Effect of Preheating Resin Composite and Light-curing Units on the Microleakage of Class II Restorations Submitted to Thermocycling

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Clinical Relevance
Deficient polymerization can occur in deeper cavities due to the dispersion of light irradiance, and it may affect microleakage of the tooth-restoration interface. When using a quartz-tungsten-halogen light-curing unit with relatively low irradiance (420 mW/cm²) to restore a Class II restoration, microleakage can be reduced if the resin-composite is heated prior to use.

ABSTRACT
This in vitro study evaluated microleakage in Class II cavities restored with dental composite and varying light-curing units and the temperature of the composite when subjected to a thermocycling test. Ninety cavities were prepared on the proximal surfaces of bovine teeth and randomly divided according to the light-curing mode (QTH–420 mW/cm², LED 2nd generation–1100 mW/cm², or LED 3rd generation–700 mW/cm²) and...
temperature of the resin composite (23°C, 54°C and 60°C). Following the restorative procedures and thermocycling, the samples were immersed in methylene blue for 12 hours. The samples were ground and the powder prepared for analysis in an absorbance spectrophotometer. All the results were statistically analyzed using the nonparametric tests of Kruskal-Wallis and Dunn (p≤0.05). The results showed that there was no statistical difference between the light-curing modes at a temperature of 23°C. For 54°C, QTH showed a microleakage mean that was significantly lower than those of the LED groups, and for 60°C, QTH had a microleakage mean significantly lower than that of the LED 2nd generation group. There was no statistical difference between the temperatures of the resin composite when LEDs were used. For QTH, 54°C showed statistically lower microleakage than 23°C. The group preheated to 60°C showed no difference when compared to the group heated to 23°C. Preheating the resin composite (54°C and 60°C) did not improve the microleakage means when high-irradiance LED was used; however, it decreased the microleakage means when a QTH with low irradiance was used.

INTRODUCTION

The appropriate polymerization of resin composite is essential in order to produce esthetic restorations with optimal properties and to maintain the integrity of the restoration interface. Deficient polymerization can occur in deeper cavities due to the dispersion of light energy as a result of the distance between the tip of the light-curing appliance and the first resin composite increment. In a deep Class II cavity, the interface between the tooth structure and first increment of the resin composite may be underpolymerized. The exposure of this interface to the oral environment can result in restoration fracture and increased solubility of the resin composite and adhesive, leading to microleakage and secondary caries.

In those situations, some studies have shown that polymerization of the resin composite is a heterogeneous complex process. Aguiar and others showed that, even with a distance of 8 mm from the tip of the light-curing unit, the top surface of a resin receives adequate irradiant energy. Therefore, on the top surface, high-irradiance photoactivation initiated a multitude of growth centers of polymers with higher cross-linking density. Low irradiant energy reached the bottom surface, which was in contact with the cervical wall, decreasing the degree of conversion and cross-linking density.

Soares showed that a high polymerization rate on the top surface and a lower polymerization rate on the bottom surface leads to higher bond strengths to the buccal and lingual walls and lower bond strengths on the cervical walls. More polymers bonding the resin composite and adhesive will be formed on surrounding walls that are nearer to the light-curing tip than on the cervical wall, creating a stress flow of polymerization shrinkage from the cervical walls to the surrounding walls—buccal and lingual—which may open a gap at the cervical interface.

A method for improving the degree of conversion of resin composite and reducing viscosity—improving the marginal adaptation of the restoration—is to preheat the resin composite before placing it in the cavity. Daronch and others found a higher degree of conversion in the top and bottom surfaces when the resin composite was preheated to 54°C and 60°C. Lucey and others showed that preheating the composite to 60°C also improved the hardness in both the top and bottom surfaces. These effects may be highly desirable in situations in which the polymerization of the resin composite cannot be effective due to the distance between the light-curing tip and the increment of the resin composite.

An increase in temperature decreases the viscosity of a resin composite and enhances radical mobility, resulting in additional polymerization. Furthermore, the additional free volume of the resin composite increases with the increase in temperature, improving the mobility of trapped radicals, resulting in further conversion. In this way, it is possible that preheating the resin composite shows a more homogeneous polymerization in the bottom and top surfaces of the resin composite, consequently leading to more homogeneous shrinkage and decreasing the microleakage on the cervical walls.

