Fluoride-releasing materials for orthodontic appliances
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CHAPTER 2

Effect of surface treatments on the bond strength of glass ionomers to enamel

*EA Glasspoole, RL Erickson, CL Davidson. Dent Mater, in press*

**Abstract**

*Objectives.* The objective of this study was to evaluate the effect of various surface treatments on the bond strength of several glass ionomers to enamel, and to examine the resulting bond interface.

*Methods.* Ground bovine enamel specimens were divided into groups which were pretreated with one of the following: 1) no pretreatment 2) Vitremer primer 3) 10% polyacrylic acid or 4) 35% phosphoric acid. A conventional glass ionomer and two resin-modified glass ionomers (RMGI’s) were bonded to the pretreated enamel surfaces, stored in water for 24 hours and shear bond strengths measured. RMGI’s were tested as light-cured and self-cured materials.

Transverse sections of similarly prepared samples were etched with phosphoric acid for 60 seconds to partially remove enamel and expose the enamel / glass-ionomer interface. The interface morphology was examined by SEM.

*Results.* Polyacrylic acid and phosphoric acid conditioning resulted in significantly increased bond strength to enamel for all three glass ionomer materials, compared to no pretreatment (p<0.01). Light-cured bond strengths were in most cases, significantly greater than when self-cured (p<0.01). Examination of the bonded interfaces revealed the presence of polymer tags in the enamel conditioned with polyacrylic acid and phosphoric acid.

*Significance.* Conditioners significantly improved the bond to enamel for the conventional glass ionomer and RMGI’s that were examined in this study. Micromechanical bonding may play a role in the mechanism of bonding glass ionomer to enamel.

*Key words:* enamel, bond strength, glass ionomer, conditioner
Introduction

It has generally been found that a surface conditioner is beneficial for bonding Type II glass ionomer materials to enamel. For conventional glass ionomer, Hotz et al. [1] found that a citric acid pretreatment of the enamel resulted in approximately a 60% increase in bond strength compared to untreated enamel. Powis et al. [2] also examined the effect of a number of surface conditioners on bond strength to enamel and found that all the treatments resulted in an increased bond strength. In particular, a 25% solution of polyacrylic acid (PAA) was found to be quite effective, with bond strengths increasing by approximately a factor of two. However, more recently, Attin et al. [3] showed no significant difference between a conventional glass ionomer bond to unconditioned enamel, compared to enamel conditioned with 25% PAA.

Resin-modified glass ionomer (RMGI) restorative systems generally use a surface primer or conditioner as a part of their bonding procedure. Increased bond strengths, for commercial RMGI's to enamel, have been reported with the use of recommended surface pretreatments [3-5]. However, because RMGI materials contain monomers, the possibility of enhanced bonding by acid etching of enamel has been examined. Cortes et al. [6] found a substantial increase in bond strength to enamel for RMGI's when the enamel was etched with 10% phosphoric acid, compared to unetched enamel. Similar results have been reported by other authors [4,5,7,8]. Shear bond strengths of around 20 MPa were achieved in some of these studies, a value that approaches bond strengths more typical of composite than glass ionomer.

The aforementioned studies have shown that recommended conditioning or acid etching can improve the bond strength of conventional and light-cured RMGI to enamel, however, bonding of self-cured RMGI's and the effect of conditioners for this mode of cure has received little attention in the literature. The purpose of this study was to examine the effect of a range of surface pretreatments on bond strength to enamel for a conventional glass ionomer and two RMGI materials, both in their light-cured and self-cured form, and in each case, to examine the resulting bond interface with enamel by SEM.
Materials and methods

Commercially available materials used in this investigation are listed and described briefly in Table 1.

