Original Article

Shear Bond Strength of a New High Fluoride Release Glass Ionomer Adhesive

Samir E. Bishara[a]; Manal Soliman[b]; John F. Laffoon[c]; John Warren[d]

ABSTRACT

Objective: To determine the shear bond strength of a new resin glass ionomer adhesive with higher fluoride release properties when bonding orthodontic brackets.

Materials and Methods: Sixty freshly extracted human molars were collected and stored in a solution of 0.1% (weight/volume) thymol. The teeth were cleaned and polished. The teeth were randomly separated into three groups according to the enamel conditioner/etchant and adhesive used. Group I: 20 teeth conditioned with 10% polyacrylic acid and brackets bonded with the new glass ionomer adhesive. Group II: 20 teeth conditioned with 37% phosphoric acid and brackets bonded with the new glass ionomer adhesive. Group III (control): 20 teeth etched with 37% phosphoric acid and brackets bonded with a composite adhesive.

Results: The results of the analysis of variance comparing the three experimental groups ($F = 10.294$) indicated the presence of significant differences between the three groups ($P = .0001$). The shear bond strengths were significantly lower in the two groups bonded with the new glass ionomer adhesive whether conditioned with polyacrylic acid ($\bar{x} = 3.2 \pm 1.8$ MPa) or phosphoric acid ($\bar{x} = 2.3 \pm 1.1$ MPa), while the mean shear bond strength of the composite adhesive was 5.2 ± 2.9 MPa.

Conclusions: Although the increased fluoride release from the new glass ionomer has the potential of decreasing decalcification around orthodontic brackets, the shear bond strength of the material is relatively low.

KEY WORDS: Glass ionomer; Fluoride; Shear bond strength

INTRODUCTION

Since Buonocore[1] introduced the acid etch bonding technique in 1955, the concept of bonding various resins to enamel has developed applications in all fields of dentistry including the bonding of orthodontic brackets.[2,3] This approach has several advantages such as enhanced ability for plaque removal by the patient, minimization of soft-tissue irritation, elimination of the need for separation, absence of posttreatment band spaces, facilitation of application of attachments to partially erupted teeth, minimization of the danger of decalcification with loose bands, easier detection and treatment of caries, and a much more esthetic appearance for the patient.[4] In spite of all these advantages, the problem of enamel decalcification around orthodontic brackets is a serious problem that clinicians are still facing, particularly in patients with less than optimal oral hygiene.

The surface layer of enamel which is lost during etching with phosphoric acid was estimated to vary between 10 and 30 μm,[5] while the depth of penetration of the resin tags reached up to 50 μm.[6] The clean-up procedure of the adhesive following debonding may remove up to 55.6 μm of surface enamel.[7] As a result of this potential for significant enamel loss, various investigators considered alternative treatments of the enamel surface in preparation for the bonding procedure including the use of maleic acid[8,9] and polyacrylic acid,[10] together with the use of glass ionomer adhesives that are also able to release fluorides.[11–18]

[a] Professor of Orthodontics, College of Dentistry, University of Iowa, Iowa City, Iowa.

[b] Instructor, Department of Conservative Dentistry, Menia University, Menia, Egypt.

[c] Research Assistant, College of Dentistry, University of Iowa, Iowa City, Iowa.

[d] Associate Professor, Department of Preventive and Community Dentistry, College of Dentistry, University of Iowa, Iowa City, Iowa.

Corresponding author: Dr Samir E. Bishara, Orthodontics, University of Iowa, Iowa City, S219 DSB, Iowa City, Iowa 52242 (e-mail: Samir-bishara@uiowa.edu)

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In general, glass ionomer products are divided into three different categories: luting cements, restorative materials, and liners. Liner glass ionomer materials are differentiated from other glass ionomer cements by their extremely small particle size (about 5 μm or less). Because of the favorable characteristics of glass ionomer liners,[11–14] particularly the long-term release of fluorides,[12,13] attempts were made to improve their physical properties to make them more useful in areas where strength is of primary importance.

From an orthodontic perspective one of the disadvantages of glass ionomer products is their relatively low shear strength.[15] As a result, glass ionomer hybrids were introduced that combine the properties of composites and glass ionomers.[16] The use of a 10% polyacrylic acid solution is recommended for use with these adhesive systems to minimize enamel loss. This combination of using polyacrylic acid as an enamel conditioner together with the glass ionomer adhesives provided the advantages of minimal loss of the enamel surface and the availability of fluoride ions around the brackets during orthodontic treatment.[16]

Continued attempts have been made to improve the initial bond strength of the glass ionomers while enhancing its fluoride-releasing characteristics.[16–18] A new glass ionomer bonding agent that is suggested to have an exceptional fluoride release ability was recently introduced and can be used as sealant, surface protection, and restorative material.[19] Such a bonding material, if it also has adequate shear bond strength, will have the important advantage of providing added protection around orthodontic brackets.