This in vitro study measured the microleakage of Class II dental restorations made with an adhesive system and a dental composite that are submitted to thermocycling, varying the light-curing unit and temperature of the composite. Thus, it was hypothesized that: 1) heating the resin composite leads to lower microleakage at the cervical interface of a restoration and 2) light-curing units with different irradiance levels show similar patterns of microleakage at the cervical interface when preheated resin composite is used.

METHODS AND MATERIALS

Ninety bovine incisors were cleaned with a periodontal curette to remove organic debris and polished with a rubber cup and pumice paste under water. They were then stored in distilled water until used. Bovine teeth present similarities to human teeth, such as the same number, density and diameter of dentinal tubules and prism orientation of the enamel; these teeth can be used as a substitute for human teeth.

The teeth were sectioned perpendicular to their long axes at a distance of 10 mm from the proximal cemento-enamel junction (Figures 1A and B) using a double-
faced diamond disc (KG Sorensen, Barueri, SP, Brazil). After cutting, the specimens were finished with water-abrasive papers (#600) to obtain a smooth, flat incisal surface.

**Specimen Preparation:** Cavities were made using a diamond tip #3146 (KG Sorensen) coupled to a cavity preparation unit on the flattest proximal surface, simulating Class II cavities measuring 8 mm high, 4 mm wide and 1.5 mm deep (Figure 1C) under irrigation with an air/water jet. The burs were replaced after every five preparations. The cavities were randomly sorted into one of four experimental groups and restored following the manufacturers’ instructions. The preparations were etched for 15 seconds using 35% phosphoric acid (3M ESPE, St Paul, MN, USA), then washed for 15 seconds and gently air-dried to prevent excessive dentin drying. The adhesive system Single Bond 2 (3M ESPE) was applied in two consecutive coats, lightly air-dried for 10 seconds and light-polymerized for 10 seconds. The nanofilled resin composite Filtek Z350, shade A2 (3M ESPE), was inserted in four horizontal increments, each 2 mm thick. The last coat of the adhesive and all increments of the resin composite were polymerized in accordance with their experimental group (n=10) (Table 1). Each increment of the resin composite was light-cured for 20 seconds. The resin composite used was stored in a bacteriological incubator (502, Fanem Ltda, Guarulhos, SP, Brazil) with respective preheating temperatures for one hour before use.

After 24 hours of storage at 37°C, the restorations were finished and polished with Sof-Lex Pop-on aluminum oxide disks (3M ESPE) in decreasing order of granulation. The samples were thermocycled 1000 times (5°C ± 2°C and 55°C ± 2°C), with a dwell time of 30 seconds each at each temperature and a transfer interval of five seconds. The microleakage test used in the current work was performed based on previous studies, and the method followed is featured below.

**Dye Immersion:** Upon completion of these procedures, the entire sample (except for the interface between the restoration and tooth) was protected with two layers of fast-setting cyanoacrylate-based Superbonder adhesive (Henkel Locite Adhesives Ltd, São Paulo, Brazil). Before dye immersion, a 1 mm strip of adhesive tape was placed around the area that was infiltrated (Figure 1D) and two layers of nail varnish

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**Table 1: Experimental Groups**

<table>
<thead>
<tr>
<th>Groups</th>
<th>Light Curing Unit</th>
<th>Polymerization Mode</th>
<th>Irradiance (mW/cm²)</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bluephase 16i</td>
<td>Light-emitting diodes (LED) 2nd generation</td>
<td>1100</td>
<td>23°C</td>
</tr>
<tr>
<td>2</td>
<td>Ultra-Lume LED5</td>
<td>LED 3rd generation</td>
<td>700</td>
<td>23°C</td>
</tr>
<tr>
<td>3</td>
<td>XL 3000</td>
<td>Quartz Tungsten Halogen (QTH)</td>
<td>420</td>
<td>23°C</td>
</tr>
<tr>
<td>4</td>
<td>Bluephase 16i</td>
<td>LED 2nd generation</td>
<td>1100</td>
<td>54°C</td>
</tr>
<tr>
<td>5</td>
<td>Ultra-Lume LED5</td>
<td>LED 3rd generation</td>
<td>700</td>
<td>54°C</td>
</tr>
<tr>
<td>6</td>
<td>XL 3000</td>
<td>QTH</td>
<td>420</td>
<td>54°C</td>
</tr>
<tr>
<td>7</td>
<td>Bluephase 16i</td>
<td>LED 2nd generation</td>
<td>1100</td>
<td>60°C</td>
</tr>
<tr>
<td>8</td>
<td>Ultra-Lume LED5</td>
<td>LED 3rd generation</td>
<td>700</td>
<td>60°C</td>
</tr>
<tr>
<td>9</td>
<td>XL 3000</td>
<td>QTH</td>
<td>420</td>
<td>60°C</td>
</tr>
</tbody>
</table>

*(Bluephase 16i, Vivadent, Büs-Austria A-6706; UltraLume LED 5, Ultradent Products, Inc, South Jordan, UT, USA; XL 3000, 3M ESPE, Grafenau Germany).

