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Effect of Activation Mode on Shear Bond Strength of Metallic Brackets

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The aim of this study was to evaluate the shear bond strength (SBS) of metallic orthodontic brackets bonded to bovine teeth using light-activated or chemically activated composite resins. One hundred and twenty bovine mandibular incisors were divided into 6 groups (n=20), according to the bonding materials: Transbond XT (T); Enforce Dual (ED); Enforce chemical (EC); Enforce Light-activated (EL); Concise Orthodontic (C); and RelyX Unicem Capsule (UN). Metallic brackets were positioned and firmly bonded to the teeth. Light-activation for T, ED, EL and UN was carried out with four exposures on each side of the bracket with 20 s total exposure times using XL2500 (3M ESPE). EC and C were chemically cured. Next, all specimens were stored in deionized water at 37 °C for 24 h. The shear bond strength was carried out at a crosshead speed of 1.0 mm/min. Data were subjected to one-way ANOVA and Tukey's test (α=0.05). The adhesive remnant index (ARI) was evaluated at 8× magnification. C (17.72±4.45) presented significantly higher SBS means (in MPa) than the other groups ($p<0.05$), followed by EC (11.97±5.77) and ED (10.57±1.32). EL (5.39±1.06) and UN (4.32±1.98) showed the lowest SBS means, while T (9.09±2.56) showed intermediate values. For ARI, there was a predominance of score 0 for EC, C and UN, and score 3 for T, ED and EL. In conclusion, the activation mode influenced the SBS.

Key Words: shear bond strength, light-activation, dual curing cement.

Introduction

The light-cured composite resins are routinely used for bonding orthodontic brackets to the teeth (1,2). The advantage of light-cured composite is that the clinician has enough time to place the brackets in the correct position and easily remove any excess material before the light-activation and insertion of the orthodontic archwire (3).

The bonding strategies of brackets comprise a series of technique-sensitive steps. Failures with light-cured composite resins have been attributed to moisture contamination or incomplete polymerization when considering the light exposure time or limited depth polymerization (4), which varies with the light penetration into the material (5). This reduction in polymerization has been called depth of cure and has significant influence on physical (5) and biological properties of composite resins. Adequate polymerization is necessary for the bonding material. Dual-curing resin cements could be used for bonding orthodontic brackets to enamel especially when effective light-activation is not possible. They are used to ensure the polymerization of the resin cement, even below opaque and thick restorations, where the light is not able to reach (6).

Recently, in order to reduce the operative steps and decrease the sensitivity of dental techniques, self-adhesive resin cements have been introduced (6). These materials are based on new monomer, filler and initiation technology. They combine etchant, primer and adhesive resin in a single paste. This approach could reduce the saliva contamination, which is an undesirable event during bracket bonding (7). Thus, it would be interesting to use the self-adhesive cements for bracket bonding.

The aim of this study was to evaluate the shear bond strength of metallic orthodontic brackets bonded to bovine teeth using light-cured or chemically activated composite resins. The hypothesis tested was that there is no significant difference on the shear bond strength among composite resins with different activation modes.

Material and Methods

Preparation of Specimens

One hundred and twenty bovine mandibular incisors without cracks or surface defects were collected. The roots were sectioned with a water-cooled diamond saw (Isomet; Buehler Ltd., Lake Bluff, IL, USA) and the crowns were embedded in self-curing acrylic resin (Clássico Produtos Odontologicos, São Paulo, SP, Brazil) in polyvinyl chloride tubes, with the buccal face perpendicular to the tube. The vestibular faces of all teeth were cleaned with a rubber cup and non-fluoridated pumice-water slurry for 10 s, rinsed with air-water spray for 10 s and air-dried for 10 s.

The teeth were divided into 6 groups (n=20), according to bonding materials: Transbond XT (T - 3M Unitek, Monrovia, CA, USA), Enforce Dual (ED - Dentsply Caulk, Milford, DE, USA), Enforce Chemical (EC - Dentsply Caulk), Enforce Light-activated (EL - Dentsply Caulk), Concise

Orthodontic (C - 3M ESPE, St. Paul, MN, USA) and RelyX Unicem Capsule (UN - 3M ESPE).

The middle third of the buccal face of teeth from groups T, ED, EC, EL and C were etched with 35% phosphoric acid gel (Concise etching; 3M ESPE) for 20 s, rinsed with air-water spray for 20 s and air-dried for 20 s. In group T, one layer of Transbond XT Primer (3M Unitek) was applied on the tooth and light-activated for 10 s using a halogen lamp XL2500 (3M ESPE), with 700 mW/cm^2. Then, stainless steel standard maxillary incisor brackets (Morelli Ortodontia, Sorocaba, SP, Brazil) were positioned and firmly bonded to the tooth using Transbond XT light-cured bonding resin (3M Unitek), excess was removed using a microbrush (KG Sorensen) and light-activated.

