

Effect of light-curing units on gap formation and microleakage of class II composite restorations

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Abstract

Aim: This in vitro study evaluated gap width formation and marginal microleakage in Class II composite restorations light-cured with three different light-curing units. **Methods:** Standardized cavities in the proximal surfaces of 36 human third molars were made with margins located below the cemento-enamel junction. Cavities were restored with Filtek P60 (3M ESPE), inserted with a photocondenser tip and light-cured with three different methods: GI - Optilux401 (halogen); GII - Colt luxLED (LED) and GIII - UltraLumeLED5 (LED). After finishing the restorations, teeth were subjected to a thermal cycling regimen of 500 cycles (5°C ± 2°C and 55°C ± 2°C), totalizing 500 cycles. Thereafter, the teeth were sectioned in a buccolingual direction and in the center of the restorations. Half of the specimens (18) were used to evaluate marginal microleakage, by measuring of dye penetration in cross-sectioned specimens, and the other half was used to analyze the gap formation width by SEM observations (1000X). Data were submitted to Kruskal-Wallis ($\alpha=0.05$). **Results:** The mean values of gap width (μm) were: GI 3.28±3.34; GII 1.48±1.89 and GIII 3.11±3.45, and microleakage was not affected by the light-curing units. **Conclusions:** There were no differences between the light-curing methods in gap formation and marginal microleakage.

Keywords: composite resins, dental curing lights, polymerization.

Introduction

Light-cured composite remains in focus since its introduction in Dentistry in the 1960's¹. Its importance is due to several factors, among which aesthetics is considered essential. However, the adhesion between composite resin and dental tissues remains a challenge for dental practice after all these years²⁻⁵.

Resin-based materials have an inherent characteristic, which is due to the polymerization of monomers to polymers¹. When this strength exceeds the adhesive bond strength to cavity walls, marginal gaps may appear between restoration and tooth⁶⁻⁷, predisposing the restoration to marginal infiltration⁸. A range of undesirable effects that include penetration of bacteria and oral fluids can result in staining, recurrent caries, postoperative sensitivity and ultimately irreversible pulp pathologies², thereby decreasing the longevity of the restoration^{2,9}.

Several techniques have been proposed to reverse the problems caused by polymerization shrinkage of resin, including the use of an adhesive layer with sufficient bond strength and elasticity modulus to withstand the stresses transmitted

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to this interface¹⁰⁻¹¹, as well as the use of the so-called low-shrink composites currently available in the dental market¹²⁻¹⁶.

The complexity of the factors that determine the stress generated by polymerization shrinkage is so great, that it could also be cited other contributing factors: cavity configuration¹⁷⁻¹⁸, placement technique^{8,17}, radiant exposure (dose)¹⁹, curing techniques^{17-18,20} and inherent properties of resin-based materials, such as the amount of filler load^{12,17-21}. It is known that resin composite restorations with enamel margins have higher bond strength values than those with margins located in dentin, because this substrate is more critic²².

Among different light-curing units (LCUs) developed for photoactivation of resin-based materials, quartz-tungsten halogen (QTH) lamps and light-emitting diodes (LEDs) are still the most common devices. These LCUs emit blue light close to the absorption spectrum of camphorquinone (468 nm), the most common photoinitiator in resin-based materials²³. Despite their popularity, halogen lamps have some disadvantages, such as accelerated degradation of the internal components, due to overheat generated by the lamp, requiring frequent replacement. LEDs are smaller, cordless and do not require filters. There is no heat output, so a cooling fan is not needed. However, they cost more than conventional halogen lamps and their battery must be recharged²⁴. Studies have showed the LCUs may interfere on staining susceptibility and conversion degree of composites²⁵, as well as in the amount of residual monomers found in adhesives²⁶. On the other hand, the literature has reported no significant differences on the color stability²⁷, conversion degree²⁸ and surface energy of various composite resins after curing by LED or halogen devices²⁹.

