The ART of GIC proximal restorations in primary teeth
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Chapter 6

Flowable glass-ionomer cement layer bonding to sound and caries-affected primary dentin

Lenzi TL, Bonifácio CC, Bönecker M, van Amerongen WE, Nogueira FN, Raggio DP
Abstract

**Aim:** To evaluate the effect of flowable glass-ionomer cement (GIC) layer application on bond strength to sound (SD) and caries-affected (CAD) primary dentin.

**Methods:** Flat dentin surfaces from primary molars were randomly assigned to 4 groups (n = 5) according to substrate: SD or CAD (pH-cycling for 14 days) and layers of GIC: 1 layer/control (regular powder/liquid ratio) or 2 layers (firstly a flowable layer of GIC and, secondly, a regular powder/liquid ratio layer of GIC). After 24 hours water storage, specimens were prepared for being tested under microtensile test (1 mm/min). The fracture pattern was evaluated at 400 X magnification (stereomicroscope).

**Results:** No significant difference was observed between one or two layers insertion of GIC (p>0.05). However, the bond strength to sound dentin was higher than to caries-affected dentin when GIC was inserted in two layers (p=0.02). For all groups, adhesive/mixed fracture prevailed.

**Conclusion:** The effect of the application of flowable GIC layer on bond strength to dentin is substrate dependent and results in a decrease in adhesion for caries-affected primary dentin.
**Introduction**

Ultraconservative treatment approaches are recommended for treating cavitated dentin lesions (1, 2). The Atraumatic Restorative Treatment (ART) is one of the proposed treatment approaches. This technique is based on caries removal, using only hand instruments, filling the dental cavity and sealing the adjacent pits and fissures with high viscous glass-ionomer cement (GIC), without requiring energy sources (3).

GIC is the material of choice for ART (4) due to its physical and chemical properties, such as fluoride release and uptake, biocompatibility, bonding to enamel and dentin and chemical set reaction. The high viscous GICs were developed specifically for this approach, with better mechanical properties than conventional GICs, by increasing the powder/liquid ratio (5, 6). Nevertheless, this material presents a viscous consistency which makes it a cement with complex handling and insertion characteristics.

Despite similar clinical behavior of GICs (ART) and amalgam in single surface restorations (7-9), the performance of GICs in proximal-ART restorations is far from ideal (10-13). This performance is even poorer in primary teeth, with survival rates lower than those in permanent teeth (3).

Due to the difficulty in handling high viscous GIC, inadequate adaptation to the cavity walls may result. Cervical gaps and open margins may contribute to proximal–ART restoration failures (14-16).

The insertion must be performed when the consistency is not too thick and the material is still shiny (17, 18), indicating that remaining polyacrilic ions are available for chemical bonding to the dental structure. A recent laboratory study (19) demonstrated that the insertion of a flowable GIC layer in proximal cavities of primary teeth before the insertion of a regular GIC layer improves the material adaptation to the tooth surface, and consequently, reduces the microleakage. Although the results are encouraging, the bond strength properties of the flowable GIC layer to dentin is still unknown.

Therefore, the aim of this study was to evaluate the effect of the application of a layer with a flowable consistency of a high viscous glass-ionomer cement (GIC) on bond strength to sound (SD) and caries-affected (CAD) dentin of primary teeth.

**Methods**

*Teeth selection and preparation*

Twenty sound second primary molars naturally exfoliated were selected after the patient’s informed consent was obtained under protocol approved by the local Research Ethics Committee. Teeth were disinfected in 0.5% chloramine and stored in distilled water at 4ºC until use.

The occlusal surfaces were removed with a water-cooled diamond disc in a cutting machine (Labcut 1010, Extec Co., Enfield, USA) to obtain flat dentin surfaces. Surrounding enamel was also removed with a diamond bur in a high-speed hand piece with water spray (#3195, KG Sorensen, Barueri, BR).

Exposed occlusal dentin surfaces were then polished with 600-grit silicon-carbide paper under running water for 30 s to create a standardized smear layer (20).
Flowable GIC layer bonding to sound and caries-affected primary dentin

Artificial caries induction

Half of the previously prepared teeth (n = 10) were subjected to pH-cycling to create artificial caries-affected dentin. The roots and cervical portions were sealed with epoxy resin (Araldite Hobby, Ciba Especialidades Químicas Ltda, São Paulo, BR) and received two layers of acid-resistant nail polish (Colorama Maybelline Ltda, São Paulo, BR).

The specimens were individually submitted to 14 cycles of immersion for 8 hours in 10 ml of demineralizing solution (2.2 mM CaCl₂, 2.2 mM NaH₂PO₄, 50 mM of acetic acid adjusted pH of 4.8) and for 16 hours in the same volume in remineralizing solution (1.5 mM of CaCl₂, 0.9 mM of NaH₂PO₄, 0.15 mM of KCl adjusted pH of 7.0) (21). The solutions were changed every cycle and at each interval, the teeth were rinsed with deionized water and dried with absorbent paper.

