Effect of Different Cavity Lining Techniques on Marginal Sealing of Class II Resin Composite Restorations In Vitro

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This study investigated the effect of different cavity lining techniques on the marginal sealing of Class II composite restorations. A total of 36 human molar teeth, free of caries and fillings, were each prepared with two proximal Class II boxes mesially and distally. In mesial boxes, cavity liners were applied as follows: in group 1, separately cured flowable composite; in group 2, co-cured flowable composite; and in group 3, resin-modified glass ionomer (RMGI). The remaining cavities were filled incrementally with a universal restorative composite. The distal boxes were filled with no liner as controls. After thermocycling, the specimens were immersed in a silver nitrate solution and the microleakage was evaluated. Analysis of variance showed that the degree of microleakage for group 3 was significantly lower than that of the other groups. Based on the results, it was concluded that the use of RMGI as a cavity liner under composite restorations showed the least microleakage. Flowable composites, whether co-cured or separately cured, had no influence on the marginal sealing. Int J Periodontics Restorative Dent 2018;38:895–901. doi: 10.11607/prd.3331

Resin composites have undergone developmental improvements in terms of several characteristics, including esthetics, wear rate, and handling. However, polymerization shrinkage remains a major disadvantage of composite restorations. In vitro measurements of polymerization shrinkage of resin composites range from 1.9% to 6%.1 This shrinkage can create contraction forces that lead to the disruption of the bond to the tooth structure.

Esthetic dentistry is based on adhesive procedures to increase the retention and resistance of the tooth-restoration interface and hence to obtain a better marginal sealing.2 With advances in dental adhesives, esthetic resin composites have become more widely used in posterior restorations. However, marginal sealing remains a problem, especially at the gingival wall of Class II composite restorations. Poor marginal sealing can be associated with postoperative sensitivity, secondary caries, marginal discoloration, and restoration failure. Various clinical procedures, lining materials, and incremental techniques have been suggested to reduce polymerization shrinkage and improve the marginal sealing of composite restorations. The use of self-curing composites for deeper cavities or dentogingival margins has been suggested.3 Other studies have reported that glass-
ionomer (GI) liners could reduce marginal leakage\textsuperscript{4,5} or enhance the bond strength between composite and dentin.\textsuperscript{6} The use of flowable composites and resin-modified glass ionomers (RMGI) also has been advocated as a means to reduce the possibility of microleakage.\textsuperscript{4,7–9} However, none of these techniques completely prevented marginal leakage.

Another suggestion has been the use of flowable composites in conjunction with posterior resin composite restorations, which is called snowplow technique.\textsuperscript{10} In this technique, an initial thin increment of flowable composite is placed over the gingival and/or pulpal floors of the cavity preparation. This layer is not cured at this stage. A heavily filled restorative resin composite is pushed into the unset flowable composite. Most of the flowable resin composite is displaced by the restorative composite and is subsequently removed from the cavity. Therefore, a small amount of flowable composite would remain in those areas where the higher-viscosity composite cannot completely adapt to the cavity walls. The combined layer of flowable and restorative composites is then cured. This technique may significantly reduce void formation compared to the placement of restorative composite alone.

The purpose of this in vitro study was to evaluate the degree of microleakage of Class II composite restorations in comparison with the restorations associated with flowable composites (light-cured separately or co-cured) and RMGIs as cavity liners.

### Materials and Methods

A total of 36 human molar teeth, free of caries and fillings, were selected, disinfected in 0.5% chloramine-T solvent for 7 days, and then stored in distilled water at room temperature until use. The teeth were prepared with two proximal Class II boxes mesially and distally, approximately 3 mm wide and 2 mm deep, that ended at the cementoenamel junction. Each diamond bur was used to prepare four cavities. Descriptions of the materials used are provided in Table 1. The teeth were then randomly divided into three groups (n = 12). The mesial boxes of each group were restored as test groups.

