Microleakage of acid etched glass ionomer sandwich restorations

Bona A D¹, Pinzetta C¹, Rosa V²

Abstract

The objectives of this study were to evaluate the sealing ability of different glass ionomer cement (GIC) materials used for sandwich restorations and examine the influence of acid etching the GIC on microleakage of GIC-resin composite interface. Two cavities were prepared in 20 teeth, divided in four groups (n=10) and restored as follows: CIE – conventional GIC (CI) was applied onto the axial and cervical cavity walls, allowed to set for 5 min and acid etched (E) along with the cavity margins, with 35% phosphoric acid for 15 s, washed for 30 s and blotting the water; the adhesive system was applied and light cured for 10 s, completing the restoration with resin composite cured for 40 s; CIN – same procedure as described for CIE, but no acid was applied onto the CI; RME – same procedure as for CIE, but using the resin modified GIC (RMGIC); RMN – same procedure applied for RME without acid etching the RMGIC. Specimens were soaked in 1% methylene blue dye solution at 24°C for 24 h, rinsed under running water for 1 h, cut and dye penetration was measured following the ISO/TS 11405-2003 standard. Results were statistically analyzed using Kruskal-Wallis and Chi Square tests (α=0.05). Dye penetration scores were as follow: CIE– 2.5; CIN– 2.5; RME– 0.9 and RMN– 0.6. Results suggest that acid etching the GIC prior the placement of resin composite do not improve the sealing ability of sandwich restorations. The RMGIC was more effective at preventing dye penetration at the GIC-resin composite-dentine interfaces than CI. First published in J Appl Oral Sci 2007; 15: 230-4.

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Introduction

The glass-ionomer cement (GIC) was presented by Smith in the late 1960’s, resulting from the replacement of phosphoric acid to polyacrylic acid in zinc phosphate cements. The original idea was to unite properties such as high strength, hardness and the capacity to release fluoride from the silica glass powder with the biocompatibility and adhesion ability of the polyacrylic acid liquid¹. The anticariogenic property resulted from fluoride release turned out to be the most attractive aspect of this dental material. In addition, the GIC adhesion mechanism to tooth structure, the thermal compatibility with tooth enamel, the biocompatibility and low cytotoxicity render to GIC an interesting clinical option for restorative treatments².
Since the first commercial appearance of GIC (ASPA, Dentsply De Trey Ltd, Weybridge, UK) in 1976, this material has undergone important modifications in composition to improve the tensile strength, fracture toughness, working time, chemical solubility, and polishing appearance. Therefore, new varieties of this material were developed, such as the light-cured resin modified glass ionomer cement (RMGIC). This material is obtained by adding a resin, usually the water-soluble polymerizable 2-hydroxy-ethyl methacrylate (HEMA), into the liquid and the bonding process to tooth structure takes place by micromechanical retention, as in the resin composites. The setting reaction of RMGIC follows two distinct mechanisms: the resin polymerization and the acid-base reaction. The former can be initiated by light exposure or by an oxidation-reduction reaction (self-curing) and is responsible for the immediate set. The acid-base reaction takes place slowly and continues after clinical set.

The advantages of this restorative material include longer working time and operator control over the setting reaction by light activation of the resin component and, consequently, an earlier development of higher bond strength, reduced brittleness, increase of tensile and flexural strengths, resistance to desiccation and acid attack, lower moisture sensitivity and solubility. Yet, the mechanical properties (Table 1) and aesthetic appearance still limit the clinical use. Thus, the so-called sandwich restoration or “composite-laminated GIC” technique has been used by clinicians to preserve the fluoride release mechanism and the chemical bond to tooth structure provided by the GIC and RMGIC, and to improve the aesthetic and mechanical properties using a resin composite laminate. Leakage has long been recognized as a problem in restorative dentistry. Microleakage evaluations are used to estimate the resistance of tooth-restoration interface to the passage of bacteria, fluids, chemical substances, molecules and ions.