Shear bond strength
Two hundred fifty extracted bovine incisors, which had been stored in deionized water, were embedded in self-curing acrylic, (Quickmount, Fulton Metallurgical Products Corp., Saxonburg, PA, USA) and an area of flattened enamel was exposed by wet grinding on 120, 320 and 600 grit silicon carbide papers. The specimens were randomly divided into groups of at least ten teeth each, and pretreatment of the enamel was performed for each of the groups as follows:

1) No pretreatment
2) Vitremer primer (Vit Pri): Vitremer primer is applied to the enamel for 30 seconds, air dried gently for 10 seconds, followed immediately by light curing with a Visilux™ 2 Visible Light Curing Unit (3M Dental Products, St. Paul, MN, USA) at 650 mW/cm² for 20 seconds (this pretreatment used only with Vitremer). Vitremer primer is a one-part, visible light-cure liquid composed of a copolymer of alkenoic acids, HEMA, ethanol and photoinitiators, and is acidic by nature.
3) 10% Polyacrylic Acid (PAA): GC Dentin Conditioner (GC Corporation, Tokyo, Japan) was applied for 20 seconds, rinsed and air-dried.
4) 35% Phosphoric Acid (PA): 3M Scotchbond Gel Etchant (3M Dental Products, St. Paul, MN, USA) was applied to the enamel surface for 15 seconds, rinsed and air-dried.

After the specified enamelpretreatment, a 2 mm thick Teflon mold with a hole, 4 mm in diameter, was clamped over the treated area and filled with the appropriate glass ionomer material. Each glass ionomer was mixed according to manufacturers instructions. The glass ionomers were allowed to self-cure, or in the case of the two RMGI's, additional groups were visible light-cured, in one increment, for 60 seconds. All specimens were left undisturbed for 30 minutes in 100% humidity, at which time the clamp was removed and the samples were stored in deionized water at 37º C for 24 hours. The shear bond strength between the glass ionomer and enamel was then measured on an Instron universal testing
### Table 1
Materials investigated in bond strength study

<table>
<thead>
<tr>
<th>Material (abbreviation)</th>
<th>Manufacturer</th>
<th>Type</th>
<th>Batch Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>3M™ Vitremer™ Tri-cure Glass Ionomer System</td>
<td>3M Dental Products</td>
<td>resin-modified</td>
<td>powder (A3) 315R</td>
</tr>
<tr>
<td>(Vitremer)</td>
<td>St. Paul, MN, USA</td>
<td>glass ionomer</td>
<td>liquid 434</td>
</tr>
<tr>
<td>GC Fuji II LC (Fuji II LC)</td>
<td>GC Corporation</td>
<td>resin-modified</td>
<td>powder (A3) 071234</td>
</tr>
<tr>
<td></td>
<td>Tokyo, Japan</td>
<td>glass ionomer</td>
<td>liquid 291132</td>
</tr>
<tr>
<td>GC Fuji II (Fuji II)</td>
<td>GC Corporation</td>
<td>conventional</td>
<td>powder (A3) 930928A</td>
</tr>
<tr>
<td></td>
<td>Tokyo, Japan</td>
<td>glass ionomer</td>
<td>liquid 930929B</td>
</tr>
<tr>
<td>3M™ Vitremer Primer (Vit Pri)</td>
<td>3M Dental Products</td>
<td>self-etching</td>
<td>419</td>
</tr>
<tr>
<td></td>
<td>St. Paul, MN, USA</td>
<td>primer</td>
<td></td>
</tr>
<tr>
<td>GC Dentin Conditioner (10% PAA)</td>
<td>GC Corporation</td>
<td>10% polyacrylic</td>
<td>240321</td>
</tr>
<tr>
<td></td>
<td>Tokyo, Japan</td>
<td>acid gel</td>
<td></td>
</tr>
<tr>
<td>3M™ Scotchbond Etchant (35% PA)</td>
<td>3M Dental Products</td>
<td>35% phosphoric</td>
<td>2LG</td>
</tr>
<tr>
<td></td>
<td>St. Paul, MN, USA</td>
<td>acid gel</td>
<td></td>
</tr>
</tbody>
</table>
machine at a crosshead speed of 2 mm/min, using a wire loop shearing apparatus.

