Evaluation of shear bond strength of brackets bonded with orthodontic fluoride-releasing composite resins

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Abstract

Objective: To evaluate the shear bond strength of stainless steel brackets bonded with fluoride releasing composite resins, comparing them with a conventional resin and to analyze the amount of resin left on the enamel surface. **Methods:** Sixty premolars were randomly divided into three groups: Group I – Concise (3M), Group II – Ultrabond (Aditek do Brasil) and Group III – Rely-a-Bond (Reliance). After bonding, the samples were thermocycled (500 cycles) at 5°C and 55°C temperatures. After 48 hours they were subjected to shear bond strength testing, in the occluso-gingival direction, using an MTS 810 Universal Testing Machine with load speed of 0.5 mm/min. **Results:** The results demonstrated a mean shear bond strength of 24.54 ± 6.98 MPa for Group I, 11.53 ± 6.20 MPa for Group II, and 16.46 ± 5.72 MPa for Group III. Analysis of Variance (ANOVA) determined a statistical difference in the mean shear bond strengths between groups ($p < 0.001$). The Tukey test evidenced that the averages of the three groups were significantly different ($p < 0.05$), with the highest values for Group I and the lowest for Group II. The Kruskal-Wallis test did not show significant differences in the amount of resin left on the enamel in any of the three groups ($p = 0.361$). **Conclusion:** All materials exhibited adequate adhesive bond strength for clinical use. Concise exhibited the highest degree of shear bond strength but no significant differences were found in Adhesive Remnant Index (ARI) between the groups.

Keywords: Shear bond strength. Brackets. Composite fluoride resin.

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INTRODUCTION

Several advances have contributed to the improvement of the technique of bonding orthodontic accessories, such as, the introduction of enamel acid etching by Buonocore,[7] and its association with composite resins based on bisphenol A glycidyl methacrylate (Bis-GMA). As a result, this technique has become the method of choice for bonding orthodontic accessories.[11,12]

However, during treatment with fixed orthodontic appliances certain problems may occur, such as: (1) fractures or even loss of enamel, which may be related to the pretreatment of the enamel surface during prophylaxis[27] and/or during phosphoric acid etching;[6] (2) additional loss of enamel during bracket debonding, removal of debris from the tooth, or rebonding procedures;[2] and (3) decalcification of the enamel around the brackets, which is considered the most common problem in patients undergoing orthodontic treatment with fixed appliances.[2,4,14,17,23,26]

The presence of brackets and resin predisposes to a greater accumulation of plaque around the brackets,[2] which can cause white spot lesions likely to occur after the first four weeks of orthodontic treatment.[17] These changes appear mainly in the cervical region of upper incisors.[1]

The risk of demineralization can be countered by performing plaque control and fluoride application.[1,17] However, it has been found that the fluoride toothpaste brushing program did not prevent enamel decalcification around the brackets because the effectiveness of plaque control depends on the daily routine followed by the patient.[16]

Given the fact that it is difficult to secure patient compliance in plaque control and the use of fluoride, and due to the inconvenient effects caused by the unsightly white spots, researchers started to develop adhesives with the addition of fluoride to prevent enamel demineralization around the brackets.[25] These materials were investigated for their fluoride releasing efficacy, which has been confirmed by several studies.[9,16,23,26,28,29]

Fluoride inhibits bacterial activity and can remineralize enamel.[25] However, such materials are relatively new and the need therefore arises to ascertain that the bond strength is sufficient to meet clinical needs, and also whether or not the fluoride comprised in these materials decreases its strength. For these reasons, the authors set out to evaluate the shear bond strength of stainless steel brackets bonded with fluoride-releasing resins, compare them with conventional resins and assess the amount of adhesive left on the enamel surface.

MATERIAL AND METHODS

This study used 60 freshly extracted permanent premolars—all extractions indicated for orthodontic purposes—of patients aged between 12 and 14 years. The design of this study was submitted to and approved by the Ethics Committee of the Ponta Grossa State University.

