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Tensile bond strength of a light-cured glass ionomer cement when used for bracket bonding under different conditions: an *in vitro* study

I. Kirovski and S. Madzarova
Center of Military Health Institutions, Skopje, Former Yugoslav Republic of Macedonia

SUMMARY The purpose of this study was to investigate the tensile bond strength of a new light-cured resin reinforced glass ionomer cement (Fuji Ortho LC), following the bonding of stainless steel brackets to 40 extracted human premolar teeth under four different enamel surface conditions: (1) non-etched, moistened with water; (2) etched, moistened with water; (3) etched, moistened with human saliva; and (4) etched, moistened with human plasma.

The etched surface produced a higher bond strength than the non-etched surface when contaminated with distilled water. Contamination with human saliva resulted in a further increase in bond strength whilst plasma contamination produced an even higher strength. However, one-way analysis of variance showed no statistically significant difference between the various groups. After debonding, enamel and bracket base surfaces were examined for residual adhesive. The location of the adhesive also indicated improved bonding to etched enamel. This investigation shows that regardless of enamel surface pre-treatment or environment, Fuji Ortho LC provides an adequate strength for bonding of orthodontic brackets.

Introduction

Bonding of orthodontic brackets is one of the most sensitive chairside orthodontic procedures, therefore, the properties of the bonding material are of great importance. Composite resin adhesives are still most commonly used for bracket bonding, however, they have some disadvantages; a perfect dry field of operation is needed throughout.

Glass ionomer cements (GICs) might be an appropriate alternative. First described by Wilson and Kent in 1972, GICs have been extensively used for cementation of orthodontic bands, and then for direct bonding of orthodontic brackets (White, 1986). The potential advantages of GICs are adhesion in a wet field, a non-etching technique, and quicker chairside procedure. In addition, GICs are fluoride releasing and rechargeable, absorbing fluoride from fluoridated toothpaste (Cook, 1990; Silverman *et al*., 1995; Hatibovic-Kofman and Koch, 1991). The biggest disadvantage of GICs is their weak bond strength, well documented in several *in vivo* (White, 1986; Cook, 1990) and *in vitro* studies (Fajen *et al*., 1990; Wiltshire, 1994; Örtendahl and Thilander, 1998).

Light-cured (LC) GICs were introduced in an attempt to retain the positive characteristics of GICs, but also to improve bond strength. Several authors have investigated the bonding properties of LCGICs and compared them with light- and chemically-cured composite resins, or chemically-cured GICs. However, there is disagreement in their recommendations.

McCourt *et al*. (1991) considered Vitrabond, a LCGIC, to have a significantly weaker bond strength than light-cured composite bonding. Øen *et al*. (1991) compared Vitrabond with a composite resin (Concise) and with chemically-cured GICs (Aqua Cem and Ketac-Fil). They found that Vitrabond showed no advantage in bond strength. Compton *et al*. (1992) compared Cionomer (LCGIC) with a chemically-cured

GIC and found the bond strength of the LCGIC to be higher.

Lippitz *et al*. (1998) found similar bond strengths for LCGICs to those of composite resins. Cook *et al*. (1996) did not support the use of materials other than composite resins for bonding of orthodontic brackets.

Silverman *et al*. (1995) compared four different chemically-cured GICs and Fuji Ortho LC (LCGIC), and found the LCGIC to be much stronger, with a long-term success rate of 96.8 per cent, and recommended Fuji Ortho LC as the material of choice. Jobalia *et al*. (1997) investigated Fuji Ortho LC and compared it with a conventional resin one-step (Rely-a-Bond) and a conventional resin two-step (Phase II) self-cured orthodontic adhesive. They found that the difference in bond strength was not significant. Cacciafesta *et al*. (1998) considered Fuji Ortho LC to have the highest bond strength compared with other three LCGICs and with Concise, when bonding to a mechanically retentive base. The same study ranked Concise the highest when boding to a chemically retentive base.

However, opinions have been expressed (Kusy, 1994) that the aim should be for a satisfactory, rather then the maximum bond strength.