In group 1, the teeth were etched by 35% phosphoric acid for 20 seconds, rinsed for 10 seconds, and slightly dried. Two layers of bonding (Adper Single Bond 2) were applied, air-dried gently with oil-free compressed air for 5 seconds, and then light-cured for 20 seconds using an LED light-curing unit (BlueLex GT1-200, Monitex, at 800 mW/cm² light intensity). One layer of a flowable composite (Filtek Z350 XT, 3M ESPE) approximately 1 mm thick was then applied on the axial and gingival walls of the cavities and light-cured for 40 seconds, and the remaining cavities were incrementally filled with a universal composite (Filtek Z350, 3M ESPE) and light-cured for 40 seconds.

### Table 1 Materials Used

<table>
<thead>
<tr>
<th>Material</th>
<th>Type</th>
<th>Composition</th>
<th>Manufacturer</th>
<th>Lot no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultra-Etch</td>
<td>Etchant</td>
<td>35% phosphoric acid</td>
<td>Ultradent</td>
<td>B7F3P</td>
</tr>
<tr>
<td>Adper Single Bond 2</td>
<td>Adhesive</td>
<td>Silica nanofiller, bisGMA, HEMA, dimethacrylates, ethanol, water. A novel photo initiator system and a methacrylate functional copolymer of polyacrylic and polyitaconic acid.</td>
<td>3M ESPE</td>
<td>N460339</td>
</tr>
<tr>
<td>Filtek Z350 (shade A1)</td>
<td>Universal restorative resin composite</td>
<td>BisGMA, UDMA, TEGDMA, bis-EMA, PEGDMA. The fillers are a combination of nonagglomerated/nonaggregated 20-nm silica filler, nonagglomerated/nonaggregated 4- to 11-nm zirconia filler, and aggregated zirconia/silica cluster filler; 78.5% filler by weight (wt %).</td>
<td>3M ESPE</td>
<td>N286019</td>
</tr>
<tr>
<td>Filtek Z350 XT (shade A1)</td>
<td>Flowable resin composite</td>
<td>Bis-GMA, TEGDMA and bis-EMA, dimethacrylate polymer; 65% filler by weight (wt %)</td>
<td>3M ESPE</td>
<td>N398475</td>
</tr>
<tr>
<td>GC Gold Label FUJI II LC (shade A1)</td>
<td>Resin-modified glass ionomer</td>
<td>Powder: fluro alumino silicate glass; liquid: polyacrylic acid, 2-HEMA, distilled water, initiator, urethane dimethacrylate, camphorquinone</td>
<td>GC</td>
<td>1402071</td>
</tr>
</tbody>
</table>

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The teeth in group 2 were prepared the same as in group 1, but the flowable composite was not light-cured separately. The flowable composite was applied on the axial and gingival walls of cavities, and a thin layer of universal restorative composite was packed inside the cavities such that some of the flowable composite was pushed out and removed. The flowable and universal restorative composites were then co-cured together. The remaining cavities were incrementally filled with the universal restorative composite and light-cured.

In group 3, the cavities were first filled with the RMGI cement (FUJI II-LC, GC) as a liner (approximately 1 mm thick) and light-cured for 20 seconds. The cavities were then etched with 35% phosphoric acid for 20 seconds, rinsed, and slightly air-dried. Two layers of bonding (Adper Single Bond 2) were applied, air-dried gently, and light-cured for 20 seconds. The remaining cavities were then filled incrementally with the restorative composite.

The distal boxes in each group were restored with no liner as controls. The distal boxes were etched with 35% phosphoric acid for 20 seconds, rinsed, and slightly air-dried. Two layers of bonding (Adper Single Bond 2) were applied, air-dried gently for 5 seconds, and light-cured for 20 seconds. Then the restorative composite was placed incrementally and light-cured for 40 seconds.

All the composite restorations were then polished with soft burs and polishing points and stored in distilled water at 37°C for 24 hours in an incubator (Memmert). The specimens were thermocycled between 5°C and 55°C for 3,000 cycles with 20 seconds of dwell time. After thermocycling, all the apices were sealed with the resin composite, and two layers of nail polish were applied to the whole surface of the specimens with the exception of approximately 1 mm surrounding the cavity margins. The specimens were immersed in a 1-M silver nitrate solution for 6 hours. They were then washed under running water, submerged in a radiographic developing solution for 12 hours, and kept under a fluorescent light for 6 hours.