After extraction, the teeth were cleaned with a scalpel blade n° 11, spatula LeCron and a spray of bicarbonate, washed and stored in chilled distilled water changed weekly. Prior to the preparation of the specimens, the teeth were immersed in a 0.5% chloramine solution for disinfection for 48 hours in a closed container, as directed by the ISO/TS 11405 (2003) standard. A 6.5X magnification stereomicroscope was used to select teeth with the following characteristics: A healthy enamel surface or at least an intact facial surface, i.e., should not present decay, decalcification, restorations, cracks, fractures, and should not have undergone any treatment with chemical agents, such as formaldehyde, hydrogen peroxide, alcohol or thymol. The teeth selected for this study were healthy and free of any flaws that might impair adhesion.

For the preparation of the samples an acrylic square was used to standardize the position of the teeth on a PVC tube. This square was

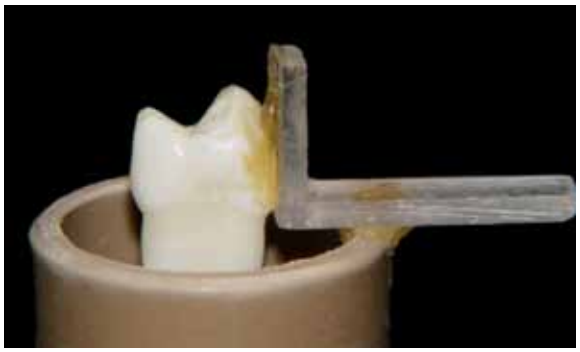

FIGURE 1 - Tooth-square set bonded to PVC tube with sticky wax.

made from two 2 mm thick acrylic sheets. Each acrylic sheet was 5 mm wide, one measuring 10 mm in length and one 20 mm. These sheets were glued with universal instant adhesive. Each tooth was attached to the acrylic square with sticky wax while keeping the buccal surface parallel to the surface of the square and the cemento-enamel junction was used as the lower limit. The tooth-square set was bonded with sticky wax to a PVC tube measuring 25 mm in diameter and 35 mm in height (Fig 1).

The crown was centered and the root completely inserted inside the tube, which was filled with hard plaster type IV (SS White, Rio de Janeiro, Brazil). After the hard plaster had set the square was removed. The bonding area ran perpendicular to the base of the PVC tube to keep the buccal surface parallel to the force during the shear bond strength test. All traces of wax and plaster were removed from the samples, which were stored in distilled water for 24 hours in a closed container.

Prior to bonding, buccal surface prophylaxis was performed using a rubber cup and pumice and water, ensuring that the rubber cup was replaced following five prophylaxis procedures. The teeth were washed with water sprays for 15 seconds and dried with moisture-free air sprays for 15 seconds.[12,24]

Buccal surface enamel etching was performed with 37% phosphoric acid gel (Dentalville, Joinville, Brazil) for 30 seconds in all groups. The buccal surfaces were then washed with air and water sprays for 20 seconds and dried with moisture-free air sprays for 10 seconds.

Premolar stainless steel brackets (Morelli, Lot No. 664362) were bonded with the following orthodontic resins: Concise (3M/ESPE, Dental Products Division, St. Paul, Minnesota, USA - Lot No. 17093), Ultrabond with fluoride (Aditek do Brazil, Cravinhos, São Paulo, Lot No. 9776) and Rely-a-Bond with fluoride (Reliance Orthodontic Products, Itasca, Illinois, Lot No. 046602). The brackets were pre-adjusted with -7° torque, 0° angulation and had a 13.02 mm^2 base area, which was automatically obtained using Solidworks software (SolidWorks Corp., USA), according to the manufacturer's instructions. The samples were divided into three groups with twenty sampling units, according to the orthodontic resin that was used.

After etching the enamel, a sealant—specific for each group—was applied, followed by the resin. Bonding was then performed according to manufacturer's recommendations.

During bonding, an ABZ-0179 (Ormco Corp., USA) positioner was used at a distance of 4 mm from the occlusal surface to the bracket slot to standardize bracket positioning. A standard seating pressure of 300 grams was used throughout bonding of all teeth, with the aid of a Correx dynamometer (Haag-Streit, Switzerland).[3,4,5] Excess resin was removed with an explorer probe prior to polymerization.