A one factor ANOVA was used to analyze the mean bond strengths between surface treatment groups for each material, with Tukey-Kramer post-hoc analysis. Differences in mean bond strength between light-cure and self-cure groups for each RMGI were analyzed by a t-test.

**Determination of fracture mode**
Visual examination of failure mode of the bonding specimens was accomplished by viewing all of the debonded specimens under a light microscope at about 12x. Failure was identified as “adhesive” if no observable glass ionomer remained on the enamel surface and it had a polished appearance; “minimally cohesive” if a visible thin coating of glass ionomer remained on the enamel surface giving a frosty appearance; or “cohesive in ionomer” if bulk amounts of glass ionomer remained on the enamel surface. Failure modes were estimated to the nearest 5%.

**SEM analysis of etch pattern**
Scanning electron microscopy was used to visualize the effect on bovine teeth, of the various surface treatments used in the bonding study. Areas of flattened enamel were exposed using 120, 320 and 600 grit silicon carbide papers, with three specimens prepared with each of the following surface treatments: 1) 30 second application of Vitremer primer, rinsed with ethanol for 15 seconds to remove primer, then air-dried. 2) 20 second application of 10% PAA, rinsed with deionized water for 15 seconds, and air-dried and 3) 15 second application of 35% PA, rinsed with deionized water and air-dried. All specimens were affixed to SEM stubs, sputter coated with gold-palladium and examined on a JEOL 820 scanning electron microscope. Representative images for the different surface treatments were obtained.

**SEM analysis of monomer/polymer penetration**
The glass ionomer and enamel interfaces were examined for evidence of monomer/polymer penetration. Three bonded specimens were prepared similarly to each group that was tested in the bonding study. For the RMGI specimens, the materials were light-cured on one-half of the tooth and self-cured on the other half. For each specimen, a section was cut from the middle and polished on 600
grit silicon carbide papers. The polished sections were etched for 60 seconds with 35% PA, rinsed thoroughly with deionized water and gently air-dried. Specimens were mounted on SEM stubs with the cross-sectioned surfaces exposed for examination by SEM. Representative images were saved.

Results

Shear bond strength
The mean shear bond strengths and standard deviations for each group are shown in Table 2. For all three materials and both curing modes, pretreatments with either 10% PAA or 35% PA resulted in statistically significant increases (p<0.01) in bond strength compared to no pretreatment of the enamel surface. The mean bond strengths resulting from use of the Vitremer primer were significantly lower than those obtained with PAA or PA pretreatments, but were not statistically greater than with no pretreatment. There was no statistically significant difference in bond strengths obtained with PAA and PA pretreatment, with the exception of Fuji II LC (self-cured).

For each RMGI material, there were statistically significant differences (p<0.01) between self-curing and light-curing for all surface treatments, except Vitremer primer and Fuji II LC with 35% PA pretreatment. The bond strengths were significantly lower for light-curing compared to self-curing when no pretreatment was used, while in the case of PAA and PA pretreatments, the light curing results gave significantly higher bond strengths than self-curing, except for Fuji II LC with PA pretreatment.

Fracture mode
Adhesive failure was observed only when no pretreatment was used. Figure 1 shows the results of the mode of failure analysis for the bond strength specimens. For the conventional glass ionomer, pretreatments resulted in roughly 50% cohesive failure within the material, whereas only about 12% cohesive failure was noted when no pretreatment was used. The mode of failure for the RMGI materials differed between self-curing and light-curing; for self-curing materials, the failure was predominantly minimally cohesive with all pretreatments, whereas, in the light cured specimens, approximately equal amounts of cohesive and
Table 2
Mean bond strength of several glass ionomers to pretreated bovine enamel, MPa (sd)

