

Shear bond strength of metallic and ceramic brackets using color change adhesives

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Objective: To determine the shear bond strength of orthodontic brackets using color change adhesives that are supposed to aid in removing excess of bonding material and compare them to a traditional adhesive. **Methods:** Ninety metallic and ninety ceramic brackets were bonded to bovine incisors using two color change adhesives and a regular one. A tensile stress was applied by a universal testing machine. The teeth were observed in a microscope after debonding in order to determine the Adhesive Remnant Index (ARI). **Results:** The statistical analysis (ANOVA, Tukey, and Kruskal-Wallis tests) demonstrated that the mean bond strength presented no difference when metallic and ceramic brackets were compared but the bond resistance values were significantly different for the three adhesives used. The most common ARI outcome was the entire adhesive remaining on the enamel. **Conclusions:** The bond strength was similar for metallic and ceramic brackets when the same adhesive system was used. ARI scores demonstrated that bonding with these adhesives is safe even when ceramic brackets were used. On the other hand, bond strength was too low for orthodontic purposes when Ortho Lite Cure was used.

Keywords: Orthodontic brackets. Dental materials. Adhesives.

Objetivo: determinar a resistência adesiva à tração de braquetes ortodônticos usando resinas coloridas que se propõem a ajudar na remoção do excesso de material adesivo e compará-las com um adesivo tradicional. **Métodos:** Noventa braquetes metálicos e 90 cerâmicos foram colados com dois adesivos coloridos e com um adesivo tradicional em incisivos inferiores bovinos, sendo aplicada tração com uma máquina de ensaios universal. Após a descolagem, os dentes foram observados em microscópio para a determinação do índice de adesivo remanescente (ARI). **Resultados:** a análise estatística (testes ANOVA, de Tukey e de Kruskal-Wallis) demonstrou que a força de união média foi significativa entre os adesivos usados. Os ARIs mais comuns foram aqueles onde o adesivo permaneceu no esmalte. **Conclusão:** a resistência adesiva foi similar entre braquetes metálicos e cerâmicos quando o mesmo adesivo foi usado. Os resultados do ARI demonstraram que esses adesivos são seguros, mesmo com o uso de braquetes cerâmicos. A resistência adesiva foi muito baixa para Ortodontia no grupo colado com Ortho Lite Cure.

Palavras-chave: Braquetes ortodônticos. Materiais dentários. Adesivos.

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» The authors report no commercial, proprietary or financial interest in the products or companies described in this article.

How to cite this article: Stumpf ASG, Bergmann C, Prietsch JR, Vicenzi J. Shear bond strength of metallic and ceramic brackets using color change adhesives. *Dental Press J Orthod.* 2013 Mar-Apr;18(2):76-80.

Submitted: November 07, 2008 – **Revised and accepted:** June 19, 2009

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INTRODUCTION

Brackets bonding on tooth enamel is one of the most important procedures in orthodontic practice. The adhesive force should be enough to keep the bracket in position throughout the orthodontic treatment, but not strong enough to cause damage on its debonding. Lopez,¹⁴ as well as Reynolds,²¹ suggests that shear strength should be 6-8 MPa. Equivalent traction would be about 5 MPa.¹ This adhesive force would be clinically effective and would minimize the risk of enamel fracture. Unions stronger than 14 MPa can be disastrous to human enamel.²⁰

Bonding strength depends on the design of the bracket base, the adhesive used, the bonding technique, the adhesive thickness, the bracket geometry and experience of the professional.^{2,6,8,23} Experimental procedures used in the test brackets may affect the results.¹² Bonding force may vary according to the material used in manufacturing the bracket. Currently, the use of ceramic brackets is becoming increasingly common as more patients seek esthetic appearance.⁵ Unfortunately, the bond strength between ceramic brackets and enamel can be very high, causing damage to the enamel during debonding.⁴

Besides the adhesive strength, while fixing orthodontic appliances, it is important to consider that they may increase the accumulation of dental plaque, enabling the development of gingival inflammation and carious lesions.^{10,16} In a short period of 3 months, orthodontic appliances can alter the subgingival microbiota.¹⁶ Thus, removal of any excess of adhesive material around the bracket is highly recommended. It is sometimes difficult to remove all material since the color of resins is very similar to enamel. Recently, colored resins that aid in the removal of excess material were introduced in the orthodontic market. These adhesives lose their color after polymerization.

