieved even without pretreatment of the dental substrate²⁰.

The literature reports that most of the remaining cement after debonding is located in the bracket interface². This is due to incomplete polymerization of the cement below the base of the metal substrate, because the light is not able to reach the cement behind the bracket metal mesh²². In an attempt to improve the values of SBS of metal brackets bonded with self-adhesive cement, a project to redesign the bracket base was developed.

The innovative design of the metal bracket base consists of a thin layer of multifunctional methacrylate derivative of Bis-GMA. In our study, this experimental brackets bonded with self-adhesive cement (G6) had a significantly higher mean SBS compared with the metal brackets bonded with the same cement (G4). However, the SBS values were lower than metal brackets bonded with Transbond XT (G1). In addition, SBS of brackets bonded with self-adhesive cement (G4) were insufficient for bonding orthodontic brackets successfully. Low values found in experimental brackets can be explained by the fact that alterations were hand made and some details at the base of the brackets could be improved. Furthermore, the experimental brackets had better results than metal base brackets bonded with self-adhesive cement.

Traditional adhesive systems used for bonding orthodontic brackets depends of acid etching for better retention^{15,19,25}. Although traditional adhesives are widely used, methods to simplify bonding procedures have been reported in the literature, most of which derived from the self-adhesive cements^{19,25}.

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Self-adhesive resin cements are used for luting crowns, inlays, onlays and fixed partial dentures^{8,11,13,29}. The use of these materials simplifies the bonding procedure because it reduces the number of adhesion steps. RelyX Unicem was the first product from the class of self-adhesive cement to be introduced on the market and is the most tested material. It contains multifunctional monomers with phosphoric acid groups which simultaneously demineralize and infiltrate adhesive monomers in the enamel and dentin^{8,11}.

Vincent et al.²⁹ reported that RelyX Unicem has less SBS values than conventional adhesive system after storage of the samples in water for 24 hours at 37 °C. However, the SBS values were clinically sufficient to support the activation device. Moreover, Bishara et al.⁴ and Al-Saleh & El-Mowafy² found that the SBS of metal brackets bonded with self-adhesive resin cement was insufficient for bonding orthodontic brackets successfully.

The magnitude of the bond strength clinically necessary to support orthodontic treatment without the occurrence of failure is difficult to measure. Literature reports that strength between 5.9 and 8 MPa are sufficient to satisfy the clinical requirement^{10,23}.

CONCLUSION

The results showed that the means values of SBS values found in the experimental brackets groups were higher compared to the ones that were not modified. Also, in experimental brackets a larger amount of adhesive remnants were adhered to the bracket base, minimizing the risk of damage to the tooth enamel since it would require minimal finishing. These results suggest that the experimental brackets are interesting options for future use in orthodontics.

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Tables legends

Table 1 – Experimental groups.

Table 2 - Description of the mean, standard deviation, minimum, maximum, and a confidence interval of 95% expressed in MPa of the groups submitted to SBS test.

Table 3. ARI was evaluated according Artun and Bergland (1984) and the frequency of the appearance of scores were analyzed in each group.

Table 1 – Experimental groups.

Groups	Bracket	Adhesive procedure
G1	Traditional Metallic*	Total etch adhesive system**
G2	APC System***	None
G3	APC System***	Self-etching adhesive system****
G4	Traditional Metallic*	Self-adhesive resin cement*****
G5	Modified*****	Total etch adhesive system**
G6	Modified*****	Self-adhesive resin cement*****

*Victory™ series 3M Unitek, Monrovia, Calif, USA

**Transbond™ XT, 3M Unitek, Monrovia, Calif, USA

***APC System, 3M Unitek, Monrovia, Calif, USA

****Transbond™ Plus Self-Etching Primer, 3M Unitek, Monrovia, Calif, USA

*****RelyX U200, 3M ESPE, Seefeld, Alemanha

***** Alteration in the base of the bracket Victory™ series 3M Unitek, Monrovia, Calif, USA

Table 2 - Description of the mean, standard deviation, minimum, maximum, and a confidence interval of 95% expressed in MPa of the groups submitted to SBS test.

Group	Mean	S.D	Minimu m	Maximu m	95% C. I. (Min;Max)
1	14,33	4,01	8,76	20,60	12,11; 16,56
2	4,78	1,95	2,15	8,64	3,69; 5,86
3	10,46	4,18	4,57	20,59	8,14; 12,78
4	2,36	0,79	0,98	3,45	1,92; 2,80
5	9,99	1,94	7,20	13,41	8,92; 11,08
6	5,33	1,22	3,12	7,53	4,65; 6,01

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Table 3. ARI was evaluated according Artun and Bergland (1984) and the frequency of the appearance of scores were analyzed in each group.

Group	Score			
	0	1	2	3
1	0	6	7	2
2	2	7	3	3
3	1	5	6	3
4	4	11	0	0
5	1	6	5	3
6	1	14	0	0

Score 0 - no amount of adhesive left in the tooth; score 1 - less than half the adhesive left in the tooth; score 2 - more than half of the adhesive left in the tooth; and score 3 - all adhesive adhered to the tooth.