After bonding, the samples were stored for 24 hours in distilled water at room temperature in sealed plastic containers and labeled according to each group. The samples were then subjected to thermocycling in an MSCT-3 machine (Marcelo Nucci ME, Brazil), applying 500 cycles at 5°C (± 3°C) and 55°C (± 3°C) temperatures. Each cycle was performed for 20 seconds with 7-second intervals.

After a 48-hour interval, counted from the end of thermocycling, the samples were subjected to shear bond strength tests in the occluso-cervical direction and with the chisel positioned at the tooth-bracket interface. The tests conformed to the ISO/TS 11405 (2003) standard and were performed with a universal electronic machine for mechanical tests (MTS 810, MTS Systems Corp., USA), with 1 kN load cell, and crosshead speed of 0.5 mm/min. The breaking loads were recorded in Newtons and converted to Megapascal. This conversion was carried out automatically by the test machine itself, or else it could have been calculated using the following formula: R = F/A, where R = shear bond strength in Megapascal, F = breaking load or debonding force in Newtons, and A = bracket base area in mm^2.

After debonding, the teeth with their respective brackets were stored in individual plastic bags for later analysis of the amount of adhesive remnant. The teeth and brackets were examined with the help of a stereomicroscope using 40X magnification and classified according to the adhesive remnant index (ARI) proposed by Artun and Bergland[1], with scores of 0 to 3, indicating:

- Score 0 = no adhesive remnant left on the tooth.
- Score 1 = less than 50% adhesive remnant left on the tooth.
- Score 2 = more than 50% adhesive remnant left on the tooth.
- Score 3 = 100% adhesive remnant left on the tooth.

Statistical analysis

Analysis of Variance (ANOVA) is a useful statistical procedure, provided that certain conditions are met, such as: (1) data should be obtained randomly and independently—which is true on this study; (2) there should be homogeneity of variance between experimental groups and residuals should be within a normal range. Homogeneity of Variance, i.e., the requirement that the variances or standard deviations of the bond strength measurements be equivalent across the three experimental groups, was tested using Levene statistics. Normality of Residuals, which can be defined as estimates of experimental errors determined by the difference between each bond strength measurement and the average of the group to which each measurement belongs, was tested using Shapiro-Wilk statistics. A 5% significance level was adopted.

Analysis of Variance was utilized to assess shear bond strength of brackets bonded with two resins, both containing fluoride (Ultrabond and Rely-a-Bond) and a conventional resin (Concise). Analysis was complemented by the Tukey test for multiple comparison of means in pairs.

In addition, 95% confidence intervals were constructed for the population means of the experimental groups. These intervals allow researchers to quantify the differences between the means since the tests only indicate whether or not there is evidence that these differences are significant at 5%.

The Kruskal-Wallis nonparametric test was used—at 5% significance level—to evaluate the adhesive remnant index.

RESULTS

Table 1 shows the means and standard deviations in MPa, according to the experimental groups analyzed: Group I - Concise (3M/ESPE), Group II - Ultrabond with fluoride (Aditek do Brasil) and Group III - Rely-a-Bond with fluoride (Reliance Orthodontic Products).

The result of the Levene Statistics ($p = 0.366$) and the result of the Shapiro-Wilk Statistics ($p = 0.164$) demonstrated that there was homogeneity of variance and normality of residuals since the p values are greater than 0.05 (Table 2), which ensured that analysis of variance could be applied.

Analysis of variance (Table 2) showed compelling evidence of significant differences be-

TABLE 1 - Mean and standard deviation by experimental group.

SAMPLE	GROUP		
	I	II	III
mean	24.54	11.53	16.46
standard deviation	6.98	6.20	5.72

TABLE 2 - Summary of analysis of variance applied to compare the study groups in terms of shear bond strength.

EFFECT	DEGREES OF FREEDOM	RMS	F	p
Group	2	862.66	21.59	< 0.001
Residuals	57	39.95		

Homogeneity of variances: p = 0.366 (Levene).