<table>
<thead>
<tr>
<th>Group</th>
<th>None</th>
<th>Vitremer Primer</th>
<th>10% PAA</th>
<th>35% PA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitremer (self-cured)</td>
<td>6.8 (1.8) a,b</td>
<td>7.1 (1.6) a,b</td>
<td>13.0 (2.3) b,α</td>
<td>14.0 (3.1) b,α</td>
</tr>
<tr>
<td>Vitremer (light-cured)</td>
<td>4.9 (2.4) a,b</td>
<td>7.2 (1.5) a,b</td>
<td>17.0 (3.1) b,β</td>
<td>18.4 (2.8) b,β</td>
</tr>
<tr>
<td>Fuji II LC (self-cured)</td>
<td>6.9 (1.5) a,b</td>
<td>14.6 (2.6) b,α</td>
<td>18.2 (3.1) c,α</td>
<td></td>
</tr>
<tr>
<td>Fuji II LC (light-cured)</td>
<td>3.6 (4.2) a,b</td>
<td>18.9 (2.6) b,β</td>
<td>20.5 (2.7) b,α</td>
<td></td>
</tr>
<tr>
<td>Fuji II (conventional)</td>
<td>3.4 (0.9) α</td>
<td>6.9 (2.6) b</td>
<td>7.2 (1.8) b</td>
<td></td>
</tr>
</tbody>
</table>

a, b, c  Mean values with different superscript letters within a group are statistically different (p<0.01)

α, β  Mean values with different superscript letters (Greek) between light-cured and self-cured groups for a material and a surface treatment are statistically different (p<0.01)
Figure 1a. Mode of failure observed for bonding specimens when Fuji II conventional glass ionomer was bonded to enamel using various pretreatments. Adhesive failure was seen only with no pretreatment, while approximately equal amounts of cohesive failure within the material and minimally cohesive failure occurred when 10% PAA or 35% PA pretreatment was used. Figure 1b. Mode of failure observed when Vitremer (self-cured) was bonded to enamel using various pretreatments. The failure was predominantly minimally cohesive with all pretreatments. Figure 1c. Mode of failure observed when Vitremer (light-cured) was bonded to enamel using various pretreatments. Adhesive failure was observed when no pretreatment or Vitremer primer was used. Approximately equal amounts of cohesive failure within the material and minimally cohesive failure were seen when PAA or PA was used. Figure 1d. Mode of failure observed when Fuji II LC (self-cured) was bonded to enamel using various pretreatments. Failure was predominantly minimally cohesive for all pretreatments, with some adhesive failure seen when no pretreatment was used. Figure 1e. Mode of failure observed when Fuji II LC (light-cured) was bonded to enamel using various pretreatments. Failure was predominantly adhesive with no pretreatment, while approximately equal amounts of cohesive failure within the material and minimally cohesive failure were seen when PAA or PA was used.
minimally cohesive fracture were observed for PAA and PA pretreatments.

**SEM analysis of the etch pattern**
Enamel surfaces treated with various pretreatments are shown in Figure 2. There is a progression in the degree of demineralization that results, with Vitremer primer showing the least effect and 35% PA the greatest.

**SEM analysis of monomer/polymer penetration**
Figure 3 shows representative SEM's of the degree of penetration of monomer and/or polymer into enamel treated with 35% PA or 10% PAA. Tag formation relates to the degree of demineralization provided by the specific pretreatment and is analogous to the type of tag formation seen with composite resin systems. These appear to be a negative replica of etch patterns demonstrated in Figure 2.

When Vitremer primer was used, and also with no pretreatment, the microporosity created was minimal and any resin penetration present was not able to be seen using this observation method.

**Discussion**

It is generally believed that glass ionomers, particularly conventional glass ionomers, bond to enamel by an ionic interaction with the mineral phase, however, the exact mechanism is undefined [9]. Polyalkenoic acids have been shown to be irreversibly adsorbed onto hydroxyapatite surfaces [10, 11] and bonds between adsorbed PAA and metal ions have been demonstrated by x-ray photoelectron spectroscopy [12]. Recently, the latter technique was used to provide evidence for a chemical interaction between calcium and carboxyl ions for both human enamel and hydroxyapatite [9, 13].

