Original Article

Shear Bond Strength of Resin-modified Glass Ionomer Cement with Saliva Present and Different Enamel Pretreatments

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Abstract: The purpose of this study was to evaluate the shear bond strength of resin-modified glass ionomer cement in a saliva-contaminated environment, using different enamel pretreatments. A total of 125 freshly extracted, bovine permanent inferior incisors were divided into five groups. Group I received 10% polyacrylic acid, moistened with saliva/Fuji Ortho LC (FOLC); group II received 37% phosphoric acid, moistened with saliva/FOLC; group III was moistened with saliva/FOLC, without acid etching; group IV received 10% polyacrylic acid, not moistened with saliva/FOLC; and group V was used as a control with 37% phosphoric acid/dry/Transbond XT. After the bonding procedures, all samples were thermocycled, tested in a shear mode on a testing machine, and the Adhesive Remnant Index was evaluated. One-way analysis of variance and Tukey's honestly significant difference (HSD) tests indicated that group V yielded the highest shear bond strength (4.09 MPa) but with no statistically significant difference from group II (3.88 MPa). There were no statistically significant differences between groups I, III, and IV (2.84, 2.90, and 3.22 MPa, respectively) ($P \geq .05$). In groups I, II, IV, and V, where enamel was etched, more than 50% of the samples showed that all material adhered to the teeth surfaces. This was opposed to group III, where the bond failure was mostly between the enamel interface and the bonding material. The results indicated that in a saliva-moistened environment, FOLC achieved higher shear bond strength when 37% phosphoric acid is used, with no statistically significant difference from Transbond XT. (*Angle Orthod* 2006;76:470–474.)

Key Words: Bond strength; Saliva; RMGIC

INTRODUCTION

Humidity contamination is a frequent cause for bonding failure when brackets are bonded with resin composites. For clinical success, these materials need a dry field and enamel conditioning.[1,2] Clinically, enamel contamination with saliva is difficult to control; therefore, less moisture-sensitive materials are always being sought.

For orthodontists, another concern is enamel demineralization that often develops around brackets[3–6] within a few weeks.[5] Although fluoride mouth rinses are efficient in reducing enamel demineralization,[3] the patient's cooperation is essential. Geiger et al[7] verified that only 13% of orthodontic patients fully complied with the fluoride rinse protocol. The ideal bonding material should release fluoride, thereby reducing these unfavorable iatrogenic effects of orthodontic therapy.[3]

The properties of glass ionomer cements (GICs) have enlarged their use in dentistry because of their physicochemical adhesion to enamel even in a wet field[2,8] without acid conditioning.[2] In addition, they can release fluoride ions over long periods into adjacent enamel and absorb fluoride from other sources, such as fluoride toothpastes and mouth rinses, thus acting as a rechargeable, slow-release fluoride device.[9] This reduces the incidence of decalcification and white-spot lesions around bonded orthodontic appliances.[2,6,10] Be-

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Accepted: March 2005. Submitted: February 2005.

TABLE 1. Groups Description According to Enamel Pretreatment

Group n[a] = 25	Enamel Pretreatment	Enamel Contamination	Bonding Material
I	10% Polyacrylic acid	Saliva	Fuji Ortho LC
II	37% Phosphoric acid	Saliva	Fuji Ortho LC
III	None	Saliva	Fuji Ortho LC
IV	10% Polyacrylic acid	None	Fuji Ortho LC
V	37% Phosphoric acid	None	Transbond XT (control)

[a] n indicates number of samples per group.

cause of this preventive property, Pascotto et al[6] encouraged the use of GICs for orthodontic bonding.

