

Effect of Time on the Flexural Strength of Glass Ionomer and Composite Orthodontic Adhesives

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Abstract: The purpose of this study was to compare the effects of time on the flexural strength of a resin-reinforced glass ionomer and a composite adhesive system, specifically at three time frames corresponding to the three stages of polymerization of Fuji Ortho LC. Ten rectangular specimens of each material were prepared in a metal mold (25 × 2 × 2 mm) and then stored at 37°C and 100% humidity in an incubator. Six test groups were created, in which each specimen was fractured using a 3-point-bending test at a crosshead speed of 0.5 mm/min. The test results indicated that there were significant differences among the groups ($P = .0001$). The flexural strengths were significantly higher in the two groups (III and VI) that were fractured after seven days. This was true for both the Fuji Ortho LC ($\bar{x} = 77 \pm 6.1$ MPa) and the Concise ($\bar{x} = 103.9 \pm 4.2$ MPa). The flexural strength of the resin-modified glass ionomer adhesive was significantly lower than that for the composite whatever the time of fracture, 10 minutes, one hour, or seven days. The analysis of the strength-deformation curve of the group of Fuji Ortho LC, which was fractured within 10 minutes after setting (group I), showed viscoplastic behavior, whereas that of all the others groups showed elastic behavior. According to this study, clinicians must consider the mechanics of Fuji Ortho LC setting and, when this material is used, wait for at least one hour to ligate initial or repaired arch wires. (*Angle Orthod* 2004;75:114–118.)

Key Words: Resin-reinforced glass ionomer cements; Flexural strength; Orthodontic bracket adhesive

INTRODUCTION

Interest in using resin-reinforced glass ionomer cements as orthodontic bracket adhesives has grown because of their potential for fluoride release and absorption.^{1,2} This helps to minimize the incidence of caries and decalcification around orthodontic appliances and the prevalence of plaque accumulation observed with composite resin.^{3–5}

Resin-modified glass ionomer cements are a combination of glass ionomer cements, first introduced for use in clinical restorative dentistry 20 years ago, and composite resin.⁶ The resulting resin-modified glass ionomer cements exhibit many of the advantages of both resin cements and glass ionomer cements and are defined as materials that undergo both polymerization reactions and acid-base reactions.^{7,8}

Silverman et al⁹ found that resin-reinforced glass ionom-

er cement (1) eliminates the need for working in a dry field, (2) eliminates the need for etching and priming enamel surfaces, and (3) makes bracket repairs quick and easy and that the use of Fuji Ortho LC increased patient and operator comfort.

On the other hand, results of the shear bond strength test, which was most often used to characterize and compare the various orthodontic adhesive systems, showed that it was not as strong as the composite resins,^{10–12} yet it was still found to be above the minimal bond forces required for orthodontic purposes as suggested by Reynolds.¹³ Several authors, such as Bishara et al,¹⁴ think that the orthodontist and the patient are better served by using a phosphoric acid/composite resin adhesive system.

A knowledge of the mechanical properties of a material, with regard to its chemical setting, can help in understanding its behavior and, therefore, in determining its clinical uses.¹⁵ For example, Lippitz et al¹⁶ did not expect and could not explain the difference in shear bond strength at 24 hours and 30 days for the Fuji Ortho LC in a group of brackets bonded to the non-acid-etched enamel surface. This article suggests that the material did not achieve its full bond strength until after 24 hours.

The purpose of this study was to determine the effects of time on the flexural strength of a resin-modified glass ionomer adhesive compared with a composite adhesive sys-

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TABLE 1. Reactions That Take Place in Resin-Modified Glass Ionomer Cements

Reacting Components	Reaction Type
Polyacid + fluoroaluminosilicate glass particles	Acid-base
Monomer + photoinitiator + light	Polymerization (light initiated)
Monomer + initiator + catalyst	Polymerization (chemically initiated)

tem, specifically, within 10 minutes after setting, corresponding to the mechanical properties related to the photopolymerization of the Fuji Ortho LC, at the time the initial or repaired arch wires are ligated; within one hour after setting, when the acid-base reaction completes the polymerization of the Fuji Ortho LC; and at least seven days from the time of setting, when the adhesive has achieved most of its bond strength.