Bonding procedures

The dentin surfaces for all teeth (sound dentin – SD and caries-affected dentin – CAD) were conditioned with diluted liquid of Fuji IX (GC Europe, Leuven, BE) for 10 s (22), rinsed and dried, using cotton pellets. A teflon matrix was positioned surrounding the prepared surface for high viscous GIC insertion, resulting in cylindrical specimens with 4mm diameter and 5mm height. After these procedures, specimens were randomly reassigned into two groups:
- Control group: The high viscous GIC (Fuji IX; GC Europe, Leuven, Belgium) was mixed according to manufacturer’s instructions: 1 powder scoop (3.6 g) and 1 liquid drop (1 g) (1:1); hand mixed until a homogeneous consistency was achieved. The GIC was inserted with a syringe (Centrix®) to avoid the inclusion of air bubbles into the material. A finger press technique was applied for 10 s with a gloved index finger with petroleum jelly (23).
- Two layers group: In the first layer the high viscous GIC was hand mixed with 1 powder scoop (3.6 g) and 2 liquid drops (2 g) (1:2). A flowable consistency mix was achieved. The first layer was inserted with the syringe Centrix®, and the second layer was hand mixed according to the manufacturer’s instructions (powder/liquid ratio 1:1) and applied before the hardening of the first layer. Pressure was applied for 10 s with a gloved index finger ("finger press technique") with petroleum jelly (25).

After 6 minutes, the teflon matrix was removed and petroleum jelly was applied on all surfaces of the specimens to avoid water uptake and loss (23). Specimens were stored in distilled water at 37°C for 24 hours.

Microtensile test

Teeth were sectioned both in “x” and “y” directions across to the adhesive interface using low-speed diamond disc in a cut machine (Labcut 1010, Extec Co., Enfield, USA) to obtain bonded sticks with a cross-sectional area of approximately 0.65 mm². The cross-sectional area of each stick was measured with the digital caliper (Absolute Digimatic, Mitutoyo, Tokyo, JP).

Specimens were immediately attached to a testing apparatus with a cyanoacrylate adhesive on a universal testing machine (Kratos Dinamômetros, São Paulo, BR) and were submitted to a tensile test at 1 mm/min. Bond strength was expressed in MPa.

Fracture pattern

The fracture pattern was determined under 400 X magnification using a stereomicroscope (HMV II, Shimadzu, Kyoto, Japan) and classified as: adhesive/mixed
fracture (presence of dentin or GIC adjacent to interface) or cohesive (fracture in dentin or GIC).

**Statistical Analysis**

The experimental unit in the current study was the tooth. Thus, the mean of the microtensile bond strength values of all sticks from the same tooth were averaged for statistical analysis.

Since a high number of premature debonded specimens during the preparation phase mean high fragility of the bonding area, it was assigned 4.0 MPa as value for each stick and the specimens were included in the statistical analysis (24).

Normal distribution of data was confirmed using Kolmogorov-Smirnov test. Data obtained were submitted to two-way ANOVA (group and substrate) and Tukey’s post hoc at the 5% significance level. A Chi-square test was applied to analyze the fracture pattern proportions among experimental groups. We calculated the sample power. After calculating the effect size of our sample, the power reached was 0.72, which represent a reliable sample for detecting differences between groups.

**Results**

Microtensile bond strength means (MPa) and standard deviations for all experimental groups are displayed in Table 1. ANOVA revealed that cross-product interaction (group x substrate) was statistically significant ($p<0.05$).

No significant difference was observed in bond strength using one or two layers of GIC ($p>0.05$). However, when flowable GIC layer was applied, higher values of bond strength were obtained when applied to sound dentin ($p=0.02$), compared to caries-affected dentin, demonstrating a substrate-dependant result.

**Table 1** - Microtensile bond strength means (MPa) and standard deviations for all experimental groups.

<table>
<thead>
<tr>
<th>Group</th>
<th>Sound dentin</th>
<th>Caries-affected dentin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>13.12 ± 3.28 A,a</td>
<td>8.55 ± 2.45 A,a</td>
</tr>
<tr>
<td>2 layers</td>
<td>17.57 ± 4.19 A,a</td>
<td>9.14 ± 1.16 B,a</td>
</tr>
</tbody>
</table>

Different capital letters indicate significant difference between the main factor “substrate”; equal lower letters indicate no difference between the main factor “group”.

The distribution of fracture pattern is summarized in Table 2. For all groups, adhesive/mixed fracture prevailed. No difference was observed in relation to the percentage of cohesive fracture in GIC among experimental groups. The percentage of cohesive fracture in dentin was higher in the two layers group, independent of the substrate. A lower percentage of premature fractures was observed for caries-affected dentin when a flowable GIC layer was applied.
Table 2 - Fracture pattern for all experimental groups. Chi-square test results of the fracture pattern proportions among groups.

