Flexure strength of resin-modified glass ionomer cements and their bond strength to dental composites

Jianguo Li, Yajuan Liu, Yun Liu, Rune Söremark and Folke Sundström
Center for Oral Biology at Novum and Departments of Dental Toxicology, Clinical Research, and Cariology, Faculty of Odontology, Karolinska Institute, Huddinge, Sweden

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The flexure strength of three resin-modified glass ionomer cements and one conventional glass ionomer cement and their bond strength to dental composites were studied by measuring the three-point bending and the shear strengths. The bond strengths between the dental composite and the resin-modified glass ionomer cements were dependent on the curing modes. Resin-modified glass ionomer cements bonded significantly more strongly to cured dental composites than dental composites bonded to cured resin-modified glass ionomer cements. However, the dental composites showed a significantly stronger bonding to the resin-modified glass ionomer cements than to the cured conventional glass ionomer cement, to which the dental composite did not adhere without acid etching. The flexure strengths of the resin-modified glass ionomer cements were significantly improved compared with the conventional one but were still significantly lower than that of the dental composites. □ *Acid etching; dental bonding; dental cements; dental materials*

Jianguo Li, COB, Box 4064, S-141 04 Huddinge, Sweden

Bonding to tooth substance and slow release of flouride are two of the advantages of glass ionomer cements. Both lead to a significant reduction of secondary caries due to reduced microleakage around glass ionomer cement fillings and increased acid resistance of the tooth tissue (1–3). However, the strength of conventional glass ionomer cements, particularly the flexure strength, has been too low to withstand high clinical loadings. A so-called sandwich or laminate technique, introduced by McLean et al. in 1985 (4), was a practical approach to utilize the advantages of glass ionomer cements in combination with dental composites. The bond strength between these two materials is of importance for the quality of the fillings. Acid etching of the glass ionomer cements was recommended to improve bonding to the composite (5, 6). Lately, however, the etching procedure has been rejected because it leads to a decrease in the strength of the glass ionomer cements (7). Besides dissolution, cracks are introduced by acid etching (8). Resin adhesive or liner has been suggested as an intermediate bonding layer to increase the bonding between dental composite and glass ionomer cements (9).

Obviously, the bond strength is limited by the low cohesive strength of the conventional glass ionomer cement and also by the lack of chemical bonding due to the difference in setting reactions between dental composites and conventional glass ionomer cements. Recently, the strength of glass ionomer cements has been improved significantly by the introduction of photocurable resin in the polyalkenoate matrix (10). These resin-modified glass ionomer cements are cured by free radical polymerization in addition to the acid-base setting reaction. Compared with conventional glass ionomer cements, resin-modified ones have a higher cohesive strength (11) and, possibly, improved bonding to the dental composites.

It is known that a thin viscous layer is formed on the dental composite surface during polymerization because of inhibition by oxygen (12). It has been suggested that this not completely cured layer improves the bonding between the cured material and the applied next portion of the material (13). It is of interest to ascertain whether similar effects occur on the bonding of dental composites to resin-modified glass ionomer cements containing a similar initiator system for polymerization.

The purpose of this investigation was to measure the bond strength between resin-modified glass ionomer cements and dental composites and to compare the bond strength between conventional glass ionomer cement and dental composites and the flexure strength of these materials.

Materials and methods

Two dental composites (Heliomolar and Z-100), three resin-modified glass ionomer cements (Vitremer, Photac-fil Aplicap, and Fuji II LC), and one conventional glass ionomer cement (Ketac-Bond) (Table 1) were used. Powders and liquids of Ketac-Bond, Fuji II LC, and Vitremer were mixed in accordance with the manufacturers' instructions. Photac-fil was prepared in a capsule mixer, and dental composites were supplied as a one-paste component. The light-curable materials

Table 1. Materials studied

Material	Batch no.	Manufacturer
*Heliomolar	460243, Universal	VIVADENT
*Z-100	5904A3	3M
†Vitremer	3303A3, 3303L	3M
†Photac-fil Aplicap	Lot No. 2312, A3	ESPE
†Fuji II LC	L:080341, P:170641	ESPE
‡Ketac-Bond	Lot No. 0033x228	ESPE

* Dental composite.
† Resin-modified glass ionomer cement.
‡ Conventional glass ionomer cement.

were cured with a curing lamp (VLC 400, Demetron, USA) for 40 sec.

