Original Article

Effect of Enamel Etching on Tensile Bond Strength of Brackets Bonded In Vivo with a Resin-reinforced Glass Ionomer Cement

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ABSTRACT

Objective: To evaluate the influence of enamel etching on tensile bond strength of orthodontic brackets bonded with resin-reinforced glass ionomer cement.

Materials and Methods: The sample group consisted of 15 patients who had indications for extraction of four premolars for orthodontic reasons, equally divided into two different groups according to bracket and enamel preparation. Brackets were bonded in vivo, by the same operator, using a split mouth random technique: Group 1 (control), phosphoric acid + Fuji Ortho LC; Group 2, Fuji Ortho LC without acid conditioning. The teeth were extracted after 4 weeks using elevators. An Instron Universal Testing Machine was used to apply a tensile force directly to the enamel-bracket interface at a speed of 0.5 mm/min. The groups were compared using a Mann-Whitney *U*-test and Weibull analysis.

Results: Mean results and standard deviations (in MPa) for the groups were: Group 1, 6.26 (3.21), Group 2, 6.52 (2.73). No significant difference was observed in the bond strengths of the two groups evaluated ($P = .599$).

Conclusions: Fuji Ortho LC showed adequate shear bond strength and may be suitable for clinical use.

KEY WORDS: Bond Strength; RRGIC; Tensile; Acid etching

INTRODUCTION

The enamel-etching technique presented by Buonocore[1] is commonly used with composite resin when attaching brackets to the enamel surface. Phosphoric acid etching causes dissolution of interprismatic material in the enamel, producing a roughened enamel surface, and forms enamel resin tags. In recent years, there has been a major research drive to increase bond strength between dental materials and dental hard tissues, although most adhesive systems have provided clinically acceptable bond strengths. The acid-etching technique is a useful procedure in the orthodontic field, but there is a need to improve the bonding procedure in order to maintain clinically useful bond strengths while minimizing the amount of enamel loss, and to simplify the technique, reducing the number of steps.[2,3]

The use of glass ionomer cements (GICs) appears to be a valuable option,[4] considering the low sensitivity to a moist environment and the chemical bonding to enamel that could make etching treatment unnecessary.[5,6] However, some in vitro and in vivo studies have reported that GICs have a weaker bond strength,[5,7–10] with higher bond failure rates,[6,11] when compared with composite resins.

In order to improve bond strengths of GICs and their mechanical properties, a light-cured resin-reinforced glass ionomer cement (RRGIC) was developed (Fuji Ortho LC, GC Corporation, Tokyo, Japan). This

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RRGIC shows an increase in bonding strength, and its use is suggested with and without etching of enamel and in the presence of saliva. In vitro studies have shown that the bond strength of RRGIC is higher than that of conventional GIC, but lower than that of composite resins.[12–16]

To our knowledge, no studies in the literature have evaluated the effect of enamel etching on the tensile bond strength values in vivo of resin-reinforced glass ionomer cement. The purpose of this study was to determine the effects of acid etching on the tensile bond strength of orthodontic brackets bonded in vivo to enamel with Fuji Ortho LC. The null hypothesis was that there would be no difference in the tensile bond strength between groups whether RRGIC was used with or without enamel etching.

MATERIALS AND METHODS

Fifteen patients were selected from the orthodontic department of the State University of Rio de Janeiro to participate in this study. Patients were eligible for the study if they required extraction of four premolars for orthodontic reasons; gender, age, race, and malocclusion differences were ignored. Ethical approval was obtained from the local research committee.

Before extraction, standard edgewise twin brackets (American Orthodontics, Sheboygan, Wis) were bonded to the buccal surfaces of each one of the 60 premolars. The average bracket base surface area was determined to be 13.98 mm.[2]

The teeth were divided into two groups, with equal numbers of first, second, upper, and lower premolars in each group, to prevent bias caused by possible differences in bond strength among tooth types.[8] All materials were mixed and applied according to the manufacturer's instructions by a single operator, following one of two protocols on each tooth:

Group 1: The teeth were etched with 37% phosphoric acid (3M ESPE, St. Paul, MN) for 15 seconds, rinsed with water for 15 seconds, and dried. Orthodontic brackets were then bonded with Fuji Ortho LC.