**Table 1.** Representative properties (references) of GIC and RMGIC materials.

<table>
<thead>
<tr>
<th>Property</th>
<th>GIC</th>
<th>RMGIC</th>
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<tbody>
<tr>
<td>Working time</td>
<td>2 min</td>
<td>3 min 45 s</td>
</tr>
<tr>
<td>Setting time</td>
<td>4 min</td>
<td>20 s</td>
</tr>
<tr>
<td>Young’s Modulus</td>
<td>20.5 GPa</td>
<td>55.9 GPa</td>
</tr>
<tr>
<td>Compressive strength</td>
<td>265.3 – 306.2 MPa</td>
<td>196.5 – 301.3 MPa</td>
</tr>
<tr>
<td>Diametral tensile strength</td>
<td>16 MPa</td>
<td>37 MPa</td>
</tr>
<tr>
<td>Flexural strength</td>
<td>71 – 82 MPa</td>
<td>21.2 – 31.4 MPa</td>
</tr>
<tr>
<td>Knoop hardness</td>
<td>66.4 – 84.5 KHN</td>
<td>29.7 – 176.8 KHN</td>
</tr>
<tr>
<td>Tensile bond strength</td>
<td>4.9 MPa</td>
<td>11.36 MPa</td>
</tr>
<tr>
<td>Tensile bond strength</td>
<td>2.52 MPa</td>
<td>5.55 MPa</td>
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<tr>
<td>Shear bond strength</td>
<td>4.6 MPa</td>
<td>11.3 MPa</td>
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<tr>
<td>Shear bond strength</td>
<td>4.3 MPa</td>
<td>8.2 MPa</td>
</tr>
</tbody>
</table>
The absence of a seal at restoration margins promotes tooth discoloration, adverse pulp response, postoperative sensitivity, and recurrent caries. Thus, some in-vitro studies intended to predict the clinical marginal sealing ability of several restorative techniques found lower levels of microleakage when the GIC was used as a filling material below the resin composite. Despite these enthusiastic results, the clinical performance of sandwich restorations does not seem to be very effective and some failures were reported, mainly concerning the GIC portion. Some authors testify that this laminate restoration is an interesting alternative to amalgam, especially in patients with caries risk. Other studies suggested that the failures could be related to an inadequate selection of the GIC-composite system, which should offer great tensile strength, a bonding agent with high wettability and a resin composite with small setting shrinkage.

The bonding mechanisms of restorative materials to tooth tissues are often explained in the literature. Yet, few studies reported on aspects regarding the restorative materials used in sandwich techniques. Meaning, the pre-treatment of enamel and dentin before the application of a bonding system and restorative materials is well established in the literature, however the need of a GIC surface treatment before the application of the resin composite in sandwich restorations still remains debatable. Although acid-etching of GIC increases the tensile bond strength to resin composite, the influence of this conditioning step on microleakage has not been reported. The objectives of this study were to evaluate the influence on sealing ability of different GIC materials used for a sandwich restoration technique and the effect of acid etching the GIC surface on microleakage between the restorative materials, testing the hypothesis that acid etching the GIC surface do not increase the sealing ability between the GIC materials and the resin composite.

**Material and method**

Twenty extracted non-carious permanent human premolars with fully developed roots were selected for this study, which was approved by the local Ethics in Research Committee. The teeth were cleaned from calculus, soft tissue and other debris, and stored in 2% chloramine solution at 5°C. Two window-like cavities were performed on both proximal sides of each tooth using diamond burs (no. 3145 and FG58L, KG Sorensen, São Paulo, Brazil), as shown in Figure 1.

![Figure 1. Schematic image of the window-like cavity used in this study and its dimensions](image)

The study included a conventional (CI) (Ketac Fill Plus, lot 178566, 3M-ESPE St. Paul, USA) and a light cured resin modified glass ionomer cement (RMGIC) (Vitremer, lot 4JP 2007-12, 3M-ESPE St. Paul, USA) materials, an adhesive system (AS) (Adper Single Bond, lot 4BU 2007-11, 3M-ESPE St. Paul, USA) and a resin composite (RC) (Filtek Z250, lot 2LR 2006-05, 3M-ESPE St. Paul, USA). All materials were manipulated at room temperature (23°C) following the
manufacturers’ instructions. The forty cavities were randomly divided into four groups (n=10) and restored using the sandwich technique\(^\text{19}\). The experimental groups were as follows: CIE- CI was applied onto the axial and cervical cavity walls, allowed to set for 5 min and acid etched (E), along with the cavity margins, with 35% phosphoric acid for 15 s, washed with air-water spray for 30 s, and blotting the water with an absorbent sponge. The AS was applied and light cured (XL 3000, 3M-ESPE St. Paul, USA) for 10 s, completing the restoration with a layer of RC that was light cured for 40 s.