<table>
<thead>
<tr>
<th>Fracture pattern</th>
<th>1 layer SD</th>
<th>1 layer CAD</th>
<th>2 layers SD</th>
<th>2 layers CAD</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adhesive/mixed</td>
<td>34</td>
<td>38</td>
<td>46</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Cohesive in GIC</td>
<td>17</td>
<td>7</td>
<td>15</td>
<td>11</td>
<td>0.178</td>
</tr>
<tr>
<td>Cohesive in dentin</td>
<td>1</td>
<td>1</td>
<td>9</td>
<td>5</td>
<td>0.032</td>
</tr>
<tr>
<td>Premature</td>
<td>15</td>
<td>17</td>
<td>3</td>
<td>19</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

SD: sound dentin; CAD: caries-affected dentin

Discussion

High failure rates of proximal-ART restorations have been reported in literature (10-13, 25, 26). A recent laboratory study (19) revealed that the insertion of a flowable GIC layer into proximal cavities prior to the insertion of a regular high-viscous GIC layer seemed to improve the material’s adaptation to tooth structures. The presence of a flowable GIC layer seems to enhance adhesion in proximal cavities. The adhesive principles suggest that low viscous materials penetrate in the substrate more effectively, enhancing the micromechanical adhesion (27). However, it is unknown if the insertion of the flowable GIC layer influences the bond strength to dentin. Thus, this study aimed to evaluate the bond strength of high viscous GIC to sound and caries-affected primary dentin inserted in two layers with different viscosities.

No significant difference was found in bond strength values between control and two layers groups. However, the bond strength to sound dentin was higher than to caries-affected dentin when flowable GIC layer was applied, suggesting the substrate dependant behavior of this insertion technique.

Despite the fact that the GIC bonding mechanism to the tooth structure is not completely clear, chemical adhesion is attributed to ionic interaction between carboxylic groups from polyacids and the hydroxyapatite from the tooth surface, dislocating calcium and phosphate ions from the latter (28, 29). As affected dentin is demineralized due to the carious process, the GIC bonding to this substrate may be reduced compared to sound dentin. Moreover, the lower powder/liquid ratio used for the flowable layer has important characteristics related to the adhesion. The higher polyacrilic acid available can be responsible for increasing the number of cross-links and a better wettability in sound dentin and consequently, higher bond strength values compared to caries-affected dentin.

Even though the caries-affected dentin has shown lower bond strength in the two-layered group, the values were similar compared to caries-affected dentin in the control group. This indicates that the application of a flowable GIC layer does not necessarily decrease the adhesion to caries-affected dentin, but increases the bonding to sound dentin.

Previous studies (20, 30) that evaluated the microtensile bond strength of high viscous GIC (Fuji IX) to sound dentin found values means between 9.7 to 12.4 MPa. Considering that the bond strength values to caries-affected dentin obtained in this study to control and two-layered group were, respectively, 8.55 and 9.14 MPa, it seems to be the
threshold for bonding success. Moreover, clinically, caries-affected and sound dentins coexist in the cavity preparations and, a proper adhesion can be expected.

Even though smaller specimens in microtests allow the more uniform stress distribution along the adhesive interface, a higher number of cohesive fractures were observed in this study, especially in the cement, which seems to be a typical finding for GIC (31). This fracture pattern has often been interpreted as indicating that the bond to the dentin was stronger than cohesive strength of the cement. However, bond rupture is far more complex than this. There are inherent problems with the tensile tests since there are several layers of substrates and materials bonded together: glass-ionomer cement, hybrid-like layer, demineralized dentin, and dentin, all of which have different elastic moduli. In addition, GIC may contain numerous air bubbles that can act as stress points, thus giving rise to the increased likelihood of cohesive fracture within the cement (20). Since a large number of cohesive fractures were observed, they were included in the statistical analysis, although, the true bond strength is represented by fracture in the adhesive interface.

We speculated that a larger number of cohesive fractures in GIC would be observed in the two-layered group, which did not occur. Although it was not possible to evaluate if cohesive fractures occurred between the two layers, no difference was found compared to control group. In contrast, cohesive fracture in dentin was more prevalent in the two-layered group, probably due to the presence of less voids in the two-layered GIC (19), which could improve the strength properties of the material. Likewise, premature fractures were less prevalent when flowable GIC layer was applied to sound dentin (around 5% compared to others groups) indicating a better adhesion.

Long term studies should be conducted to confirm the bonding success of the two-layered GIC to dentin clinically before encouraging the use of a flowable GIC as a liner to enhance the longevity of proximal-ART restorations in primary teeth.

Conclusion

The effect of the application of flowable GIC layer on bond strength to dentin is substrate dependent and results in a decrease in adhesion for caries-affected dentin.

Acknowledgements

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References