Shear/bond strength measurement

Pastes of the materials were filled into a cylindrical cavity (4 mm in diameter and 3 mm in depth) in a brass mold. A thin glass plate (about 100 μm) was pressed on the cavity filled with the pastes, and the wand of the curing lamp was applied directly against the glass for 40 sec, which resulted in a smooth surface. Immediately after curing, a new portion of paste was added on top of the specimen by means of a second, demountable mold with a hole (4 × 2 mm) centered on the first specimen and was cured with light from the top of the specimens. This second mold was then removed.

Three groups of specimens were prepared.

Group I: Resin-modified glass ionomer cement or conventional glass ionomer cement was cured in the first mold, and then dental composite paste was applied on top of the glass ionomer cement and cured. (Acid etching with 37% H_3PO_4 for 1 min was used for the Ketac-Bond, to obtain a measurable bond strength to the composite).

Group II: Dental composite was cured in the first mold, and then resin-modified glass ionomer cement paste or conventional glass ionomer cement paste was applied on top of the cured dental composite and cured.

Group III: Dental composite or glass ionomer cement was cured in the first mold, and then the same material was applied and cured on top.

The specimens were immersed in deionized water at 37°C for 24 h (the specimens with conventional glass ionomer cement were kept in a humidity chamber at 37°C for 1 h before being immersed in water at 37°C for 23 h). The specimens were mounted in a universal testing machine (Alwetron 50T, Sweden). The shear strengths were measured at a cross-head speed of 1 mm/min. Six to nine specimens were used at each condition for each material combination. The fracture surfaces were examined under a stereo microscope.

Flexure/3-point bending strength measurement

Test bars, 25 × 2 × 2 mm, were prepared in a stainless steel mold with one side open. The specimens were irradiated first in the center and then on both ends with overlapping irradiation. The test bars were immersed in deionized water at 37°C for 24 h (the test bars of Ketac-Bond were kept in a humidity chamber at 37°C for 1 h before being immersed in water at 37°C for 23 h). Three-point bending tests were carried out on the test bars at a span of 22 mm and at a cross-head speed of 1 mm/min. Ten bars of each material were used.

The results were treated statistically with one-way ANOVA for the shear strengths of three groups and the flexure strength of the materials. When there were significant results in the ANOVA, Newman–Keuls multiple range tests were applied. Student's *t* test was performed between group I and group II for the same glass ionomer cements. $P < 0.05$ was used as the level of significance. A correlation analysis was made between group III and the flexure strength of the materials.

Table 2. The shear strengths (MPa) of group-I specimens (dental composites bonded to cured glass ionomer cements) and group-II specimens (glass ionomer cements bonded to cured dental composites) (mean ± SD)

	Group I		Group II	
Material	Heliomolar	Z-100	Heliomolar	Z-100
Vitremer	5.0 ± 2.1	8.6 ± 4.7	16.6 ± 3.1	18.2 ± 2.7
Photac-fil	3.9 ± 1.2	10.9 ± 3.7	19.5 ± 2.1	16.4 ± 2.8
Fuji II LC	2.9 ± 0.9	5.7 ± 2.7	18.0 ± 3.9	17.9 ± 4.4
Ketac-Bond	1.7 ± 0.8*	1.9 ± 1.1*	ND†	ND†

Mean values connected by a vertical line do not differ significantly from each other.
* Acid etching was applied to the Ketac-Bond in group I, to obtain a measurable strength. Without acid etching most of the specimens fell off before the specimens could be mounted in the testing machine, and strength was thus not measurable.
† ND = not measurable.

Results

The bond/shear strengths of groups I and II are listed in Table 2. For group I the dental composites bonded to cured resin-modified glass ionomer cements significantly more strongly than to the etched conventional glass ionomer cement. But the difference was not significant between Heliomolar versus Fuji II LC and Heliomolar versus etched Ketac-Bond. Among the resin-modified glass ionomer cements the shear strengths of the Z-100 versus Photac-fil was significantly higher than that of Heliomolar versus Photac-fil and Heliomolar versus Fuji II LC. Adhesive failure was the main fracture mode in group I. For group II no significant differences were seen in the shear strengths of the resin-modified glass ionomer cements to both dental composites. Most of the Ketac-Bond specimens

Table 3. The shear strength of group III and the flexure strength of the materials (MPa) (mean ± SD)