MATERIALS AND METHODS

Adhesives used

Two orthodontic adhesive systems were used.

The first, the Fuji Ortho LC bonding system (GC Corp., Tokyo, Japan, batch No. 290391), is a light-cured resin-reinforced glass ionomer adhesive based on the widely accepted technology of the hybrid glass ionomer restorative materials. The main component of Fuji Ortho LC powder is a finely ground fluoroaluminosilicate glass, whereas the liquid contains polyacrylic acid, water, monomer, and an activator. Mixing the components of the material initiates the conventional glass ionomer acid-base setting reaction. Exposure to visible light initiates polymerization of both the water-soluble resin monomers and the methacrylate groups attached to the glass ionomer acid chains. The resin component is actually a mixture of three monomers, with 2-hydroxyethyl-methacrylate (HEMA) being the major constituent.¹⁵⁻¹⁷

In summary, the setting of resin-modified glass ionomers involves the polymerization of the HEMA monomer by light activation and the classic acid-base reaction between a polyacid and the basic glass particles. However, in many cases the monomer will polymerize even without light because the manufacturer has added a catalyst to the composition. The acid-base reaction proceeds within the polymer network that has been formed by the light curing, and the two reactions ultimately result in the formation of two interpenetrating matrices. The third reaction is a self-curing of the resin monomers. Table 1 provides an overview of the three reactions that can occur in resin-modified glass ionomer cements.

The second, Concise (3M Dental Products Division, St. Paul, Minn, USA, batch No. 19990716), is a chemically cured composite. The main component of Concise is a Bis-GMA and poly-HEMA matrix reinforced with silica and quartz fillers. This composite adhesive system was used as the control.

Specimen preparation

Flexural strength was determined according to EN 24049:1993. Ten rectangular specimens of each material were made by inserting the material into a metal mold (25 × 2 × 2 mm) and then covering the surfaces with mylar matrix to prevent air-inhibited layers. Specimens of Fuji Ortho LC were polymerized according to the manufacturer's instructions and light cured for 60 seconds in a dental light-curing unit (De Trey Dentsply International, York, Penn, USA, model No. Euro Max serial No. EM 24397). Samples then were stored at 37°C and 100% humidity in an incubator to permit adequate water sorption equilibration.

Flexural strength measurements

Flexural strength was determined by a universal testing machine (JJ LLOYD 6000R) in flexion mode, using a crosshead speed of 0.5 mm/min with a 50-kN load cell. The testing machine was a 3-point-bending test device, with 20-mm distance between supports, and assured an equally distributed load.

Flexural strength (FS) was calculated using the following equation:

$$FS_{(MPa)} = 3F_m l / 2bd^2$$

where F_m is the maximal load before rupture, l is the distance between the two supports, and b is the breadth and d the depth of the samples. Ten measurements were made for each material, and the flexural strength was calculated and expressed in megapascals.

Groups evaluated

Group I: samples of Fuji Ortho LC fractured within 10 minutes of the initial setting; group II: samples of Fuji Ortho LC fractured within one hour of the initial setting; group III: samples of Fuji Ortho LC fractured seven days after the initial setting; group IV: samples of Concise fractured within 10 minutes of the initial setting; group V: samples of Concise fractured within one hour of the initial setting; group VI: samples of Concise fractured seven days after the initial setting.

For all the groups, samples were stored at 37°C and 100% humidity in an incubator to permit adequate water sorption equilibration before the flexural test.