The use of GIC for orthodontic bonding is limited because of its low shear bond strength[11,12] and high bond failure rates.[13] Miguel et al[13] verified a bond failure rate of 50.89% for brackets bonded with GIC. The resin-modified glass ionomer cements (RMGICs) have 4 to 6% resinous component.[10] This combination results in a material that has GIC's properties with an improved bond strength and has been used successfully for orthodontic bonding.[10,14–17]

The development of light-cured RMGIC has allowed orthodontists to take advantage of the positive features of conventional glass ionomers, combining them with the mechanical and physical properties of composites. The manufacturer of Fuji Ortho LC (FOLC, GC Corporation, Tokyo, Japan), reports that RMGIC can be used in a moistened environment with no acid etching and obtain clinically acceptable bond strengths. This was verified by Silverman et al[2] in a clinical study. These features would save chair time and allow a safe debonding without enamel damage.[14]

However, besides the improvement achieved by the combination of resin composites, the resin-reinforced GICs still have a lower shear bond strength.[3,10,18,19] Gaworski et al[3] verified a failure rate of 24.8% for RMGIC. Some investigators have evaluated various methods to increase RMGIC bond strength, such as using different enamel conditioners and concentrations for different periods of time and increasing the light curing time.[20–22]

Therefore, the purpose of this in vitro study was to evaluate three different enamel pretreatments: (1) etching with 10% polyacrylic acid; (2) etching with 37% phosphoric acid; and (3) no acid etching on the shear bond strength of commercially available RMGIC in a saliva-contaminated environment.

MATERIALS AND METHODS

A total of 125 freshly extracted, bovine permanent inferior incisors that had been stored in a 0.1% thymol solution were freed of soft tissues, the pulp removed, and the root sectioned in the middle third. The teeth were stored in room-temperature distilled water.

The crowns of all samples were embedded in acrylic resin and the buccal surfaces wet ground until a 5 mm-diameter flat area was obtained. The roots were embedded in a plastic mold with acrylic resin. Each tooth was oriented so the bonding area would be parallel to the force applied during the shear strength test through an ''L'' acrylic appliance.

The samples were randomly divided into five groups (Table 1). The bonding area was cleaned with a mixture of distilled water and fluoride-free pumice powder, with a rubber polishing cup in a low-speed handpiece for 10 seconds, rinsed with distilled water for 15 seconds, and dried with oil-free compressed air (MS Compact) for 15 seconds.

Enamel pretreatment

In groups I and IV, the enamel surfaces were etched with 10% polyacrylic acid for 20 seconds; in groups II and V, the enamel surfaces were etched with 37% phosphoric acid for 20 seconds; and group III had no enamel etching. Groups I, II, IV, and V were rinsed for 20 seconds and dried for 30 seconds with oil-free compressed air.

Enamel contamination with saliva

The bonding area in groups I, II, and III was contaminated with freshly collected human saliva, with no stimulation from a voluntary female donor 5 hours after eating and brushing her teeth.

Bracket bonding

Stainless steel mandibular incisors brackets with an 0.022×0.030-inch slot and a base surface area of 12 mm^2 were bonded with the slot perpendicular to the horizontal plane, using an acrylic guiding device. This was done so that during the debonding test the ''wings deformity'' factor would be reduced. The bonding procedures followed the manufacturer's instructions except for the enamel pretreatments described previously. A force of 400 g was applied to each bracket using a dynamometer to standardize the film thickness. Any excess cement was removed with a sharp scaler.

The bonding material was light-cured on the mesial,

TABLE 2. Descriptive Statistics for the In Vitro Shear Bond Strength Test in MPa

Group	Mean	SD	Minimum	Maximum	Groups Differences[a]
I	2.84	0.45	2.02	3.98	A
II	3.88	0.54	2.91	5.04	B
III	2.90	0.57	1.68	4.09	A
IV	3.22	0.34	2.63	3.92	A
V	4.09	0.56	2.97	5.21	B

[a] Groups with the same letter have no statistically significant differences at $P \geq .05$.

distal, incisal, and gingival aspects for 10 seconds for a total of 40 seconds. The light curing unit (Optilux 500, Demetron Research, Danbury, Conn) was checked before each curing procedure to ensure a 540 ± 20 mW/cm^2 output of light. After the bonding procedures, the samples underwent 500 thermocycles of 30 seconds each in water baths between 5°C and 55°C.