Several studies have compared microleakage and gap formation in Class II composite restorations and the influence of different LCUs^{17,22,30-31}, but with no consensus between the authors. Gap formation and leakage studies have been used as *in vitro* indicators of both retention and marginal sealing abilities of composite restorations²². Thus, the objective of this study was to evaluate gap formation and microleakage of Class II composite restorations light-cured with three different LCUs (one halogen lamp and two LED units). The null hypothesis tested was that LCUs do not influence gap formation or microleakage of Class II composite restorations.

Material and methods

Specimen preparation and restorative procedures

This study was approved by the Ethics Committee

(COEP) of the State University of Ponta Grossa – UEPG, under the reports number 08/2005 (microleakage analysis) and 09/2005 (gap measurement) and protocols number 01211/05 and 01212/05, respectively.

Thirty-six sound human third molars extracted for orthodontic reasons, with no defects, were selected for this study. Immediately after extraction they were hand scaled to remove tissue remnants and stored in distilled water at 4 °C and used for no longer than 6 months after extraction³².

Two Class II cavities were made in each tooth – one on each proximal surface – totalizing 72 cavities. All cavities were prepared as vertical slots, with the cervical margin in cementum, using a diamond bur #4137 (KG Sorensen, Barueri, SP, Brazil) mounted in a mechanical device (El Quip, São Carlos, SP, Brazil) that allowed standardized preparation of cavities with the following dimensions: 4 mm occlusal-cervical length, 1.8 mm buccolingual width and 2.1 mm cervical-axial depth. A new bur was used after five preparations.

Teeth were randomly divided in three groups (12 teeth/group, totalized 24 restorations/group) according to the LCU used: Group I: halogen - Optilux 401 (Kerr/Demetron Res. Corp., Orange, CA, USA); Group II: LED – Coltolux (Coltène Whaledent, Altstätten, Switzerland) and Group III: LED – UltraLume LED 5 (Ultradent, South Jordan, UT, USA). Table 1 shows more details concerning the LCUs used in the study.

All cavities were restored with the same adhesive system (Adper Single Bond, 3M ESPE, St. Paul, MN, USA) and composite resin (Filtek P60, 3M ESPE). The composite resin was inserted according to the oblique technique, in increments of 2 mm, using a photocondenser tip (TDV Dental Ltda, Pomerode, SC, Brazil). Each increment was light-cured for 40 s, using the tested LCUs. The length of the photocondenser tip served as a guide to standardize the distance of the LCU from the restoration.

After 24 h of water storage at 37°C, the restorations were finished and polished with Sof-Lex discs (3M ESPE) according to the manufacturer's instructions. Specimens were then subjected to a thermal cycling regimen of 500 cycles (5°C ± 2°C and 55°C ± 2°C), with a 15-s dwell time in each bath. The 36 teeth were bisected in a buccolingual direction with a water-cooled diamond saw (Isomet 1000, Buehler, Lake Bluff, IL, USA) to obtain mesial and distal halves, each one with a restoration, totalizing 72 restorations. Then, each half was sectioned longitudinally in the middle of the restorations, in such a way that each half produced

Table 1 – Light-curing units used in the study

Light Curing Unit ^a	Type	Light intensity (mW/cm ²)	Wavelength (nm)	Energy Density Per Increment ^b (J)
Optilux 401	QTH	600	390 - 530	24
ColtoluxLED	LED	1000	450 - 480	40
UltraLume 5 LED	LED	800	370 - 500	32

^a Information supplied by the manufacturers.

^b Calculated based on the curing time used for each increment, and the light intensity generated by each unit, as measured with the appropriate radiometer.

two hemi-sections: one buccal and one lingual.

Gap measurement

Eighteen teeth were taken to a vacuum desiccator and sputter coated with gold-palladium (Polaron SC7620, Quorum Technologies Ltd., East Sussex, UK) for 5 min at 10 mA. Each specimen was examined by a scanning electron microscope (JSM 6360LV, Jeol Ltd., Tokyo, Japan) at a 15-kV accelerating voltage at $\times 1000$ magnification and SEM micrographs were taken for evaluation of gap width (μm) (Figure 1).