Group 2: The teeth received no acid conditioning; enamel surfaces were dried with a stream of oil-free air and brackets bonded with Fuji Ortho LC.

Firm pressure was used to completely seat the bracket on the tooth, after which excess bonding cement was removed with a small scaler. Each bracket was light-cured with an Ortholux XT Visible Light Curing Unit (3M Unitek, Monrovia, Calif) for 60 seconds, four 15-second durations from the mesial, distal, incisal, and gingival margins of each one.

Premolars were maintained in the mouth for at least 30 days before extraction. Teeth were extracted using only surgical elevators to avoid contact with the brackets. However, seven brackets were accidentally debonded during the surgical procedure. The extracted teeth were washed and stored in a solution of 0.1% (wt/vol) thymol.

The specimens were mounted in plastic rings with acrylic. A mounting jig was used to align the bracket base parallel with the bottom of the mold and perpendicular to the force during the tensile strength test. An Instron Universal Testing Machine (São Paulo, SP, Brazil) was used to apply a load to the bracket, which produced a tensile force at the tooth-bracket interface. A computer connected to the machine recorded the results of each test in MPa. Shear bond strengths were measured at a crosshead speed of 0.5 mm/min.

After debonding, the teeth and brackets were examined under 10× magnification to evaluate the amount of resin remaining on each tooth. The adhesive remnant index (ARI)[17] was used to describe the quantity of resin remaining on the tooth surfaces. The ARI score has a range from 0 to 3, as follows: 0, no adhesive remained on the tooth; 1, less than half of the enamel bonding site was covered with adhesive; 2, more than half of the enamel bonding site was covered with adhesive; and 3, the enamel bonding site was entirely covered with adhesive.

Descriptive statistics, including the mean, standard deviation, minimum, and maximum values, were calculated for each group tested. The data of bond strength were tested for normality with the Shapiro-Wilk method. The Mann-Whitney *U*-test was used to check differences between groups. Weibull analysis, which relates the probability of bracket failure to the applied load, was also carried out. The chi-square test was used to evaluate differences in the ARI scores between groups. All statistical analyses were performed at the 5% level of significance.

RESULTS

Descriptive statistics comparing the tensile strength of the two groups are shown in Table 1. The Mann-Whitney *U*-test did not show any significant differences ($P = .599$) between the groups evaluated. Group 1 had mean shear bond strength of 6.26 ± 3.21 MPa, whereas Group 2 had a mean of 6.52 ± 2.73 MPa.

Table 2 presents the Weibull analysis of the test groups. Weibull analysis was undertaken to examine the probability of failure; the resulting curves are shown in Figure 1. The curves consist of the cumulative probability of bond failure plotted against applied load.

The ARI scores for the two groups tested are listed in Table 3. The results of chi-square comparisons for

TABLE 1. Results of Mann-Whitney *U*-test Comparing Tensile Bond Strengths (MPa) of Groups

Group Tested	n	Mean*	SD	Range
Phosphoric acid + Fuji Ortho LC	28	6.26	3.21	1.96–14.13
Fuji Ortho LC without etching	25	6.52	2.73	2.24–14.13

* $P = .599$.

TABLE 2. Weibull Parameters for Test Groups

Group	Weibull Modulus	Characteristic Bond Strength (MPa)	Shear Stress at 10% Probability of Failure (MPa)	Shear Stress at 90% Probability of Failure (MPa)
1	2.14	7.11	2.48	10.50
2	2.59	7.36	3.09	10.15

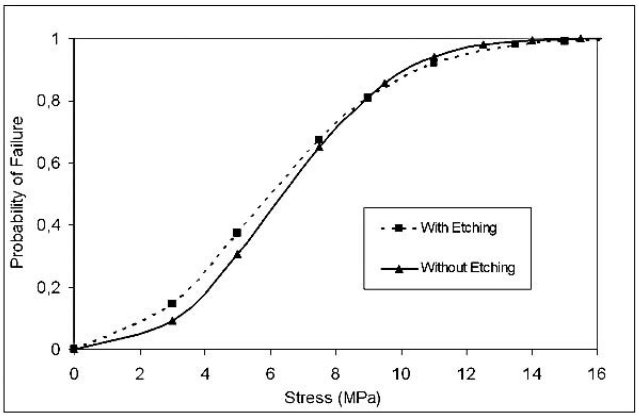

Figure 1. Weibull distribution plots for test groups.