A computer connected to the shear testing machine (DL 500, EMIC, Sao José dos Pinhais, PR, Brazil), recorded the results of each test at a crosshead speed of 0.5 mm/minute. After the bond failure, the teeth and brackets were examined under a 50× magnification using a stereomicroscope (BX 60M Olympus). The Adhesive Remnant Index (ARI) scores[23] were classified as: 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; and 3, all adhesive left on the tooth, with distinct impression of the bracket mesh.

RESULTS

The descriptive statistics for the shear bond strength for different enamel pretreatments are presented in Table 2. A one-way analysis of variance test comparing the five experimental groups revealed significant differences between the mean MPa values ($P \leq .05$). The Tukey's HSD method showed no statistically significant differences between mean bond strength values for groups I, III, and IV. On the other hand, the groups where enamel was pretreated with a 37% phosphoric acid (groups II and V) showed higher shear bond strength values, with no statistically significant difference between them.

The relative frequencies of ARI scores for the five experimental groups are shown in Figure 1. Kruskal-Wallis indicated that there were statistically significant ARI differences between group III and all other groups. Spearman's test verified that there was no correlation between shear bond strength and ARI ($P \leq .05$).

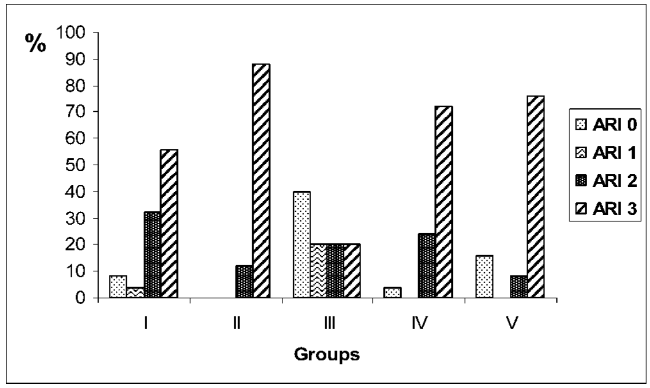

FIGURE 1. Adhesive Remnant Index score distribution.

DISCUSSION

Some previous studies have shown that humidity does not reduce the bond strength of FOLCs.[14,20,24,25] Others have reported that humidity even increases it.[8,26,27] Jobalia et al[8] reported that FOLC needs a moistened environment to achieve acceptable bond strength, but Chung et al[28] reported that this material needs dry enamel to obtain clinically acceptable bond strengths.

The results of this study indicated that the presence of saliva does not significantly decrease FOLC bond strength. Although group I was contaminated with saliva, it had a lower, but not statistically significant, shear bond strength (2.86 MPa) than group IV (3.22 MPa), which was not contaminated. The saliva did not influence FOLC's bond strength, as verified in previous studies.[14,20,24,25]

One of these studies that had also verified that saliva does not influence FOLC's bond strength was carried out by Itoh et al,[24] who compared the effects of saliva and water contamination on FOLC's bond strength. The authors observed that saliva had a less deleterious effect on bond strength than water, despite the fact that they were expecting the opposite. According to Mojon et al,[29] this happens because some components from natural or artificial saliva protect the cement cure reaction and compensate for the deleterious effects of the water contained in saliva.

It has been reported that it is necessary to condition the moistened enamel before the bonding procedure with FOLC, but some studies have verified that this material achieves clinically acceptable bond strength with no previous acid conditioning.[8,14,25,27,30] Silverman et al[2] reported a success rate of 96.8% for FOLC in a saliva-moistened environment with no acid etching. On the other hand, Bishara et al[20] concluded that when the enamel was unetched, the shear bond strength of FOLC is reduced by half, and this bond strength might not be enough for clinical use.