Conventional glass ionomers bond to enamel, even with the presence of a smear layer, but surface conditioners have been found to improve the bond strength. Conditioners such as citric acid [1] improve bond strength and PAA was also shown to be an effective conditioner [2]. In the current study, conditioners improved the bond of Fuji II conventional glass ionomer to enamel, in agreement with these earlier studies. This includes conditioning with PA, which gave a result
**Figure 2a.** SEM of the enamel etch pattern after 30 s application of Vitremer primer to flat-ground enamel. Little retentive surface is exposed.

**Figure 2b.** SEM of the enamel etch pattern after 20 s pretreatment of flat-ground enamel with 10% PAA. The enamel rod structure has been exposed in the shallow etch.

**Figure 2c.** SEM of the enamel etch pattern after 15 s pretreatment of flat-ground enamel with 35% PA. A characteristic etch pattern showing enamel rods and deep interrod porosity is exposed.
that was similar to when PAA conditioning was used. The role of the conditioner probably involves effective removal of the smear layer and provides for good wetting of the surface by the glass ionomer, an essential requirement for good bonding [14]. However, as acidic materials, the conditioners may also produce microporosity in the enamel surface that could contribute to either increased surface area for chemical bonding or micromechanical bonding through polymer penetration.

When PA was used, the expected enamel etch pattern and resultant microporosity was produced as shown in Fig 2c, while in Fig 2b, the etch pattern produced by PAA conditioning, while shallower, also exposed enamel rods and interrod porosity. In Fig. 3a, remaining polymer tags from Fuji II are shown after some of the enamel has been etched away. For the case of PAA pretreatment, there were suggestions of subtle tag formation, but definitive micrographs could not be obtained. It is possible that the polymer could not maintain topography of tags following the specimen preparation with PA.

The presence of polymer tags into the microporosities of conditioned enamel suggests that micromechanical bonding could play a role. For the case of bonds to dentin, studies have shown that conditioning with acids did not diminish the bond strength, and in some cases improved them [15,16,17]. Since dentin is depleted of mineral by conditioning, it might be expected that the bond strengths would be severely reduced if calcium binding is the mechanism of adhesion. The authors of these studies proposed that the bond mechanism was due, at least in part, to diffusion of polymer into the demineralized dentin and tubules, forming micromechanical bonds. Therefore, if this mechanism is viable for dentin bonding, it seems reasonable that resin tags into conditioned enamel may also contribute to a micromechanical component of bonding to enamel. However, to separate the relative contributions of micromechanical bonding and chemical bonding would be quite difficult for enamel.

The improved bond to enamel with the use of pretreatments is reflected in the mode of failure data as shown in Fig. 1a. Ideally, with no pretreatment, the conventional glass ionomer should penetrate the smear layer through a self-etching process and effect a bond to the underlying enamel. The degree to which this
Figure 3a. Cross-sectional SEM view of Fuji II conventional glass ionomer and enamel interface. Enamel was pretreated with PA. Polymer penetration into enamel is evident.

Figure 3b. Cross-sectional SEM view of Vitremer (light-cured) and enamel interface pretreated with PAA. Tag formation appears to be a negative replica of the etch pattern demonstrated by PAA in Fig 2b.

Figure 3c. Cross-sectional SEM view of Vitremer (self-cured) and enamel interface pretreated with PA. Tag formation is evident.
Figure 3d. Cross-sectional SEM view of Vitremer (light-cured) and enamel interface pretreated with PA. Tag formation appears as a negative replica of the etch pattern demonstrated by PA in Fig 2c.

Figure 3e. Cross-sectional SEM view of Fuji II LC (self-cured) and enamel interface pretreated with PA. Tag formation is evident.