Groups I and IV were tested within 10 minutes of the initial setting, which corresponds to the first polymerization

TABLE 2. Descriptive Statistics (in MPa) Comparing the Flexural Strength of the Six Groups Studied

Groups Tested ^a	n	Mean ^b	SD	Range
Glass ionomer: Fuji Ortho LC				
I: 10 minutes	10	24.8 A	7.1	5.7–37.2
II: one hour	10	46.9 B	4.3	43.2–57.8
III: seven days	10	77.1 C	6.1	60.6–72.7
Composite: Concise				
IV: 10 minutes	10	47.2 B	8.8	26.6–54.4
V: one hour	10	69.5 D	9.9	55.8–89.8
VI: seven days	10	103.9 E	4.2	108.7–145

^a Groups I and IV: tested within 10 minutes from the initial setting; groups II and V: tested within one hour from the initial setting; groups III and VI: tested seven days after the initial setting.

^b Means followed by the same letter are not significantly different, $P > .05$.

stage of the Fuji Ortho LC with light curing and closely simulates the timing of arch wire placement and ligation in a clinical situation. Groups II and V were tested after one hour, when the second stage of acid-base polymerization of the Fuji Ortho LC completes photopolymerization, and Groups III and VI were tested after seven days, when most of the bond strength of the adhesive has been achieved.

Statistical analysis

Two tests, the nonparametric Kruskal-Wallis H -test and the Mann-Whitney U -test, were used in this study because of the small number of samples ($n = 10$). Indeed, the results of each group were not governed by a normal distribution.

The means, standard deviations, and ranges for all six groups tested were calculated. The H -test was used to determine whether significant differences existed among the three groups of Fuji Ortho LC (I, II, and III) on the one hand and among the three groups of Concise (IV, V, and VI) on the other. Then, the U -test was used to compare the three groups of Fuji Ortho LC with the three groups of Concise, two by two, so as to identify which of the groups were different. Significance for all statistical tests was predetermined at $P \leq .05$.

RESULTS

Statistical findings for the flexural strength are presented in Table 2. The results of the Kruskal-Wallis test comparing the three groups of the resin-modified glass ionomer (I, II, and III) on the one hand and the three groups of the composite (IV, V, and VI) on the other indicated the presence of significant differences between the two sets of groups ($P = .0001$). In general, the flexural strengths were significantly larger in the two groups (III and VI) that were fractured after seven days. This was true for both the Fuji Ortho LC ($\bar{x} = 77 \pm 6.1$ MPa) and the Concise ($\bar{x} = 103.9 \pm 4.2$ MPa). On the other hand, the flexural strengths were

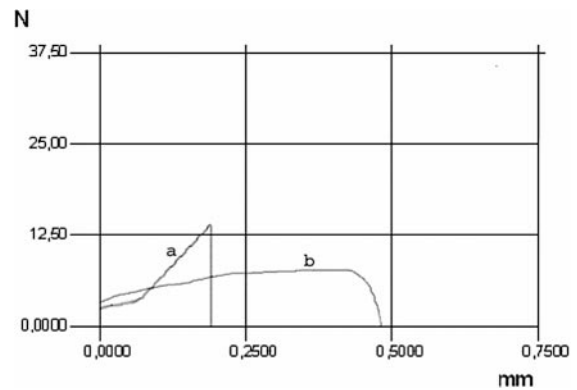


FIGURE 1. Strength-deformation curve of (a) group IV and (b) group I, showing the elastic behavior of Concise and the viscoplastic behavior of Fuji Ortho LC specimens, respectively, fractured within 10 minutes of the initial setting.

significantly lower in the two groups fractured within 10 minutes after their initial setting. Furthermore, the flexural strength of the resin-modified glass ionomer adhesive was significantly lower than that of the composite, whatever the time of fracture, at 10 minutes, one hour, or seven days.

The analysis of the strength-deformation curve, representing the group of Fuji Ortho LC fractured within 10 minutes after setting (group I), showed a viscoplastic behavior, whereas that of all the other groups showed an elastic behavior (Figure 1).