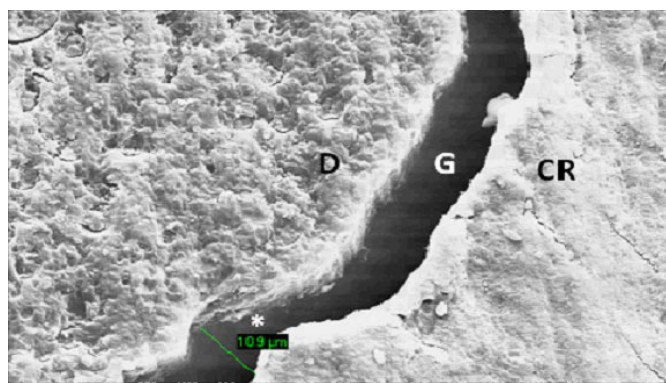


Fig. 1. Scanning electron micrograph of a representative marginal gap. A gap can be seen at the interface between dentin and the composite restoration (original magnification $\times 1000$). The asterisk indicates the gap width being measured. D - dentin; G - gap; CR - composite restoration.

Microleakage analysis

The 18 teeth were used to evaluate dye penetration at the gingival wall of each specimen. Specimens were coated with two layers of nail varnish, and then exposed to 50% silver nitrate solution (Vetec Química Fina, Xerém, RJ, Brazil) for 2 h, photodeveloped (Kodak, Eastman Kodak Company, Rochester, NY, USA) for 16 h. Afterwards, teeth were washed with tap water and nail varnish layers were removed with

the aid of manual cutting instruments.

The teeth were sectioned in the same manner as previously described, and the microleakage was evaluated by two examiners using optical stereomicroscope (Olympus BX41, Tokyo, Japan) at $\times 40$ magnification. Leakage was scored using the following criteria: 1, no dye penetration; 2, dye penetration extending up to 1/2 of cervical wall; 3, dye penetration extending to cervical wall, but without reach the axial wall; 4, dye penetration extending to cervical wall, reaching axial wall. If examiners disagreed, a forced consensus was reached and the consensus score recorded.

Statistical analysis

After measurements, as data did not confirm to the presuppositions of parametric analysis, the non-parametric Kruskal-Wallis test was used to compare the effect of each LCU on gap formation and marginal microleakage at a 5% significance level.

Results

Gap measurement

Table 2 summarizes the results (mean, median, standard deviation, minimum and maximum values) for gap formation in the experimental groups. The first null hypothesis was accepted because there were no statistically significant differences ($p=0.25$) among the groups with respect to gap width.

Marginal microleakage

The frequencies of marginal microleakage scores are presented in Table 3. The second null hypothesis was also accepted because, although Group I showed lower microleakage scores follow by Group III and Group II, there were no statistically significant differences ($p=0.072$) among the experimental groups with respect to marginal microleakage.

Table 2 – Mean, median, standard deviation, minimum and maximum values referent to gap width (μm) in all groups.

Gap width values (μm)	Group I - Optilux401 (Halogen)	Group II ColtoluxLED (LED)	Group III UltraLumeLED5 (LED)
Mean	3.28	1.48	3.11
Median	2.74	0.85	2.37
Standard deviation	3.34	1.89	3.45
Minimum	0	0	0
Maximum	10.90	5.19	11.80

Table 3 – Frequencies of marginal microleakage scores in all groups.

Scores	Group I - Optilux401 (Halogen)	Group II ColtoluxLED (LED)	Group III UltraLumeLED5 (LED)
1	7	2	5
2	5	8	6
3	-	1	1
4	-	1	-
Total	12	12	12

Discussion

The polymerization reaction of resin-based composites involves the conversion of C=C bonds in individual monomer molecules and the formation of C-C bonds to form polymer chains, causing volume reduction, as covalent bonds are created and molecular distances and free volume are reduced³³.