This study verified that in the presence of saliva, enamel conditioning with 10% polyacrylic acid did not increase FOLC's shear bond strength. Newman et al[31] also did not verify statistically significant differences between groups bonded with FOLC in a dry field, with or without enamel conditioning with 10% polyacrylic acid.

The reports in the literature are very conflicting regarding the use of FOLC for orthodontic bonding in enamel moistened with saliva and etched with 10% polyacrylic acid. Jobalia et al,[8] as in this study, found no statistically significant difference between the mean bond strength for groups contaminated with saliva either with or without previous enamel acid etching. The values, however, were inferior to the control group. Opposite results were obtained by Lippitz et al,[32] Kirovski and Madzarova,[27] and Coups-Smith et al,[33] who observed an increase in FOLC's shear bond strength when the brackets were bonded to moistened enamel with previous 10% polyacrylic acid conditioning.

Meehan et al,[18] in agreement with the findings of this study, obtained lower bond strengths for FOLC in groups with no enamel conditioning with 10% polyacrylic acid when compared with a control group (Transbond XT). On the other hand, Flores et al[34] claimed that enamel conditioning with 37% phosphoric acid was a critical factor in obtaining adequate adhesion when FOLC is used. This direct relationship between 37% phosphoric acid conditioning and increase in the shear bond strength was also observed in this study.

Cacciafesta et al,[35] in agreement with this study, observed a higher increase in FOLC's bond strength after using 37% phosphoric acid than with 10% polyacrylic acid. According to Bishara et al,[22] this happens because 37% phosphoric acid produces a qualitatively rougher enamel surface, thus facilitating the penetration of the FOLC resin.

Although Valente et al[36] reported that under wet conditions an acceptable bond strength with FOLC is achieved when there is a previous enamel etching, regardless of the acid used or concentration, Flores et al[34] and Graf and Jacobi,[30] in agreement with this study, verified that the maximum bond strength was achieved when the enamel was pretreated with 37% phosphoric acid. According to Bishara et al,[37] when the acid concentration is increased, the bond strength is also increased.

Opposing the majority of the results in the recent literature, Owens and Miller[19] verified that in dry enamel conditioned with 37% phosphoric acid, FOLC yielded significantly lower bond strength values when compared with Transbond XT. According to the authors, if bond strength is the primary consideration for choosing a bonding material, a resin composite should be used.

The ARI scores evaluation showed that with acid pretreatment, all groups, regardless of the bonding material used, had an ARI score of 3 in more than 50% of the samples. In group III, where no acid pretreatment was used, the bond failure was mostly at the enamel and bonding material interface. These findings show that the ARI is directly related to the acid etching and not to the saliva contamination or bonding material used. This is in agreement with the affirmation of Bishara et al[20] that etching is a critical variable that affects shear bond strength, as well as bond failure location, when FOLC is used.

This study did not attempt to reproduce human oral conditions or to evaluate whether FOLC shows acceptable bond strength for clinical use, as verified by other in vivo studies.[2,10,17,26] Instead, it was designed to develop an in vitro study, where the environment allows a control of the variables, to quantify and compare FOLC bond strength in enamel contaminated with saliva under different enamel pretreatments. The control bond strength was determined by Transbond XT (3M Unitek, Monrovia, Calif.), a composite resin traditionally used as a control group in orthodontic bonding studies.

Comparisons between absolute results from bonding studies are almost impossible because different methodologies are used. To obtain a better understanding, and as a means of facilitating comparisons between studies, it is suggested that the methodology used in the orthodontic field needs to be standard where bond strength tests are concerned.

CONCLUSIONS

This in vitro study indicated that in enamel contaminated with saliva:

- Enamel pretreatment with 37% phosphoric acid increased FOLC bond strength values, with no statistically significant differences from those obtained with the resin composite Transbond XT, used as a control.
- Etching the enamel surface with 10% polyacrylic acid, or not etching it, yielded the lowest shear bond strength values, with no difference between them.

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