The objective of this study is to evaluate the tensile strength of metal and ceramic brackets when two colored resins and a traditional one are used.

MATERIAL AND METHODS

Ninety metallic brackets (Morelli, Sorocaba, SP, Brazil) and 90 ceramic brackets (Virage, American Orthodontics, Sheboygan, WI, USA) were bonded in the center of the buccal surface of the lower incisors of healthy bovines, according to the manufac-

turer's instructions. Next, the teeth were placed in plastic tubes which were filled with acrylic resin.

The teeth were randomly divided into 6 groups: Group 1 (G1) = metallic brackets bonded with Ortho Lite Cure (Orthosource, N. Hollywood, CA, USA); Group 2 (G2) = ceramic brackets bonded with Ortho Lite Cure; Group 3 (G3) = metallic brackets bonded with Transbond Color Change (3M, Monrovia, CA, USA); Group 4 (G4) = ceramic brackets bonded using Transbond Color Change; Group 5 (G5) = metallic brackets bonded with Transbond XT (3M, Monrovia, CA, USA); and Group 6 (G6) = ceramic brackets bonded with Transbond XT. All teeth received prophylactic pumice stone and rubber cup for 10 seconds, washed and dried, etched with 37 % phosphoric acid according to the manufacturer's recommendations, then the primer was applied. The resin was applied at the base of the bracket and the same were placed in the center of the buccal surface of the teeth with slight hand pressure. The excess material was removed with an explorer probe. In G1, the adhesive was polymerized for 20 seconds on incisal and lingual aspects. In G2, the cure time was 20 seconds on the buccal aspect. In G3 and G5, the polymerization time was 10 seconds on mesial and distal on each bracket. In G4 and G6, the cure time was 10 seconds applied to the buccal surface. After the bonding procedure, the samples were stored in a closed container with 100% relative humidity at 23 °C for one hour and then immersed in distilled water for 23 hours.

The samples were tensioned with two segments of 0.010-in orthodontic wire tied on proximal wing and bent in the central region of the buccal surface to apply force perpendicular to the base of the bracket. The opposite end of the wire was connected to a universal testing machine (Applied Test Systems®, ATS-1105c, Butler, PA, USA). Displacement rate used was 0.5 mm/min. After bonding, all samples were analyzed by optical microscope (Olympus S7CTV, Center Valley, PA, USA) with a magnification of 10X to evaluate the adhesive remnant index (ARI) according to Artun and Bergland³ (Table 1). To illustrate the debonding pattern, photographs taken with the optical microscope with a 20X magnification were made (Fig 1).

Statistical analysis was performed using SPSS® 10.0 software. To verify the normality of the data, we used the Kolmogorov-Smirnov test. In order to



Figure 1 - Illustration of the ARI score 3 (20X magnification).

compare the results of the bond strength, analysis of variance (ANOVA) and the Tukey test were used. To compare the results of the ARI between different groups it was used the Kruskal-Wallis test.

RESULTS

The results of this study are shown in Tables 2 and 3. In G1 and G4, five specimens were excluded because of discrepancies in the obtained values.

The results show no statistical difference between the groups where the same adhesive was used for bonding ceramic and metallic brackets. However, there was significant difference between the three brands of adhesive used. The groups bonded with Transbond XT (G5 and G6) showed the highest adhesion, followed by the groups bonded with Transbond Color Change (G3 and G4). The worst results were obtained with the Ortho Lite Cure resin (G1 and G2). The results for the ARI showed no significant difference between the groups and the most frequent result was the resin completely bonded to enamel surface after debonding (Fig 1).

DISCUSSION

The bond strength between brackets and enamel has been extensively researched over the past two decades. However, some issues still persist for the choice of adhesive by the orthodontist, especially due to the large amount of materials available in the market. The main issues fall back on the safety of the procedure,

Table 1 - Adhesive remnant index (ARI).

Score	Quantity of adhesive bonded to enamel
0	No adhesive left on the tooth
1	Less than half of the adhesive left on the tooth
2	More than half of the adhesive left on the tooth
3	All adhesive left on the tooth with a distinct impression of the bracket mesh

Table 2 - Comparison of bond strength (MPa) between the groups ($p < 0.01$).