All the specimens were mounted in acrylic molds and sectioned mesiodistally with a high-speed saw under water. The degree of microleakage was then evaluated using a stereomicroscope (EZ4D, Leica Microsystems). The lengths of the axial and gingival walls were measured along with the corresponding lengths of microleakage occurring along each wall. Total microleakage percentage was defined as the sum of the measured lengths of penetrated silver nitrate along the axial and gingival walls divided by the sum of the measured lengths of the axial and gingival walls. Mean total microleakage was compared between the mesial and distal boxes prepared in one tooth as test and control groups, respectively.

Kolmogorov-Smirnov and Shapiro-Wilk test showed that the distribution of microleakage data was normal. Data were analyzed using one-way analysis of variance to compare the extent of microleakage between groups. In each group, the microleakage values of mesial boxes (test) were adjusted with those of distal boxes (control) in the same teeth, and the adjusted mean microleakage for each group was obtained. Bonferroni post hoc test was then used for pairwise comparison. To compare the mean microleakage between each group and its control in the same teeth, paired t test was used. The level of significance was set at $P < .05$ using statistical software (SPSS 11 for Windows, SPSS).

**Results**

A representative picture of the microleakage determination in the axial and gingival walls of the cavities is shown in Fig 1. The microleakage data for all groups are presented in Table 2.

The RMGI (group 3) had the smallest extent of microleakage. Statistical analysis showed that the degree of microleakage for group 3 was significantly lower than for group 1 (separately cured flowable composite) and group 2 (co-cured flowable composite), as shown in Table 3 ($P < .001$). No significant difference in the microleakage between group 1 (separately cured flowable composite) and group 2 (co-cured flowable composite) was found ($P = .07$).

In addition, the degree of microleakage for the specimens lined with the RMGI was significantly lower than that of their corresponding controls ($P = .02$). However, there was no significant difference in microleakage for the specimens lined with the separately cured or co-cured flowable composites compared with that of their controls ($P = .90$ and $P = .60$, respectively).
Discussion

Marginal seal is one of the most important factors in the clinical success of composite restorations. Microleakage evaluation is still the most popular method to evaluate the interfacial bond between the tooth structure and materials. In this study, the silver nitrate dye penetration technique was employed. The use of silver nitrate to measure microleakage is an acceptable technique. However, the silver ion is extremely small (0.059 nm) and more penetrative when compared to a typical bacterium (0.5 to 1.0 μm). Therefore, it may be assumed that any material that prevents silver ion leakage will also prevent leakage of the bacteria or even acid insult. This silver staining technique could provide a discrete and high-contrast marking of the restoration/dentin interface. Furthermore, thermocycling was used as a widely acceptable method to simulate the intraoral thermal stresses at the tooth-restoration interfaces to mimic clinical conditions in this study.

Microleakage is influenced by the structure of each tooth, including

Table 2 Mean (SD) Total Percent of Microleakage and Mean Values (μm) of the Sum of Axial and Gingival Wall Lengths and Microleakage Along the Walls

<table>
<thead>
<tr>
<th>Group 1</th>
<th>Separately cured flowable composite</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sum of axial and gingival wall length (L_A + L_G)</td>
<td>6306.79 (750.35)*</td>
<td>6201.43 (635.34)</td>
</tr>
<tr>
<td>Sum of microleakage along the axial and gingival walls (M_A + M_G)</td>
<td>4145.82 (659.93)</td>
<td>4099.63 (992.42)</td>
</tr>
<tr>
<td>Mean total % microleakage</td>
<td>65.54 (5.11)</td>
<td>65.98 (12.92)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group 2</th>
<th>Co-cured flowable composite</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sum of axial and gingival wall length (L_A + L_G)</td>
<td>6134.65 (617.82)</td>
<td>6052.6 (876.61)</td>
</tr>
<tr>
<td>Sum of microleakage along the axial and gingival walls (M_A + M_G)</td>
<td>3241.23 (1387.75)</td>
<td>2906.65 (969.23)</td>
</tr>
<tr>
<td>Mean total % microleakage</td>
<td>52.88 (21.35)</td>
<td>48.46 (16.1)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group 3</th>
<th>Resin-modified glass ionomer</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sum of axial and gingival wall length (L_A + L_G)</td>
<td>6286.91 (685.16)</td>
<td>6666.46 (753.07)</td>
</tr>
<tr>
<td>Sum of microleakage along the axial and gingival walls (M_A + M_G)</td>
<td>1039.73 (393.60)</td>
<td>2761.52 (1872.35)</td>
</tr>
<tr>
<td>Mean total % microleakage</td>
<td>17.07 (7.49)</td>
<td>40.04 (26.09)</td>
</tr>
</tbody>
</table>