CIN- same procedure as described for group CIE, except for the application of E onto the CI material.

RME- same procedure as described for group CIE, but using the RMGIC material.

RMN- same procedure as described for group CIE, but using the RMGIC material and no E applied onto the material.

All restorations were polished using sof-lex discs (Polishing Discs, 3M-ESPE St. Paul, USA). Teeth were coated with 3 layers of nail varnish (Risqué, lot 331526, Niasi S/A, Taboão da Serra, SP, Brazil), except for a window area that included the restoration and 1 mm around it, and soaked in 1% methylene blue dye solution at 24 °C for 24 h, then rinsed under running water for 1 h.

Teeth were adapted to an automatic cutting machine (Struers Minilotom, Struers A/S, Denmark, serial number 4430782) using a diamond wheel saw, low speed (250 rpm) and water refrigeration, making a longitudinal cut to separate the mesial from the distal side of all teeth. Then, at least two slices of about 1 mm thick were made within the restored area. Whenever more than two slices were obtained per restoration, only two of them were kept for the study, being one slice above the CEJ (cementoenamel junction) and another below the CEJ. Therefore, 4 surfaces per restoration were examined in an optical microscope (Meiji EMZ-TR, Meiji Techno Co LTD., Tokyo, Japan, serial number 32278, magnification 10x-65x) for marginal sealing and leakage (40 surfaces per group). Representative images were recorded from all specimens and maximum degree of dye penetration was registered according to the following scores (ISO/TS 11405-2003)\(^\text{23}\):

- 0 = no dye penetration;
- 1 = dye penetration into the enamel part of the cavity wall;
- 2 = dye penetration into the dentine part of the cavity wall but not including the pulpal floor of the cavity;
- 3 = dye penetration including the pulpal floor of the cavity.

Results were statistically analyzed using Kruskal-Wallis at a significant level of 5% (\(\alpha=0.05\)), and Chi Square tests for the two types of GIC and for the acid-etched effect on the two GIC (\(\alpha=0.05\)).

Results

The dye penetration scores by experimental groups, the mean dye penetration and the statistical grouping are summarized in Table 2. No significant differences were found between the mean dye penetration values of groups CIE and CIN (\(p>0.05\)), and between groups RME and RMN (\(p>0.05\)). When the two surface treatments (E and N) were considered, irrespective of the materials (CI and RM), no statistical differences were found (\(p>0.05\)). However, significant differences were found between the two GIC (CI and RM), regardless the surface treatments, with CI showing a significantly greater mean dye penetration score than the RM mean values (\(p<0.05\)).
Dye penetration at the GIC-RC interface occurred in 4 teeth, being 3 in the CIE group and 1 in the CIN group. This finding was statistically insignificant (p>0.05).

Whenever a microleakage was observed, the maximum degree of dye penetration was always found within the slice obtained below the CEJ.

**Table 2.** The sample size, the dye penetration scores by experimental groups, the mean dye penetration and the statistical grouping

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>Mean*</th>
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<tr>
<td>CIE</td>
<td>10</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>7</td>
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<tr>
<td>CIN</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>RME</td>
<td>10</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>RMN</td>
<td>10</td>
<td>7</td>
<td>0</td>
<td>3</td>
<td>0</td>
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</tbody>
</table>

*Group mean values succeeded of same letter are not statistically different at p>0.05

**Discussion**

The polymerization shrinkage developed during the conversion of the monomer molecules into a polymer network is an undesirable resin composite phenomenon and can be considered one of the factors responsible by the lack of restoration adaptation to the cavity wall, increasing susceptibility to caries especially in the deep part of the proximal box of Class II cavities. The use of GIC as base material in conventional sandwich restoration reduces considerably the bulk resin composite used, so, the amount of shrinkage polymerization of resin composite is decreased and the marginal adaptation may be improved. A further advantage of the sandwich technique is the fluoride releasing property of GIC, which is considered to have some inhibitory effect on caries formation and progression around the restoration.