Group	n	Mean*	SD
G1	25	2.47 ^a	1.66
G2	30	2.75 ^a	1.64
G3	30	4.26 ^b	1.20
G4	25	4.22 ^b	1.12
G5	30	5.62 ^c	0.75
G6	30	5.95 ^c	0.91

* Different letters represent statistical difference ($p < 0.01$).

Table 3 - ARI comparison between groups.

Group	Index 0		Index 2		Index 3		Total	
	n	%	n	%	n	%	n	%
G1	5	20.0	2	8.0	18	72.0	25	100.0
G2	8	26.6	4	13.3	18	60	30	100.0
G3	1	3.3	6	20	23	76.6	30	100.0
G4	-	-	4	13.3	21	70	25	100.0
G5	2	6.6	5	16.6	23	76.6	30	100.0
G6	1	3.3	3	10	26	86.6	30	100.0
Total	17	10	24	14.11	129	75.88	170	100.0

cost-benefit and efficacy of the product. Plaque accumulation around the brackets is an important issue, since the orthodontic appliances may be responsible for caries and gingival disease.^{2,17} Thus, the colored adhesives can be an important tool in reducing the excess of material and dental plaque.

In the present study, when the results of the ARI are evaluated, we note that for all groups the most common result was the score 3, where all the adhesive remains in the enamel after debonding. Olsen et al¹⁸ reported that the ARI index 3 is the safest, where the chance of dental damage is less likely. Therefore, we can conclude that the tensile strength obtained with both resins, traditional and colored, is safe.

When the bond strength is analyzed, it can be concluded that there was no differences between metallic and ceramic brackets when the same adhesive

was used, which gives the orthodontist the possibility to safely bond ceramic brackets. This fact brings tranquility, due to the increasing demand for esthetic orthodontic brackets in clinics. The bond strength obtained in G1 and G2 was too low to orthodontic use.^{9,14,19} The adhesive strength for G3 and G4 was a bit low for bonding orthodontic accessories, but it was acceptable.²² The tensile strength shown in G5 and G6 was adequate according to Aasrum et al.¹ However, while Reynolds²¹ recommends shear strength of 7 MPa, he also relates the difficulty of establishing the optimal adhesive strength between bracket and tooth enamel. Other studies have also demonstrated the difficulty of establishing a numerical value for bonding strength when it depends on many factors such as experimental procedures,¹¹ adhesive thickness,⁸ bonding procedures,⁶ type of adhesive used,^{2,18} and the direction and type of applied force,¹³ and other factors. Therefore, the comparison of results becomes difficult. This raises some questions as: Are we basing our clinical choices properly, or should further studies be conducted to clarify these issues? Murray and Hobson¹⁵ as well as Eliades et al,⁷ report the difficulty of comparing the results obtained in *in vitro* tests to the *in vivo* reality. According to these authors, methods for assessing the influence of the environment on intraoral adhesive strength of brackets to enamel should also be developed. The discrepancy between the results of this study and the results reported in the literature may be due to the different methodologies used, but probably the presence of colored pigments in orthodontic resins must reduce the bond strength of these materials.

A clinical observation noticed by the operator was that the Ortho Lite Cure orange pigment does not differentiate from tooth enamel color and it is not very useful in removing the excess of material. The pigments present in the Color Change Transbond are quite distinct from enamel and assist in the removal of resin excess, but their sandy consistency is not very pleasant to work with.

Further studies with these materials must be conducted to obtain more information about the shear strength. The impact of these adhesives on plaque accumulation must also be thoroughly investigated in order to determine whether or not they have a positive effect on plaque reduction during orthodontic treatment. Since these adhesives are more expensive than traditional ones, the benefits should be significant. It is recommended that more studies be conducted to investigate the ideal adhesion strength of orthodontic accessories in human enamel.

CONCLUSIONS

The results of this study demonstrated:

- a) Tensile strengths of metallic and ceramic brackets were similar when the same adhesive was used.
- b) Transbond XT adhesive had the highest bond strength, followed by Transbond Color Change adhesive, which presented clinically acceptable resistance values.
- c) The worst results in terms of tensile strength were obtained with the Ortho Lite Cure adhesives, which were considered low for orthodontic use.
- d) Further studies must be conducted on the clinical use of colored adhesives.

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