The purpose of this study was to investigate the adhesive properties of a light-cured resin-reinforced glass ionomer cement Fuji Ortho LC (GC Corp., Tokyo, Japan). The objectives were: (1) to investigate whether enamel etching prior to bracket bonding influences the bond strength of Fuji Ortho LC; and (2) to determine the bond strength of this cement when curing is performed under three different environmental conditions.

Materials and Methods

Sound premolar teeth (n = 40) extracted for orthodontic purposes were collected and stored in distilled water. The buccal surface of each tooth was polished using a pumice and a polish paste (Clean Polish, Hawe Neos Dental, Switzerland), then rinsed thoroughly with water. A stainless steel edgewise standard bracket for premolars with a mesh base (Ultratrimm, Dentaurum, Pforzheim, Germany) was cemented on each tooth using Fuji Ortho LC (lot no. 060961) as a bonding agent in all cases, but under four different surface conditions. The teeth were divided into four groups and the bonding procedure was performed as below.

Group 1 (unetched enamel, bonding in the presence of distilled water)

1. No etching as a pre-treatment.
2. The cement was mixed as suggested by the manufacturer.
3. Water was applied with a brush.
4. The bracket was placed on the tooth (base coated with adhesive) and pressed firmly.
5. The tooth was immersed in water, with the buccal surface approximately 1 mm under the water surface and light-cured (Heliomat, Vivadent, Shaan, Liechtenstein) for 20 seconds on each aspect: occlusally, mesially, distally, and gingivally.
6. The tooth was stored in water for 48 hours.

Group 2 (etched enamel, bonding in the presence of distilled water)

1. Enamel surface etched with 10 per cent polyacrylic acid for 20 seconds.
2. Bracket bonding performed as described for Group 1.

Group 3 (etched enamel, bonding in the presence of human saliva)

1. Enamel surface etched with 10 per cent polyacrylic acid for 20 seconds.
2. Enamel surface was then contaminated with human saliva (saliva provided from a human donor and tested for safety from infective diseases at the Department of Microbiology, Center of Military Health Institutions).
3. Bracket bonding performed as described for previous groups, but teeth were immersed in human saliva and stored in this medium for 48 hours.

Group 4 (etched enamel, bonding in the presence of human plasma)

1. Etched enamel as previously.

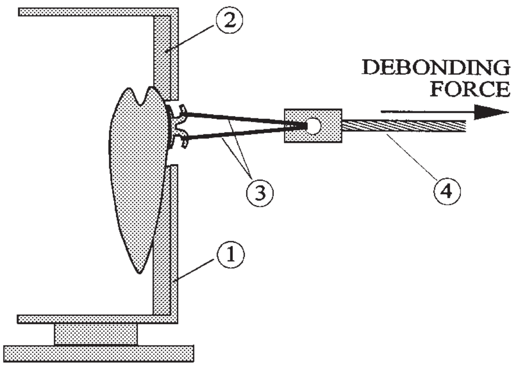

Figure 1 The testing unit: 1, metal housing; 2, rubber sheet; 3, ligature; 4, steel rope.

2. Human plasma used for enamel surface contamination (processed blood provided from the same human donor and tested for safety from infectious diseases at the Department of Blood Transfusion).
3. Bracket bonding and storage performed as previously, but with the use of human plasma.

All brackets were bonded by the same operator.

The bond strength was tested in tensile mode in a specifically designed testing unit (Figure 1). The tooth was stabilized in a metal housing and the force was applied perpendicular to the longitudinal axis of the tooth through hooks on the bracket wings. The force was increased at a rate of 16 Newtons per second, and the value recorded at the moment the bracket disengaged. The value was converted, arithmetically, to megapascals (MPa).

After debonding, the enamel surfaces and bracket bases were examined for the site of fracture and the location of the remaining adhesive.

Results

Statistical analysis was performed using SPSS computer program (SPSS Inc., USA). The values of the measured forces to debond are presented in Table 1 as mean and standard deviations.

The difference between the groups was tested using Kruskal–Wallis one-way analysis of variance (Table 2). The results of the analysis of variance showed that there were no significant differences between the investigated groups. However, some differences existed. Group 4 had the greatest mean value of the measured debond forces, followed by Groups 3, 2, and 1, respectively.