Normality of residuals: p = 0.164 (Shapiro-Wilk).

TABLE 3 - p values of the Tukey test for comparison of shear bond strength means between groups.

GROUP	GROUP		
	I	II	III
I		< 0.001	0.001
II	< 0.001		0.044
III	0.001	0.044	

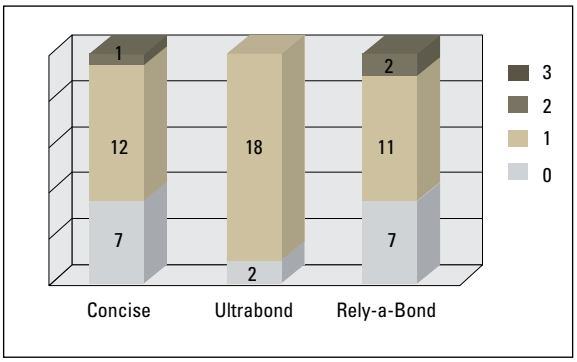

FIGURE 2 - Graphical representation of the frequencies of ARI scores.

tween the means of shear bond strength between the groups ($p < 0.001$).

The p values of the Tukey test, for comparing the means in pairs, were all lower than 0.05 (Table 3), showing that the means of the three groups were significantly different. Group I (Concise) had a significantly higher mean than the means of the fluoride-releasing resin Groups ($p < 0.001$), while group III (Rely-a-Bond) had a significantly higher mean ($p = 0.044$) than group II (Ultrabond).

Figure 2 presents the observed frequencies of ARI scores for each resin used for bonding. There was no score 3 and only one or two scores 2. Although Ultrabond showed a tendency to have more scores 1 (and consequently fewer scores 0) compared with other resins, the Kruskal-Wallis test showed no statistically significant difference between the three procedures in terms of debonding ($p = 0.361$).

DISCUSSION

Many researchers have investigated alternative materials to the use of conventional resins with the purpose of preventing enamel decalcification around the brackets—through the release of fluoride for a prolonged period of time—thus increasing enamel strength and promoting its remineralization. These authors have also investigated whether these materials have an adequate shear bond strength.[3,4,8,10,11,13,14,24,25]

Fluoride-releasing resins are a new generation of preventive orthodontic materials for bracket bonding, which combine the appropriate enamel-bonding physical properties and fluoride releasing agents. They also provide clinically desirable shear bond strength features, easy cleaning after bonding and easily removable residual materials in debonding procedures.[25]

Practitioners should be aware of the properties of resins used for bracket bonding, especially with respect to their efficiency during accessory placement.[3] This feature is essential as an orthodontic resin must be capable of keeping accessories firmly adhered to the teeth throughout treatment, resisting masticatory forces as well as those generated by orthodontic mechanics.[21,24] The minimum shear strength

of any adhesive should be between 60 Kgf/cm^2 (5.88 MPa) and 80 Kgf/cm^2 (7.84 MPa) if it is to meet clinical needs.[21,22] When the results of this study were compared with the values of reference,[21,22] all adhesives showed strength values suitable for clinical use.

Several factors can affect the final outcome of shear bond strength tests. Therefore, in an attempt to achieve more reliable results the methods were standardized according to the ISO/TS11405 (2003) standard, which is specific for shear tests and recommends that to obtain a pure shear stress it is necessary that the action of the force be parallel to the tooth surface.

This study compared two fluoride-releasing composite resins (Ultrabond and Rely-a-bond) and a conventional composite resin (Concise). All were employed as per manufacturer's recommendations. It is a known fact that improper manipulation and/or the use of inadequate quantities of resin may affect shear bond test results.

The results show that the three groups are significantly different from one another. Group I (Concise = 24.54 ± 6.98 MPa) had the highest shear bond strength mean compared with the other groups. These findings corroborate the work of Kawakami et al[13] (48 hours = 20.10 ± 1.44 MPa and 10 days = 20.62 ± 1.53 MPa), and Meister[15] (29.99 ± 15.89 MPa), which also found higher shear bond strength values when using Concise.