The purpose of this study was to evaluate the shear bond strength of orthodontic brackets bonded with a new glass ionomer adhesive with significant fluoride release properties.

MATERIALS AND METHODS

Teeth

Sixty freshly extracted human molars were collected and stored in a solution of 0.1% (weight/volume) thymol. The criteria for tooth selection included intact buccal enamel, not subjected to any pretreatment chemical agents, eg, hydrogen peroxide, with no cracks due to the pressure of the extraction forceps, and no caries. The teeth were cleaned and then polished with nonfluoridated pumice and rubber prophylactic cups for 10 seconds.

The teeth were embedded in acrylic placed in phenolic rings (Buchler Ltd, Lake Bluff, Ill). A mounting jig was used to align the facial surface of the tooth to be perpendicular with the bottom of the mold, ie, each tooth was oriented so its labial surface would be parallel to the force during the shear strength test.

Adhesive

Two orthodontic adhesive systems were used:

- GC Fuji Triage (GC America Inc, Alsip, Ill) which is a light-cured glass ionomer adhesive that chemically bonds to tooth structures. Triage is a new radiopaque glass ionomer and is suggested to have exceptional fluoride release properties and is used to seal noncavitated lesions as well as pits and fissures.[19] The continuous fluoride release from glass ionomers over the course of orthodontic treatment is thought to help protect teeth from decalcification and prevent caries.[18,19] According to the manufacturer, Triage is moisture-friendly and also provides a strong lasting bond to the tooth structure.[19]
- Transbond XT bonding system (3M Unitek, Monrovia, Calif) is a composite adhesive that contains Bis GMA, Bis EMA, and quartz/silica fillers.

Brackets

Maxillary central incisor brackets were used to bond all teeth (Victory Series, 3M Unitek). The average surface area of the bracket base was determined to be 11.7 mm^2.

Groups Tested

The teeth were randomly divided according to the enamel conditioner/etchant and adhesive used.

Group I: In 20 teeth, the enamel was conditioned with a 10% polyacrylic acid for 20 seconds and washed for 20 seconds. Excess water was blotted away with a moist cotton roll. The teeth were bonded with the Triage glass ionomer following the manufacturer's instructions. The GC Triage capsule was triturated for 10 seconds. The bracket with the adhesive was placed on the tooth and light cured for 40 seconds, 10 seconds at a time from the mesial, distal, occlusal, and gingival.

Group II: In 20 teeth, the enamel was conditioned with a 37% phosphoric acid gel for 15 seconds. The teeth were washed, dried, and then bonded with Triage as in Group I.

Group III (Control): In 20 teeth, the enamel was etched with a 37% phosphoric acid gel for 15 seconds followed by thorough washing and drying. The sealant was placed on the tooth and the brackets were bonded with the Transbond XT adhesive and light cured for 20 seconds.

In all groups, before light curing the adhesive, the brackets were pressed on the tooth with 300 g of force using a force gauge (Correx Co, Bern, Switzerland), and excess adhesive was removed with a sharp scaler.

Debonding Procedure

A steel rod with one flattened end was attached to the crosshead of a Zwick test machine (Zwick GmbH & Co, Ulm, Germany). An occlusogingival load was applied to the bracket, producing a shear force at the bracket-tooth interface. A computer electronically connected with the Zwick test machine recorded the results of each test. Shear bond strengths were measured at a crosshead speed of 5 mm/minute. Bracket removal was performed within a half hour from the time the teeth were bonded to simulate the time at which the initial archwires are ligated.

Evaluation of the Residual Adhesive

After bond failure, the teeth and brackets were examined under 10× magnification. Any adhesive remaining after bracket removal was assessed using a modified adhesive remnant index (ARI) and scored with respect to the amount of resin material adhering to the enamel surface.[20] The modified ARI scale has a range between 5 and 1, with 5 indicating that no adhesive remained on the enamel; 4, less than 10% of adhesive remained on the surface; 3, more than 10% but less than 90% of the adhesive remained; 2, more than 90% of the adhesive remained; and 1, all of the adhesive remained on the tooth, along with the impression of the bracket base. The ARI scores were also used as a more complex means of defining the site of bond failure between the enamel, the adhesive, and the bracket base.