After inspection of the enamel and bracket base surfaces, a classification as previously suggested by Jobalia *et al*. (1997) was carried out (Table 3). In four cases from Group 1 where the enamel surface had not been etched, no adhesive remained on the teeth. Enamel surfaces of the teeth from the other three tested groups were all etched and in the majority of these cases there was no adhesive left on the brackets.

Discussion

The results of this study show that enamel etching increases the bond strength of Fuji Ortho LC (Groups 1 and 2, Table 1), although not significantly. This is in agreement with the findings of Bishara *et al*. (1998), who tested Fuji Ortho LC under different enamel and environmental conditions. They also found that the differences were not statistically significant among the groups when enamel etching was performed, but all such groups had significantly higher bond strength compared with non-etched enamel groups. In the study of Lippitz *et al*. (1998), Fuji Ortho LC was found to exhibit significantly

Table 1 Tensile bond strength (MPa) of Fuji Ortho LC under different environmental conditions.

	Group 1 non-etched, distilled water	Group 2 etched, distilled water	Group 3 etched, human saliva	Group 4 etched, human plasma
Sample size	10	10	10	10
Mean	9.97	10.30	11.35	13.58
SD	3.20	3.40	4.12	6.19

Table 2 Tensile bond strength calculated using Kruskal–Wallis ANOVA.

Group	Sample size	Median	Average rank
1	10	9.29	4.58
2	10	9.22	4.87
3	10	10.46	5.90
4	10	11.72	8.86

d.f. = 4; $P < 0.05$.

Table 3 Location of the adhesive layer after debonding.

Condition	0	1	2	3	4
Non-etched, distilled water	4	3	2	1	0
Etched, distilled water	0	1	1	8	0
Etched, human saliva	0	2	2	6	0
Etched, human plasma	0	1	3	6	0

Condition: 0 = no adhesive on tooth; 1 = most adhesive on bracket; 2 = most adhesive on tooth; 3 = no adhesive on bracket; 4 = enamel or dentine tear-out.

lower bond strength when bonded to unetched water-moistened enamel, compared with two other resin-reinforced GICs.

The data in Table 3 confirms the stronger adhesion properties at the enamel–cement interface following etching. When this data is compared with the results of the investigated sites of fracture of different composite resins, which are mostly at the adhesive-bracket interface (Cook and Youngson, 1988; Cook *et al*., 1996; Jobalia *et al*., 1997), it could be hypothesized that etching of the tooth prior to bonding releases the stresses of the composite-based properties of Fuji Ortho LC.

The mean values of the debond forces from Table 1 show that Group 4 presented the highest bond strength, followed by Groups 3, 2, and 1, respectively.

It has been shown by Jobalia *et al*. (1997) that moisture is required for optimal adherence of GIC to the tooth surface. Cacciafesta *et al*. (1998) suggested that 2-hydroxyethylmeth-acrylate in the resin component of Fuji Ortho LC is responsible for higher bond strengths under wet conditions compared with the dry tooth surface. However, the higher strengths found during saliva- and plasma-contaminated bonding require further explanation. However, it is of clinical importance that under *in vitro* conditions, human saliva and plasma do not lower the bond strength of a LCGIC.

Conclusions

Etching of the surface of enamel produced higher bond strength (10.3 ± 3.4 MPa) when compared with non-etched surfaces (9.97 ± 3.20 MPa). In addition, contamination with saliva also increased the bond strength (11.35 ± 4.12 MPa), as did plasma contamination of enamel surfaces. Residual tags of adhesive following debond also implied improved adhesion; greater tags remained adherent to the surface when the bond strength was greatest. Fuji Ortho LC provides adequate bond strength for bonding orthodontic brackets to enamel.

Address for correspondence

Dr I. Kirovski
Dental Departments—Department of Orthodontics
Center of Military Health Institutions
Military Hospital—Skopje
Ilindenska bb
91000 Skopje
Former Yugoslav Republic of Macedonia

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