TABLE 3. Frequency Distribution and Results of Chi-square Analysis of the ARI of Experimental Groups

Group Tested	n	ARI Score[a] 0	1	2	3
Phosphoric acid + Fuji Ortho LC	28	1	2	15	10
Fuji Ortho LC without etching	25	0	8	10	7

[a] ARI indicates adhesive remnant index. ARI scores: 0 = no adhesive remaining on tooth; 1 = less than half of enamel bonding site covered with adhesive; 2 = more than half of enamel bonding site covered with adhesive; 3 = enamel bonding site covered entirely with adhesive. $\chi^2 = 5.98$, $P = .113$.

the ARI indicated that there was no significant difference ($P = .113$) between the groups bonded with Fuji Ortho LC with or without etching. With the use of phosphoric acid, there was a higher frequency of ARI scores of 2 and 3, which indicated that more composite remained on the teeth.

DISCUSSION

The null hypothesis was accepted. The results of this study did not detect significant differences in tensile bond strength measurements when using a RRGIC (Fuji Ortho LC) with or without previous enamel etching. Because glass ionomer cements adhere to tooth surfaces by a chemical mechanism, it has been suggested that etching of enamel is not required to achieve a micromechanical bond. These results support the findings of Wiltshire[5] that pretreatment of enamel surfaces did not improve the bond strength of glass ionomers to enamel. However, this study is not in agreement with the results obtained by Flores et al,[4] Cacciafesta et al,[18] and Toledano et al[19] who found that enamel etching with phosphoric acid significantly improved the bond strength of glass ionomer cements.

Actually, there is no universally accepted minimum clinical bond strength. However, Reynolds suggested that a minimum tensile bond strength of 6–8 MPa was adequate to withstand normal orthodontic forces. In the present study, bracket failure occurred between 6.26 and 6.52 MPa. These results are in agreement with those of other studies that suggested that the bond strength of RRGICs may be adequate for clinical use in orthodontic bracket bonding.[4,18–22]

The evaluation of the ARI scores indicated no significant difference in bond-failure site between the two groups. The current findings showed that the groups bonded with or without enamel conditioning had a greater frequency of scores of 2 and 3. This fact can be advantageous for clinicians, because bond failure at the bracket-adhesive interface or within the adhesive is more desirable than at the adhesive-enamel interface, avoiding enamel fracture at time of debonding.[23,24]

Traditionally, in vitro data have been extrapolated to in vivo situations, although bond strength values might not be the best indicators of the performance of a bonding system. The Weibull analysis has been recommended for the study of bond strengths to give the clinician more information relative to the clinical performance of the product tested.[25,26] The Weibull analysis allows one to calculate the probability of bond failure under loads encountered in the oral environment. In Weibull plots, it can be seen that the two groups are very similar, although Group 2 is initially shifted to the right, indicating a lower probability of failure at low levels of stress.

Despite all advances, bond strength tests have shown wide variation.[27] When comparing debonding forces measured in vivo and in vitro, Pickett et al[28] found that bond strengths in vivo were significantly lower than those measured in vitro. This could possibly be because of the length of time that the appliance was in the oral environment, exposing the bonded brackets to acid, saliva, variable patient abuse, and masticatory forces, all of which may have contributed to the decreased bond strength.

The findings shown in the present study provide a more accurate account of in vivo bond strength when compared with other investigations that rely on in vitro results to assess bond strengths required for clinical success. This study design is considered to be of greater value in determining bond strength values following a determined period of time in the oral environment. In addition, more clinical bond failure investigations are needed to validate the performance of Fuji Ortho LC in vivo.

CONCLUSIONS

- Under the conditions of this investigation, the results suggest no difference in tensile bond strength of brackets bonded with Fuji Ortho LC with or without enamel etching.
- There were no significant differences in the amount of adhesive on enamel between the two groups evaluated.
- The present results indicated that Fuji Ortho LC is potentially adequate for orthodontic bonding needs.

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