Table 3 Pairwise Comparison Between Groups

<table>
<thead>
<tr>
<th>Group 1</th>
<th>Separately cured flowable composite</th>
<th>Adjusted mean*</th>
<th>Standard error</th>
<th>95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>66.79a</td>
<td>4.28</td>
<td>58.07 75.51</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group 2</th>
<th>Co-cured flowable composite</th>
<th>Adjusted mean*</th>
<th>Standard error</th>
<th>95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>52.63a</td>
<td>3.91</td>
<td>44.66 60.60</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group 3</th>
<th>Resin-modified glass ionomer</th>
<th>Adjusted mean*</th>
<th>Standard error</th>
<th>95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>16.09b</td>
<td>4.14</td>
<td>7.66 24.52</td>
</tr>
</tbody>
</table>

*Mean microleakage (%) of each group adjusted with its corresponding control. Different superscript letters indicate significant differences between groups (P < .05).
the origin and quality of the tooth’s hard tissues, the diameter and direction of dentinal tubuli, tooth age, and so on. That is why the present study did not use other teeth with different parameters as a separate control group and did not compare the controls between groups. Within each group, the lining material was used in mesial boxes (test) while the distal boxes in the same teeth were considered as corresponding controls with no lining material. Therefore, the microleakage values of mesial boxes were only compared and adjusted with that of distal boxes (control) in the same teeth to determine the real effectiveness of the liner in reducing the extent of leakage.

Many studies have shown that the placement of cavity liners could reduce the microleakage and increases the bond strength and fracture-resistance values. The results of the present study showed that the use of RMGI cement as a liner (open-sandwich technique) provided the least degree of microleakage in Class II composite restorations. Previous studies have shown the benefits of RMGI cements in lowering microleakage due to its thermal expansion similar to that of dental structures that may be important for the maintenance of marginal integrity following thermal stressing. Other advantages of RMGI cement are its bacteriostatic function, molecular bonding to dentin and enamel, and low setting shrinkage.

The restoration of deep proximal cavities has several problems, including the difficulty of placement of a rubber dam, the time-consuming incremental packing technique, and the intricate handling required by some dentin-bonding systems. It would be relevant to look at the GI family materials with the aim of solving current problems in adhesive bonding, because these materials are naturally self-adhesive to tooth structure. The mechanism of this adhesion involves chelation of carboxylic groups of polyacids with the calcium in the apatite of enamel and dentin. However, the open sandwich technique failed clinically when conventional GIs were used to restore the cervical margins of Class II restorations, mainly because of a continuous loss of material. The newly developed RMGIs have been used in place of the conventional GI. These newer materials can polymerize on light activation due to the inclusion of resin in the GI formulation. The resin also completes the chemical bond GI achieves with the tooth structure by micromechanically bonding. The use of RMGI as base material in an open sandwich restoration also reduces the bulk resin composite used, decreasing the extent of polymerization shrinkage of the resin composite and possibly improving the marginal adaptation. A further advantage of the sandwich technique is the fluoride-releasing property of RMGI, which is considered to inhibit caries formation around the restoration.

In agreement with the current study, another investigation demonstrated the effectiveness of RMGI as a liner under composite restorations for decreasing microleakage. Increased silver nitrate penetration for the direct resin composite restorations under simulated extreme environmental conditions also has been reported. Restorations with RMGI cements used in the open sandwich technique appeared to be more tolerant toward temperature and relative humidity parameters, and simulated intraoral conditions compared with the modern adhesive systems.