*Irradiance was measured with the Demetron Radiometer, Demetron Research Corp, Model 100, Serial #105415 (Kerr Corporation, Orange, CA, USA).*
(Figure 1E) were applied. The tape was cut and fixed in accordance with the measures indicated on the figure, with the aid of pencil marks on the external region of the teeth. The adhesive tape was then removed, and the specimens totally immersed in 2% neutral methylene blue solution for two hours. The blocks were then removed from the dye solution, washed under running water and dried. The nail varnish was removed and the dye on the restoration was worn off 0.05 mm from the surface with Sof-Lex Pop-on aluminum oxide disks (3M ESPE), as controlled by a caliper.

Sample Trituration: To take a reading of the infiltrated dye color, the specimens (dental block + restoration) (Figures 1F and 1G) were sectioned in the mesiodistal direction in a standardized way according to the measures indicated on the figure, including depth (2 mm) and were individually weighed. After weighing, the specimens were triturated in a mill for hard tissues (Marconi Equip Ltda, Piracicaba, SP, Brazil) in order to obtain a powder composed of the tooth/restoration. They were then weighed again. If the difference between the initial and final weight was higher than 10%, the specimen was discarded. No specimens were discarded in the current study.

Dissolution: After trituration, the powder of each block was individually immersed in a glass tube containing 4 ml of absolute alcohol PA for 24 hours in order to dilute the methylene blue. The solutions were then centrifuged (Tomy—IC 15AN—Tomy Ind, Tokyo, Japan) at 3000 rpm for three minutes. The supernatant (floating solution) was analyzed through a spectrophotometer (Beckman DU-65, Beckman Coulter, Inc, Brea, CA, USA) and adjusted using a wavelength of 668 nm.

In order to determine absorbance, the spectrophotometer was adjusted with an appropriate wavelength for the methylene blue, corresponding to the maximum absorbency for the dye. To calibrate the spectrophotometer, the absorbance of the standard solutions (0.1; 0.2; 0.3; 0.5; 1; 2 µg/mL) was determined at wavelengths ranging from 400 nm to 700 nm, and the maximum value was obtained at 668 nm. At this wavelength, absorbencies for the standard solutions were obtained. With these values, a coefficient of linear correlation (r=0.9998) and a straight-line equation (y=a+bx) were determined. The following relation was obtained: Absorbance = 0.2716 x (dye concentration)-0.0075. To quantify the dye concentration (µg/mL) infiltrated between the tooth and the restoration, the “y” was changed for the absorbency value of each sample.

As the data did not conform to the presuppositions of parametric analysis, the non-parametric tests of Kruskal-Wallis and Dunn were used to compare the average of the effect of each device used for photoactivation, varying the temperature of the dental composite. To show differences between the averages of the groups, the Dunn's test was used.

RESULTS

The microleakage results are shown in Table 2. At room temperature, there was no statistical difference between the light-curing units QTH, LED 2nd generation and LED 3rd generation. However, when the resin composite was preheated, the groups that were light-cured by QTH showed statistically lower microleakage means than the groups light-cured by LED 2nd and 3rd generation (54°C) or LED 2nd generation (60°C).

Preheating the resin composite did not reduce microleakage for the groups light-cured using the LEDs. On the other hand, preheating the resin composite was effective in decreasing the microleakage means for the groups light-cured using QTH.

For the QTH lamp, the group preheated to 54°C presented better values than the room temperature group. The group preheated to 60°C showed similar results to groups preheated to 54°C and those at room temperature.

DISCUSSION

It was expected that the use of light-curing units (LCUs) with high irradiance in a preheated resin composite would improve the degree of conversion and, consequently, the bond strength and marginal adaptation of the restoration in the deeper walls of a cavity. However, based on the current results, the first hypothesis was partially rejected. Heating the resin composite only reduced the microleakage means for the groups light-cured using a halogen lamp. The temperature of the resin composite did not influence the microleakage means for the groups light-cured with LEDs (both 2nd and 3rd generation).