Material	Flexure strength	Shear strength
Ketac-Bond	10.6 ± 1.2	6.6 ± 1.9
Photac-fil	32.0 ± 5.6	8.8 ± 2.5
Vitremer	32.7 ± 6.3	7.1 ± 2.4
Fuji II LC	44.6 ± 9.3	10.7 ± 1.7
Heliomolar	70.5 ± 2.7	27.6 ± 5.4
Z-100	134.6 ± 6.4	46.7 ± 4.7

Mean values connected by a vertical line do not differ significantly from each other.

fell off from the composite surface before the shear test; the shear strength is therefore referred to as not measurable. Cohesive failure was the main fracture mode for the resin-modified glass ionomer cements, as was observed in the stereo microscope.

The bond/shear strength between two increments of the same material (group III) was significantly stronger for two dental composites than for the glass ionomer cements (Table 3). Fuji II LC had a higher bond strength than Photac-fil and Vitremer and a significantly higher one than Ketac-Bond. The flexure strengths of the three resin-modified glass ionomer cements were significantly higher than that of the conventional one but were significantly lower than that of the dental composites (Table 3). The bond strengths of the materials showed a pattern similar to that of the flexure strengths of group III, and they are highly correlated ($r = 0.954$).

Discussion

The significant improvement in cohesive strength of the resin-modified glass ionomer cements compared with the conventional glass ionomer cement, measured by flexure strength, is in agreement with other reports (10, 11). This improvement also seems to provide an increased possibility for the bonding of dental composites to the glass ionomer material. The bond/shear strengths of the composites bonded to the cured resin-modified glass ionomer cements were consistently higher than that of the composites bonded to the conventional glass ionomer cement even with acid etching. Considering the potential damage of the acid etching procedure to the strength of glass ionomer cements (7), it is a step forward that the resin-modified ionomer cements without acid etching can obtain a stronger bond to the dental composite than the etched conventional one. However, the adhesive failure of the group-I specimens indicated that a strong chemical bond in the interface was not formed. The high cohesive strength of the resin-modified glass ionomer cements was therefore not fully utilized.

The difference in shear strength between group I and group II may be due to the surface properties of the cured dental composites—for example, the presence of an oxygen-inhibited resin layer. Such a layer ought to increase the bond strengths of the resin-modified glass ionomer cements. The high bond strength between two increments of the dental composites (Table 3) may have a similar mechanism (12). Eliades & Caputo (14) suggested that the bonding of an applied new layer of composite on an oxygen-inhibited layer was explained by forming 1) covalent bonds, 2) interpenetrating networks and secondary bonding, and 3) mechanical interlocking. On the other hand, the existence of such retention-improving mechanisms seemed to have a limited effect on the resin-modified glass ionomer cements since the shear strength of the same material was low for Vitremer, Fuji II LC, and Photac-fil, even though the resin-modified glass ionomer cements have an initiator system similar to that of dental composites. The dominant cohesive fracture mode of the group-II specimens indicates the importance of the cohesive strength of the materials when a strong chemical bond is formed at the interface.

The resin-modified glass ionomer cement showed an improved flexure strength compared with the conventional one (Table 3). From the correlation analysis it seems that the stronger the materials, the higher the bond strength. The resin-modified glass ionomer cements bonded strongly to the dental composites independent of type of dental composites, hybrid or microfilled. The similarity in chemistry may be the most important issue here. Both the resin-modified glass ionomer cements and dental composites are cured by a free radical initiator system, which provides the potential of chemical bonding between these two materials. The shear strength of group I was significantly lower than that of group II. This is unfortunate, since the procedure in group I is the one used in the clinical situation. Thus, in a tooth cavity, resin-modified glass ionomer cement is placed and cured at the bottom, and a layer of composite is added and cured on top. In such a two-layer technique, if strength is the main criterion, combinations of Photac-fil and Z-100 should be considered, according to this study. Finally, the higher shear strength of the resin-modified glass ionomer cements to the dental composites indicated a potential for improvement.

In summary, the present results have shown that the resin-modified glass ionomer cements bonded to the dental composites significantly more strongly (Fuji II LC versus Heliomolar was not significant) than the conventional one with or without acid etching. The inclusion of a resin-based setting reaction in the resin-modified glass ionomer cement seems to be the main reason for the improved bonding to dental composites.

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