Figure 3f. Cross-sectional SEM view of Fuji II LC (light-cured) and enamel interface pretreated with PA. Tag formation appears related to the degree of demineralization provided by the PA pretreatment.
occurs will influence the measured bond strength and the fracture mode. In the case of no pretreatment, approximately 20% of the bond failure is adhesive at the enamel interface, with about 12% being cohesive in the material. The adhesive failure component may be indicative of areas in which the smear layer was inadequately penetrated, resulting in a weak area of bonding. With removal of the smear layer by conditioning, the glass ionomer was able to interact with the underlying enamel and a stronger, more uniform bond achieved, resulting in about 50% cohesive failure in the glass ionomer. Fig. 4 shows the effect on the enamel surface from contact with mixed Fuji II conventional glass ionomer for a period of 60 seconds, after which the glass ionomer was removed from the surface by rinsing with deionized water. The micrograph shows areas where the smear layer has been effectively removed, and other areas where smear layer removal is not

**Figure 4a.** SEM showing the effect of 60 s contact with mixed Fuji II conventional glass ionomer on a flat-ground enamel surface. Some areas of smear layer have been effectively removed, exposing enamel rods as shown by the arrows.

**Figure 4b.** Higher magnification SEM view of Fig 4a showing exposed enamel rods.
complete. Evidence of enamel rods being exposed can be seen in the areas where the smear layer has been removed, especially in the magnified view (Fig. 4b). As the material continues to set, the remaining smear layer shown in the micrograph will perhaps diminish, but may not be entirely removed, since the pH of setting glass ionomer rises with time [18,19,20]. Not only is the pH of the liquid phase of the glass ionomer important, but also of importance is its ability to reach the surface in sufficient quantity and withstand the buffering effect of enamel mineral. These aspects help to determine how well the glass ionomer etches the smear layer.

For all surface conditions, a large percentage of the bond failures were scored as “minimally cohesive”. This behavior has been observed previously [16], but such areas were scored as “adhesive”. This thin coating has also been characterized as an ion-exchange layer or interaction zone [21-23]. It would appear that this layer is well attached to the surface and that fracture usually occurs just above it, or within the bulk of the glass ionomer.

There are a number of differences between RMGI’s and conventional glass ionomers that manifest themselves in observed bonding characteristics on enamel. Because RMGI’s contain a resin component that can form a covalently bonded matrix, the materials have greater fracture strengths than conventional glass ionomers [24,25]. Also, because the resin components may penetrate microporosities, a mechanical component of bonding seems feasible. The RMGI’s examined in the current study have dual curing capabilities, these being a methacrylate, free radical polymerization which can be light or chemically activated, and a glass ionomer acid-base reaction [26,27]. The relative rate and amount of these reactions can depend on whether the materials are light-cured, or allowed to self-cure [28] (private communication, R. Halvorson, 3M Dental Products, St. Paul, MN). Because some of the water in a conventional glass ionomer is replaced by monomer, RMGI’s may have a reduced acid-base reaction [9].

For both RMGI’s, a significant increase in enamel bond strength is seen with the use of conditioners, compared to no pretreatment. Others have seen similar increases in bond strength with the use of PAA and PA conditioners [3-6].
with conventional glass ionomer, there was no significant difference between the conditioning agents, except for the case of Fuji II LC when self-cured. Desai et al. [5] also found no significant difference between the use of PAA and PA for Fuji II LC. The significant difference between conditioners for Fuji II LC in the self-cured mode is unexpected. The bond strength for Vitremer with the use of Vitremer primer was not statistically different than when no pretreatment was used. This may be due to the fact that the Vitremer primer contains ethanol and no water, so that when applied to dry enamel, it might not have a significant etching effect, as was observed in Fig. 2a. The primer may, however, improve the wetting of the restorative onto the surface and penetrate into the smear layer to reinforce it somewhat, which could account for the increased bond strength observed.