In groups ED, EC and EL, one layer of Adper Scotchbond Multi-Purpose Adhesive (3M ESPE) was applied on the tooth and light activated for 10 s. The groups were set up as follows: Group ED, Enforce catalyst and base pastes were mixed, applied on the brackets base, bonded to the teeth and light-activated; Group EC, same as group ED, but without light-activation; Group EL, Enforce PV and Enforce base pastes were mixed, applied on the brackets base, bonded to the teeth and light-activated; Group C, Concise Enamel Bond Resin A and Resin B were mixed for 10 s and one layer was applied on the tooth. Concise Orthodontic A and B pastes were mixed for 20 s, applied on the bracket bases and bonded to the teeth; Group UN, RelyX Unicem Capsule was mixed for 10 s using Ultramat 2 (Southern Dental Instruments Inc., Bayswater, Victoria, Australia), applied on the bracket bases, bonded to the teeth and light-activated.

Light-activation of groups T, ED, EL and UN was carried out with four exposures on each side of the bracket with a total exposure time of 20 s. Groups EC and C were chemically cured. All specimens were stored in deionized water at 37 °C for 24 h.

Bond Strength Testing and Failure Analysis

The shear bond strength (SBS) test was performed using a mechanical testing machine (Model 4411; Instron, Canton, MA, USA) with a knife-edged rod at a crosshead speed of 1.0 mm/min until failure. A mounting jig was used to align the tooth-bracket interface parallel to the testing device. SBS mean values were calculated in MPa and subjected to one-way ANOVA and Tukey's test (α=0.05).

After debonding, teeth and bracket surfaces were examined with a stereomicroscope (Olympus Corp, Tokyo, Japan) under 8× magnification. The Adhesive Remnant Index (ARI) (8) was used to classify the failure modes, according to the following scores: 0 - indicates that no bonding resin remained on the tooth; 1 - indicates that less than half of the bonding resin remained on the tooth; 2 - indicates that more than half of the bonding resin remained on the tooth; and 3 - indicates that all bonding resin remained on the tooth, along with a clear impression of the bracket mesh.

Results

C (17.72±4.45) showed the highest SBS mean value and differed significantly from all other bonding materials ($p<0.05$). EC (11.97±5.77) showed SBS significantly higher than T (9.09±2.56), EL (5.39±1.06) and UN (4.32±1.98) ($p<0.05$). No statistically significant difference was found between EL and UN; EC and ED (10.57±1.32); or between T and ED ($p>0.05$).

The ARI results are displayed in Table 1. A predominance of score 0 was observed for C, EC and UN, while ED, T and EL showed predominance of score 3.

Table 1. Frequency distribution (%) of the Adhesive Remnant Index (ARI) scores

Bonding Material	ARI Scores* (%)			
	0	1	2	3
Concise Orthodontic	45	5	30	20
Enforce Chemical	45	20	30	5
Enforce Dual	25	-	15	60
Transbond XT	35	-	15	50
Enforce Light-activated	5	5	20	70
RelyX Unicem Capsule	95	-	5	-

*The ARI scoring system has a range between 0 and 3, with 0 indicating that no bonding resin remained on the tooth; 1: less than half of the bonding resin remained on the tooth; 2: more than half of the bonding resin remained on the tooth; and 3: indicates all bonding resin remained on the tooth, along with a distinct impression of the bracket mesh.

Discussion

An adequate polymerization of composite resins under brackets is important to reduce the debonding during orthodontic treatment (9,10). Thus, polymerization methods that maximize the degree of conversion and mechanical properties of composite resins under brackets are recommended.

The hypothesis tested in this study was rejected since brackets bonded with resin composites presenting different activation modes showed significant differences in the shear bond strength (SBS) to enamel. The chemically activated composite resins showed SBS significantly higher than the other groups, with Concise Orthodontic having the highest SBS (17.72±4.45 MPa). The polymerization of chemically activated composite resins (groups EL and C) starts during the mixing of the base and catalyst pastes and it does not depend on extrinsic factors such as light for the light-activated composites (11). When an adequate ratio and mixing procedure are performed, the composite can reach its maximum properties and polymerization occurs homogeneously under the brackets.

Light-activated composite resins showed lower bond strength than the chemically activated ones. The polymerization of light-activated composite resins depends on light. A small amount of light is available in the central region under the brackets, due to difficulty of passing light through the bracket. The bracket retention is compromised by insufficient polymerization of the composite resins, leading to the lowest SBS. The degree of conversion and depth of polymerization of light-activated composite resins are dependent on the material composition (shade, photoinitiator system and filler content), light source and exposure time (5). The factors related to the light source are wavelength (nm) and irradiance (mW/cm^2). Energy density, which is a product of irradiance and light exposure time, was found to influence the bond strength of brackets. Increasing the energy density above 12 J/cm^2 does not seem to have a beneficial effect on SBS (12). However, there seems to be an advantage of irradiance over exposure time for metallic bracket bonding. Probably, an alternative to maximize the polymerization of the light-activated composite resins could be to extend the light exposure time or to use light sources with higher irradiation.