Statistical Analyses

Descriptive statistics including the mean, standard deviation, and minimum and maximum values were calculated for each of the three groups tested. The analysis of variance was used to determine whether significant differences existed between the various groups. If a significant difference was present, a Duncan's multiple range test was used to identify which groups were different. The chi-square test was used to determine significant differences in the ARI scores between the different groups. For the purpose of the statistical analysis, ARI scores 1 and 2 were combined, as were ARI scores 4 and 5. Significance for all statistical tests was predetermined at $P \leq .05$.

RESULTS

Shear Bond Strength

The descriptive statistics for the shear bond strength are presented in Table 1. The results of the analysis of variance comparing the three experimental groups (F = 10.294) indicated the presence of significant differences between the groups ($P = .0001$). The mean shear bond strength for the composite Transbond XT group was significantly larger 5.2 ± 2.9 MPa than for the two glass ionomer groups. The mean shear bond strength of the glass ionomer adhesive conditioned with 10% polyacrylic acid was 3.2 ± 1.8 MPa and that for the group etched with a 37% phosphoric acid was 2.3 ± 1.1 MPa.

Table 1. Descriptive Statistics[a] (in MPa) and the Results of the Analysis of Variance Comparing the Shear Bond Strengths of the Three Groups Tested

Groups Tested*	Mean	SD	Range	Duncan Test**
I. Transbond XT	5.2	2.9	1.1–10.4	A
Triage with:				
II. Polyacrylic acid	3.2	1.8	1.2–7.1	B
III. Phosphoric acid	2.3	1.1	0.9–5.1	B

[a] F ratio = 10.294; $P = .0001$.

* Group I: Composite etched with 37% phosphoric acid; Group II: Triage Glass ionomer conditioned with 10% polyacrylic acid. Group III: Triage Glass ionomer etched with 37% phosphoric acid.

** Groups with different letters were significantly different from each other.

Table 2. Frequency Distribution of the Adhesive Residual Index (ARI) Scores of the Three Groups Tested[a]

Groups Tested*	ARI Scores*					N
	1	2	3	4	5	
I. Transbond XT	—	14	4	2	—	20
Triage with:						
II. Polyacrylic acid etch	—	12	5	3	—	20
III. Phosphoric acid etch	—	9	7	4	—	20

[a] $X^2 = 2.63$; $P = .662$; Sample size in each group = 20.

* Group I: Composite etched with 37% phosphoric acid; Group II: Triage Glass ionomer conditioned with 10% polyacrylic acid. Group III: Triage Glass ionomer etched with 37% phosphoric acid. The ARI Score has a range between 5 and 1, with 5 indicating that no adhesive remained on the enamel; 4, less than 10% of adhesive remained on the tooth surface; 3, more than 10% but less than 90% of the adhesive remained on the tooth; 2, more than 90% of the adhesive remained; and 1, all of the adhesive remained on the tooth, along with the impression of the bracket base.

Adhesive Residual Index (ARI)

The ARI scores for the three groups tested are presented in Table 2. The χ^2 test results ($\chi^2 = 2.63$) indicated that there were no significant differences between the three groups ($P = .662$) regarding the site of bond failure.

DISCUSSION

Clinicians are interested in learning about the properties of the adhesive systems they use in order to optimize their ability to handle them properly and efficiently as well as provide patients with better treatment. The ability of some of these adhesives to release significant amounts of fluoride ions provides an added advantage to the bonding system by minimizing decalcification around orthodontic brackets. A new glass ionomer protective sealant/adhesive with exceptional fluoride release properties has been recently introduced.[19] The use of such a material can potentially provide a significant advantage, particularly in orthodontic patients with less than optimal oral hygiene.

The present findings indicated that the shear bond strength of the brackets bonded with the new high fluoride release glass ionomer adhesive was significantly lower than that for the group bonded with the composite adhesive. The use of 37% phosphoric acid etch did not improve the shear bond strength of the glass ionomer adhesive.

The evaluation of the ARI scores indicated that there was no significant difference in the frequency of bond failure between the various groups tested and was mostly a cohesive failure.

Although the increased fluoride release from the new glass ionomer adhesive has the potential of decreasing decalcification around orthodontic brackets, the shear bond strength of the material needs to significantly increase to allow for the reliable bonding of orthodontic brackets.

CONCLUSIONS

- When compared with a composite adhesive, the shear bond strength of the new glass ionomer adhesive was significantly lower in the initial half hour after bonding. This was true whether the enamel was conditioned with a 10% polyacrylic acid or was etched with a 37% phosphoric acid.
- The clinician needs to take into consideration all the characteristics of each adhesive system, including working properties, bond strength, and fluoride release.

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