The relatively large bond strengths obtained with the two RMGI’s when surface conditioning was used may, to a considerable extent, be due to micromechanical bonding. In Fig. 3b, the polymer tags for the light-cured Vitremer on PAA conditioned enamel are a mirror image of the etch pattern for this conditioner as shown in Fig. 2b. Figs. 3d and f show tags that result from conditioning with PA for light-cured Vitremer and light-cured Fuji II LC respectively. These tags are quite similar to those often seen when bonding composite resin to etched enamel. Similar polymer tags are found when the RMGI’s are self-cured (Figs. 3c and e).

The measured bond strengths for the two RMGI’s are greater than for Fuji II conventional glass ionomer. This may be due to both the higher fracture strength of the RMGI materials and the greater strength of the polymer projections into the enamel. Light-curing of the RMGI’s resulted in significantly greater bond strengths than when they were self-cured when the two conditioners were used. Again, this may be largely due to differences in the strength of the materials and a difference in polymerization of the resin component within the enamel surface. For Vitremer, there is about a 20% reduction in diametral tensile strength for the self-cured compared to the light-cured material [29], and the bond strength is about 24% lower. These reductions are comparable to a 20% reduction in the degree of conversion of the methacrylate component of Vitremer that has been measured for the self-cured compared to the light-cured material (private communication, R. Halvorson, 3M Dental Products, St. Paul, MN). It is likely
that the methacrylate functionality has the greatest influence on physical properties and bond strength. Fuji II LC is not recommended for use as a self-cure material, and strength values for this mode of cure were not available, however, as with Vitremer, the bond strength values for self-cured compared to light-cured Fuji II LC were reduced by about the same percentage as Vitremer.

When no pretreatment was used, the behavior between self-curing and light-curing was reversed, with self-curing having a significantly higher bond strength. One possible explanation of this result relates to the ability of the materials to penetrate the enamel smear layer. When light-cured immediately after placing, the ability of the materials to etch through the smear layer will be diminished, but if the material self-cures over a period of several minutes, greater time is allowed for etching of the smear layer and reaction with the underlying enamel. When Vitremer primer was used to pretreat the enamel, there was no difference between self-cured and light-cured Vitremer groups, but it should be noted that in both cases, the Vitremer primer was first light-cured and so may have had a leveling effect between the two modes of cure.

The modes of failure for light-cured RMGI’s with various pretreatments are shown in Figs. 1c and e. A significant amount of adhesive failure was observed when no pretreatment was used, which is in correspondence with the bond strength and proposed effect on smear layer discussed above. When conditioners were used, the RMGI’s exhibited no adhesive failure and about 50% cohesive failure in the bulk of the RMGI. The similarity of fracture mode between the two conditioners corresponds to a lack of significant difference in bond strengths observed for these conditioners. When Vitremer primer was used with the Vitremer RMGI, the failure mode was similar to no pretreatment, but with somewhat less adhesive failure. This also corresponds to the bond strength data where there is no significant difference between no pretreatment and use of Vitremer primer.

The fracture mode data for when the RMGI’s were self-cured are shown in Figs 1b and d. Compared to the fracture mode when the materials were light-cured, there is substantially less cohesive failure when the two conditioners were used. The cohesive failure for the Fuji II LC, self-cured and pretreated with PA, is somewhat greater, in correspondence with its similarly increased bond strength, however, the
large potential for error in fracture mode measurements may not allow for this type of comparison. For the most part, the majority of the failure mode was categorized as "minimally cohesive". This may be related to reduced fracture strength of the materials when they are self-cured rather than light-cured.

The results of this study indicate that acidic conditioning is beneficial in achieving better bonding to enamel for the conventional glass ionomer and RMGI's studied. While light-curing provides the optimum bond strengths for RMGI, self-curing these materials resulted in relatively good bond strengths to conditioned enamel. In addition, there is evidence suggesting that micromechanical bonding may play a role in bonding of these RMGI's and conventional glass ionomer to enamel.
References