Furthermore, it has been shown that the RMGI open sandwich technique had significantly less microleakage than the use of a dentin-bonding agent alone or in combination with flowable composite, flowable compomer, or autopolymerizing composite in deep Class II direct composite restorations. The good sealing ability of RMGI can be also explained by its water sorption and subsequent expansion of the material, which could result in decreased marginal gaps between restorations and teeth.

The other intermediate material used in this study was flowable composite, which may be able to reduce stress during polymerization shrinkage and provide better sealing to the dental structure as a result of its lower elastic modulus. Because of its low filler content, the flowable resin composite presents remarkable higher-flow characteristics compared to a restorative resin composite. As a result, improved wetting of the tooth surface and a low modulus of elasticity can be achieved. Two clinical benefits can be expected: first, a reduction in marginal microleakage in the short term as a result of stress reduction by flow property, and second, a reduction in marginal microleakage over the long term because of improved durability under
flexural load. Although the manufacturers have recommended curing the flowable composite prior to applying the restorative materials, Belvedere reported that the hydraulic pressure of heavier-viscosity composite would help uncured flowable composite penetrate better and improve the marginal sealing. Thus, it was the authors’ interest to find out whether co-cured or separately cured flowable composite under restorative composites would have any effect on microleakage. The results of the present study indicated that the use of flowable composite (either separately cured or co-cured) under nonflowable composite restorations had no benefit in reducing the extent of microleakage. The Filtek Z350 XT flowable composite used in this study has 50% to 60% filler particles by weight, which reduces its rigidity, and it contains 20% to 25% less filler in comparison with nonflowable composites. The results are in agreement with those of another investigation on Class II restorations and with those of Swift et al, who reported that the use of an intermediate low-viscosity resin did not have any consistent effect on microleakage in Class V composite restorations. In addition, no significant differences in the microleakage of the restorations with or without the use of flowable composite were found when the gingival margins were placed in the enamel. However, the leakage could be greater when the margins of filling were placed in the cementum or dentin. A recent review article concluded that the application of flowable composite as a liner in composite restorations cannot reduce microleakage or improve clinical performance. On the contrary, other studies have reported that flowable resins as liners decreased the extent of microleakage by sealing the cavity margins.

The inconsistent findings associated with the use of flowable composites can be explained in two ways. First, despite their low elastic modulus, the contraction stress produced by some flowable composites could be sufficiently high because of their high volumetric shrinkage, leading to adhesive failure at the interface between the tooth and the composite when the material is used as a thin intermediate layer or to fill the entire cavity. Second, although flowable composites generally have a lower elastic modulus than nonflowable composites, the elastic modulus for some materials might not be low enough to provide significant stress relief. Braga et al found no difference in the contraction stress level between flowable and nonflowable composite materials. They suggested that the risk of the restoration debonding from the cavity wall as a result of polymerization contraction was similar for both types of composite material. It appears that the influence of the low elastic modulus on stress development of flowable composites is surpassed by their high contraction strain, resulting in stress levels that are equivalent to those obtained with nonflowable materials.

In addition, the composition of flowable composites varies widely. Besides filler content, variables such as resin blend and the concentration and type of photosensitizers and accelerators account for differences in elastic modulus and strain capacity, which ultimately determine the percentage of stress relief they allow. These characteristics may explain the results obtained in this study. It should be noted that the different results obtained in many studies in the literature may be related to the different types of materials used, tooth structure, location of the restorations, type and size of the cavities, operator factors, and research methodologies. Besides, the results of this in vitro study might not necessarily be extrapolated to the clinical situation due to the different complications in the oral environment. Further in vitro and in vivo studies using other different types of flowable composite liners and bonding systems may be required.

Conclusions

Within the limitations of this in vitro study, the following conclusions were drawn:

- None of the liners tested in this study completely eliminated microleakage.
- The use of RMGI as a liner under Class II composite restorations showed the smallest extent of microleakage.
- There was no significant difference in the degree of microleakage between co-cured and separately cured flowable composite under Class II composite restorations compared with their corresponding control groups.
The use of flowable composite as a liner (either co-cured or separately cured) had no influence on the marginal sealing of Class II composite restorations.

Acknowledgments

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References