To control the setting time and to obtain higher initial tensile bond strength and SBS by polymerizing the resin cement under the bracket, a dual-curing system that combines both light- and chemical-curing systems, is essential (13). In this study, dual-activated resin composites showed intermediate bond strength. Dual-activated composite resins combine the advantages of light-activated composites (longer working time) with the more homogeneous and effective polymerization when light is limited for bracket bonding (14). The results obtained for dual activated resin composite classifies this material as a good alternative for bracket bonding, especially in regions where access to light is impaired (i.e., bonding of tubes and accessories in the posterior regions).

The lowest SBS was found for self-adhesive cement RelyX Unicem (4.32±1.98 MPa). This finding is in agreement with those of previous studies, which also found that brackets bonded with RelyX Unicem presented lower shear bond strength (15,16). RelyX Unicem does not need a previous surface treatment to its application. According to Hikita et al. (17) the bond strength of RelyX Unicem was significantly increased with a previous phosphoric acid etching of enamel surface. A scanning electron microscopy analysis showed that the phosphoric acid etched enamel showed consistent patterns of conditioning, while the self-etching adhesives and composite self-adhesive (RelyX Unicem) applied to intact enamel showed areas of inconsistent conditioning (18). In this study, RelyX Unicem groups showed 95% of adhesive failures (score 0), indicating lower interaction between the bonding material and enamel (Table 1). These results agree with the values obtained in shear bond strength and can be explained by the difficulty of conditioning the enamel surface by RelyX Unicem (18).

According to Reynolds (19), bond strength values between 6 to 8 MPa are adequate for orthodontic applications under clinical conditions. In this study, bond strength values lower than 6.0 MPa were detected for two groups where brackets were bonded to the teeth using Enforce Light-activated and RelyX Unicem Capsule. Therefore, Enforce Light-activated and RelyX Unicem Capsule may produce insufficient bond strengths to resist forces during the orthodontic treatment.

The results of ARI scores (Table 1) showed that prevalence of failures on debonding indicate no bonding resin on the tooth (score 0) for chemically activated composites resins (groups EC and C). Despite the higher incidence of adhesive failures for the chemically activated materials, they showed the highest shear bond strength. This suggests a better polymerization of these materials, which reduces the amount of cohesive failure of composite resin.

The dual cure and light-activated resin composites (groups T, ED and EL) showed predominance of failure between bracket and composite resin, indicating that all bonding resin remained on the tooth (score 3). Bryant et al. (20) found that the composite/bracket base interface was the weak link in the direct bonding of orthodontic attachments, due to more frequent failures of this site for clinical use. These results may be related to the lower shear bond strength shown by light-activated composite resins. Due to the difficulty of the light to reach the composite resins under brackets, the polymerization of composite resins close to the mesh of brackets is impaired, leading to increased failures between bracket and composite resin.

Although the ideal substrate for this type of study is the human tooth, bovine teeth were used as a substitute because extracted human teeth are becoming difficult to obtain due to the progress in conservative dental treatment (21). Bovine teeth are easily obtainable and are reported to be a reliable substitute for human teeth in enamel bonding (22).

In summary, the present study demonstrated that the activation mode influenced the shear bond strength. The chemically activated bonding materials showed shear bond strength higher than the light cured ones. The RelyX Unicem and Enforce Light-activated presented lower shear bond strengths. Care should be taken during bonding procedures, irrespective of the used bonding materials. Future studies should also be carried out using different storage times, thermocycling and light sources.

Resumo

O objetivo deste estudo foi avaliar a resistência de união ao cisalhamento (RUC) de braquetes ortodônticos metálicos colados ao dente bovino utilizando resinas compostas ativadas por luz ou quimicamente ativadas. Cento e vinte incisivos mandibulares bovinos foram divididos em 6 grupos (n=20), de acordo com o material de colagem: Transbond XT (T); Enforce Dual (ED); Enforce químico (EC); Enforce ativado por luz (EL); Concise Ortodontico (C); e RelyX Unicem Capsula (UN). Braquetes metálicos foram posicionados e firmemente colados aos dentes. A ativação por luz para os grupos T, ED, EL e UN foi realizada em quatro exposições, sendo uma em cada lado do braquete, para um tempo total de exposição de 20 s usando o aparelho XL2500 (3M ESPE). Os grupos EC e C foram ativados quimicamente. Após, todas as amostras foram armazenadas em água deionizada a 37 ^{o}C por 24 h. O teste de resistência de união ao cisalhamento foi realizado após o período de armazenagem, à velocidade de 1 mm/minuto. Os dados foram submetidos à Análise de Variância e ao teste de Tukey (α=0,05). O índice de remanescente adesivo (IRA) foi avaliado em aumento de 8x. O valor de RUC (MPa) do grupo C (17,72$\pm$4,45) foi significantemente maior do que o de outros grupos (p<0,05), seguido pelo grupo EC (11,97$\pm$5,77) e ED (10,57$\pm$1,32). Os menores valores de RUC foram obtidos pelos grupos EL (5,39$\pm$1,06) e UN (4,32$\pm$1,98). O grupo T (9,09$\pm$2,56) apresentou valor intermediário. O IRA mostrou predominância de escore 0 para os grupos EC, C e UN e escore 3 para os grupos T, ED e EL. Em conclusão, o modo de ativação influenciou nos valores da RUC.

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