DISCUSSION

Retention of resin-bonded brackets is predictable and reliable during therapy, but debonding procedures can be time-consuming and may cause damage to, or loss of, surface enamel. In addition, demineralization or white spot formation around brackets has been reported to occur within a month of placement.^{18,19}

The development of modified glass ionomers with the addition of resin components has rekindled interest in the use of alternative bonding materials with potential anticariogenic properties.^{20,21}

Many *in vitro* studies in the past few years have attempted to define the performance of resin-modified glass ionomers, with mixed results.^{22–25} Part of the problem was the lack of information about the chemistry of many of these materials and confusion with resins containing fluoroaluminosilicate glass filler without any acid-base polyalkenoate reaction.¹⁵

In this study a tricured resin-modified glass ionomer involving an acid-base reaction, resin photopolymerization, and oxidation-reduction self-curing resin (Fuji Ortho LC) was tested in comparison with a chemically cured resin composite (Concise). The results indicated that in both glass ionomer and composite adhesives the flexural strength is significantly stronger at seven days than within one hour or even within 10 minutes after setting.

Therefore, when the adhesive material is used in the first seven days after the initial polymerization, the reaction is not complete. Complete polymerization, however, is not indispensable to its use, but it must reach a minimal value that will enable the adhesive material used to resist permanent deformation.

The results obtained showed that Concise always had flexural strength superior to that of Fuji Ortho LC, regardless of the time differential up to seven days. At 10 minutes, for groups I and IV, the flexural strength of Concise was twice higher than that of Fuji Ortho LC. There was no significant difference between the flexural strength of Concise for group IV at 10 minutes ($\bar{x} = 47.18$ MPa) and the value for group II with Fuji Ortho LC at one hour ($\bar{x} = 46.9$ MPa).

In addition to the numerical values found at 10 minutes, the Fuji Ortho LC qualitatively presents, upon analysis of the force-deformation curve, viscoplastic behavior that indicates that there is a permanent deformation of the material if it is put under a force. This force is clinically represented, for example, by the placement of the attachment or of the arch wire. A flexural strength value of 47 Mpa seems to guarantee a mechanical resistance of the material, in keeping with the forces exercised during the placement of the orthodontic system.

All authors are unanimous concerning the advantages of using a glass ionomer as the adhesive system. These materials have the ability to bond chemically to both enamel and dentine and to nonprecious metals and plastics. In addition, their high fluoride content renders tooth structure more resistant to the caries process.

Conversely, authors are not in agreement about its use as compared with a composite adhesive system.¹⁶⁻²⁶ Indeed, the use of a glass ionomer requires that the practitioners understand the mechanical properties inherent in the type of polymerization used. From a clinical perspective the present findings suggest that the clinician should apply fairly light forces to the bracket during the ligation of the first arch wire after bonding to minimize the incidence of bracket failure at this initial appointment.

The findings of this study indicate that, clinically, it is desirable to wait one hour after bonding before placing an orthodontic arch wire when using the Fuji Ortho LC, as opposed to the use of Concise, which permits putting the orthodontic system into action at the end of the first 10 minutes. This is why, contrary to what Silverman et al⁹ have said, the use of Fuji Ortho LC, although it may have numerous advantages, requires very special attention during the first 10 minutes. This is due to its plastic behavior, which renders it less rapid and practical as compared with a composite adhesive system when performing, for example, a repair procedure.

CONCLUSIONS

Under the conditions presented in this study, the following conclusions can be made:

Fuji Ortho LC has lower flexural strength values than those of Concise regardless of the time parameters (10 minutes, one hour, seven days).

Fuji Ortho LC has a viscoplastic behavior at 10 minutes, which does not seem to be compatible with the forces transmitted during the placement of an orthodontic system, as opposed to Concise, which may be used after the first 10 minutes. Clinicians must consider the setting actions of Fuji Ortho LC and wait for at least one hour before placing an orthodontic system if they want to use this material, which has the desirable properties of fluoride release and considerable tooth protection.

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