Kawakami et al[13] evaluated Concise using 48-hour and 10-day periods after the polymerization of the material. They related their results to the time used for acid etching, whether or not etching had been performed and the time consumed in debonding brackets, since full polymerization does not occur before a period of 24 hours has elapsed. Within 10 days there was an increase in shear bond strength but for Concise no statistically significant difference was found in both periods. Meister[15] ascribed their results to method standardization and the use of premolar-specific brackets given their better fit to the tooth surface.

Concise exhibited the highest shear bond strength due to its high filler content since the content of inorganic particles directly influences the resistance of composite resins.[12] The results found by Correr Sobrinho et al[10] (after 10 min = 6.22 ± 0.28 MPa and after 24 hours = 7.73 ± 0.21 MPa) were lower than those found in this study. This is probably due to the shorter time taken to debond the brackets, which delayed polymerization. Nevertheless, Concise still showed higher shear bond strength compared with the other materials.

Group III (Rely-a-Bond = 16.46 ± 5.72 MPa) showed a significantly higher shear bond strength mean than Group II (Ultrabond = 11.53 ± 6.20 MPa). This difference becomes more pronounced when these two groups (II and III) were compared with Group I (Concise = 24.54 ± 6.98 MPa).

The results of Ultrabond (Group II) and Rely-a-Bond (Group III) were smaller and could be explained as follows. Since these are 1-paste resins the catalyst is applied to the tooth and to the base of the brackets while the paste is placed on the base of the brackets. Since these are chemical polymerization materials and are not manipulated prior to use the catalyst is mixed with the base paste only by the seating pressure exerted on the bracket during bracket placement, this procedure can lead to incomplete polymerization of some portions of the material, which compromises its strength and makes it difficult to attain the homogeneity of results for this bonding system.

When the results for the fluoride-releasing resins used in this study were observed—Ultrabond (Group II = 11.53 ± 6.20 MPa) and Rely-a-Bond (Group III = 16.46 ± 5.72 MPa)—they were found to be similar to those obtained by Sinha et al,[25] who used a fluoride-releasing self-curing resin (Rely-a-Bond = 19.0 MPa).

Simplício[24] also found similar results when using a self-curing resin (Rely-a-Bond = 13.16 ± 4.87 MPa). Komori and Ishikawa,[14] however, found a different result for the same self-curing resin (Rely-a-Bond = 25.7 ± 3.6 MPa).

As regards the adhesive remnant index, bonding failures were found to occur more frequently at the adhesive-enamel interface in all three groups assessed since there was little or no adhesive left on the teeth after debonding. Moreover, there was no damage to the enamel surface after debonding, with the exception of two samples of Group 1 (Concise), which showed fractures on the enamel. Penido et al[18] also noted a greater number of fractures at the adhesive-enamel interface in an in vitro study. However, in an in vivo study, Penido et al[18] found that bonding failures occurred at the adhesive-bracket interface, and remarked that this type of fracture, often found in clinical practice, is the most desirable since any fracture at the adhesive-enamel interface can damage the enamel. This is due to the entanglement of the resin in the bracket mesh, which makes this area more brittle. Pithon et al[19,20] found that the fracture occurred at the adhesive-bracket interface and underscored the importance that bonding materials allow for a greater amount of adhesive to be left on the tooth surface after bracket removal as this will provide greater security and maintain tooth integrity while preventing enamel damage. Removal of resin remnants is not a difficult procedure. It is part and parcel of the orthodontic office routine. Nevertheless, it does require skill as it can also damage the enamel.

CONCLUSIONS

A careful review of the results yields the following conclusions:

1. All materials tested in this investigation have adequate shear bond strength to meet clinical needs, i.e., sufficient strength to withstand the stresses generated by orthodontic mechanics and chewing. However, Concise showed greater resistance than the other two resins (Rely-a-Bond and Ultrabond).

2. Regarding the adhesive remnant index, no difference was found between the groups, and although the fractures occurred at the adhesive-enamel interface, no damage was found to have been caused to the enamel surface after debonding, except in two samples of Group 1 (Concise), which exhibited enamel fractures.

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