GIC is still considered the only material that self-adhere to tooth tissue and it has been previously shown that GIC and resin composite can adhere effectively to each other, regardless the limitations concerning this system. The bond strength between these materials is influenced by, at least, four factors: 1) the tensile strength of GIC, which is mostly dependent on the powder/liquid ratio; 2) the viscosity of the bonding agent and its ability to wet the GIC surface; 3) the volumetric change in the resin composite material during polymerization and; 4) the difficulties in packing and adaptation of the resin composite to the GIC without incorporation of voids. It was suggested that the acid etching procedure of GIC would allow for a cleaned mildly roughened surface with high surface energy. It has been assumed that this procedure could provide the requirements necessary to a closer contact and a greater interlocked interface between GIC and resin composite. Despite these considerations, the results of this study suggest that acid etching the CI and RM surfaces does no improve the seal ability for sandwich restorations.

Considering the GIC materials examined, the sandwich restorations using RM showed significantly less dye penetration than the restorations using CI, which is in agreement with the results of a previous report. In addition, no significant differences were found for the surface treatments (E and N) on same material. These findings suggest that the acid etching option for GIC is not significantly relevant compared with the type selection of the GIC, which should be one with improved mechanical properties and chemical composition (Table 1). Previous studies showed that the inability of CI material to produce an effective...
seal depends on two factors: 1) the material’s sensitivity to moisture during placement and early set; and 2) the dehydration after set, resulting in crazing and cracking. Yet, it is assumed that the superior seal behaviour of RM is a result of resin tags into the dentin tubules allied to the ion exchange process present in the interface between dentin and RM, as previously reported. Although some studies do not testify the presence of these resin tags or even the formation of an hybrid layer, this assumption stands to be the reason for the superior performance of the RMGIC. In addition, the presence of HEMA in the RMGIC is responsible for the increased bond strengths to resin composite and should contribute to prevent the dye penetration through the interface of these materials, as showed by the results of this study.

**Conclusion**

Within the limitations of this study, the results suggest that acid etching the GIC using phosphoric acid prior the placement of resin composite does not improve the sealing of sandwich restorations. The resistance to dye penetration at the interfaces (GIC-resin composite-dentine) seemed to be primarily controlled by the type of GIC, with the RMGIC producing significantly less dye penetration than conventional GIC.

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**Resumen**

Los objetivos de este estudio fueron evaluar la capacidad de sellado de los diferentes cementos ionómero vítreos (CIV) usados para restauraciones sándwich, y examinar la influencia de grabado ácido del CIV en el microfilamento de la interfase CIV-compuesto de resina. Se prepararon dos cavidades en 20 dientes divididos en cuatro grupos (n=10) y restaurados de la siguiente manera: CIE - se aplicó CIV convencional (CI) a las paredes axiales y cervicales de la cavidad, permitiendo que se asentara por espacio de 5 min., y se grabaron con ácido (E) junto con los márgenes de la cavidad, con 35% de ácido fosfórico durante 15 seg., se lavó durante 30 seg. absorbiendo el agua, se aplicó el adhesivo y se curó con luz durante 10 seg., completando la restauración con compuestos de resina curados durante 40 seg.; CIN –procedimiento igual al descrito para CIE, pero no se aplicó ácido al CI; RME – procedimiento igual al descrito
para CIE, pero utilizando CIV modificado por resina (CIV-MR); RMN – procedimiento igual al aplicado para RME sin grabar con ácido el CIV-MR. Se mojaron los especímenes en 1% de solución de azul de metileno a 24ºC durante 24 hrs., se enjuagaron bajo agua corriente durante 1 hr., se midió el corte y penetración del tinte según los estándares ISO/TS 11405-2003. Los resultados se analizaron estadísticamente utilizando las pruebas Kruskal-Wallis y ji-cuadrado (α=0.05). Los marcadores de penetración de tinte fueron: CIE = 2.5; CIN = 2.5; RME = 0.9 y RMN = 0.6. Los resultados sugieren que el grabar con ácido el CIV antes de colocar el compuesto de resina, no mejora la capacidad selladora de las restauraciones sándwich. El CIV-RM fue más eficaz que el CI en la prevención de penetración del tinte en las interfaces GIC-compuesto de resina-dentina. Publicado primero en J Appl Oral Sci 2007; 15: 230-4.

References

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Various accessories

Cervitec Gel delivery forms

Single Tube
Cervitec Gel, 20g

Single Tube
Cervitec Gel, 50g

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<td>Plaque Test</td>
<td>increasing enamel</td>
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<td></td>
<td>resistance</td>
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Literature


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