<table>
<thead>
<tr>
<th>Groups</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>23°C</td>
</tr>
<tr>
<td>LED 2nd</td>
<td>0.031 (0; 0.064) Aa</td>
</tr>
<tr>
<td>LED 3rd</td>
<td>0.035 (0; 0.145) Aa</td>
</tr>
<tr>
<td>QTH</td>
<td>0.038 (0; 0.134) Aa</td>
</tr>
</tbody>
</table>

Means followed by different letters (horizontal capital letter and vertical lower case) are significantly different (p≤0.05).
The temperature of the resin composite and irradiance of the LCUs directly influenced polymerization of the resin composite, possibly altering the degree of conversion, the polymer structure formed and polymerization shrinkage. In the current study, the halogen unit (420 mW/cm²) with the resin composite preheated to 54°C or 60°C showed lower microleakage means. The highest microleakage means were observed in all groups light-cured by LEDs (LED 2nd generation—1100 mW/cm² or LED 3rd generation—700 mW/cm²) and light-cured with the halogen lamp at room temperature.

The halogen groups with low irradiance tended to have decreased stress created by polymerization shrinkage. It has been proven that the distance between the resin composite and the light-curing unit tip decreases irradiance. The heat of the resin composite improved polymerization of the first increment of the restoration, with better adaptation to the cervical interface of the filling due to the use of a light-curing unit with low irradiance. Furthermore, heating decreases viscosity of the resin composite and, consequently, improves marginal adaptation of the resin composite with a better degree of conversion of the bottom surface of the increment.

Polymerization of resin composite with high-irradiance LCUs may have increased polymerization shrinkage, creating stress mainly in the cervical walls of the cavity. Wagner and others stated that the geometry of a Class II cavity favors shrinkage stress in the direction of the occlusal wall. This may become more pronounced when a high-irradiance light-curing unit is used. In addition, Soares reported that, when high-irradiance light-curing units were used in deep Class II cavities, a high polymerization rate occurs on the top surface of the resin composite increment and a lower polymerization rate occurs on the bottom surface. This situation creates a stress flow of polymerization shrinkage from the cervical walls to the surrounding walls—buccal and lingual—which opens a gap in the cervical interface.

In the groups with preheated resin composite and high-irradiance LCUs, a more homogenous polymerization was expected in the first increment, minimizing shrinkage polymerization stress in the direction of the occlusal surface due to the higher degree of conversion of the bottom surface of the resin composite. In addition, the preheated resin composite shows less viscosity, improving the initial adaptation of the first increment of the filling. However, the use of high-irradiance LCUs may have offset the advantages of preheating, increasing shrinkage stress. Corroborating the results of the current study, El Korashy compared a modular light-curing mode called soft-start with continuous-mode high irradiance in preheated resin composites and stated that the soft-start mode showed a similar degree of conversion and the lowest shrinkage stress. The use of a modular mode or a low-irradiance mode prolonged the pre-gel phase of the polymerization process, decreasing stress and preserving the integrity of the interface tooth-restoration.

On the other hand, both high-irradiance continuous mode and heating the resin composite reduces the pre-gel phase and, consequently, increases stress during polymerization, resulting in damage to the bond and microleakage. This was evident in the groups preheated to 60°C, where LED 3rd generation with intermediary irradiance showed intermediary microleakage means with no statistical difference to QTH and LED 2nd generation. Preheating the resin composite also increases post-gel shrinkage stress, thus it would not be prudent to use this procedure with LCUs that also increase shrinkage stress. In this way, a resin composite preheated to 54°C, combined with a QTH LCU with low irradiance, showed better results, because it maintained the benefits of preheating without increasing stress in the interface.

In the current study, different light curing units were used; however, the same curing time, according to the manufacturer’s instructions, was performed. QTH lamps and LEDs present a different spectra of wavelength, and this characteristic might have influenced the results obtained. Further studies should be done to clarify the effect of the different light curing units, with standardization of the energy density on the preheated resin composite.

Thus, based on the current results, it is possible to infer that preheating resin composite is a viable procedure for improving the quality of tooth-restoration interface if a low-irradiance mode is used to light-cure the resin composite. It is important to emphasize that preheated resin composites must be immediately placed in the preparation after removing the material from the preheating device. Only a few seconds of delay before applying to the cavity is sufficient to cool the preheated resin composite, thus reducing the benefits of this treatment.

CONCLUSIONS

Within the limits of this in vitro study, when using a QTH light-curing unit with a lower-irradiance level, preheating a resin composite is an effective way to reduce microleakage of the resulting restoration.

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References