Light-activated composite resins start the polymerization process through the absorption of light by the initiator (usually a diketone), which once activated, reacts with a reducing agent (aliphatic amine) to produce radicals that bind the monomer molecule, making it active. The unsaturated monomer link opens, and subsequently acts on the other molecules from the monomer, forming a crosslinked macromolecule. In this polymerization process, generally there are three stages: Initiation, propagation and termination. In the first stage, photons of light energy at a wavelength around 450 nm to 500 nm, activate the initiator. The initiator depends on a co-initiator for the electron transfer and the formation of free radicals. The co-initiator usually is a tertiary amine that does not absorb light, but interacts with the camphorquinone when it is excited. Free radical is a highly energetic molecule with an unpaired electron. It needs to form a covalent bond with another compound, which, in turn, may be the double bond (C=C) present in the monomers. Propagation is the stage when the free radical reacts with the first monomer unit (C=C). The formation of a radical-monomer complex occurs, which aim to produce more connections with other monomers. In other words, it is a chain reaction with rapid growth of radical-monomer complex, forming a three-dimensional network, until the polymer formation. Termination is when two macroradicals collide, or when the active extremities of two chains that propagate react with each other and bind in a bimolecular reaction to form a single molecule no more reactive, ending the chain growth³⁴.

The development of contraction stress of composites depends, among other factors, on the composition of the material (type of monomer, filler load, and their interaction), and factors related to resin composite polymerization (conversion degree, curing technique, placement technique, C-factor, and others)³⁵. Regarding the composition of the material, Filtek P60 contains 61% of filler content (in volume) - silica and zirconia fillers with mean size of 0.6 μm - and a polymeric matrix consisting of Bis-GMA, Bis-EMA, UDMA and TEGDMA. As any resin-based composite, this material undergoes polymerization shrinkage. In the present study, it was used an only type of composite, since the objective was to verify the effect of different LCUs on gap formation and marginal microleakage. Variation between resin composites were excluded, as each material could have different compositions and, consequently, distinct degrees of polymerization shrinkage. The photoinitiator of Filtek P60 composite resin is camphorquinone (maximum absorption spectrum at 468 nm), and all the LCUs used in the present study work within this spectrum. It was also employed a

device for standardization of the Class II cavities in order to avoid variations in their dimensions.

Each LCU has its own wavelength specifications, advantages, disadvantages, and curing efficiency. It has been observed that scattering is greater with the halogen units³⁶. Also, LED units has more spectral purity than halogen lamps, as it has a narrow band of light emission with a wavelength between 450-490 nm, with peak emission at 470 nm, and this is the coincident blue light band with the absorption spectrum of most of the photoinitiators included in the composite resins, which allows full use of LEDs³⁷.

The type of photoinitiator in resin-based materials significantly influences the curing efficiency of the material across the width of a restoration³⁸. It also determines the most appropriate LCU to cure a particular type of composite resin, as the wavelength emitted by a LCU should match the absorption spectrum or absorption peak of the photoinitiator in that composite. Camphorquinone can be readily cured with halogen lamps and other units, but other photoinitiators (PPD, Lucirin TPO) pose a great problem because most commercially available LCUs do not match their spectrum²⁴.

Another factor that affects light-curing efficiency is the filler particles of resin-based materials. These filler particles tend to scatter the light, and both filler content and size influence the light dispersion²⁴. Smaller filler particles (0.1 μm to 1.0 μm) have maximal scattering because these particle sizes correspond to the wavelength range of the photoinitiator. Microfilled composites with smaller or greater particles scatter more light than microhybrid resins. If the refractive indices of the matrix and filler particles have an increased difference, light scattering is also increased. Therefore, the size and concentration of filler particles should be controlled depending on the refractive indices of the filler and resin matrix, as it also influences the resin color³⁹.

The results of this study demonstrate that all groups showed gap formation. Corroborating these results, other studies have previously reported that all groups, regardless of the composite material^{12,16,21} or the curing technique^{22,40} were free of marginal gaps at tooth/restoration interface.

The results of this study are supported by the literature. Researchers^{30-31,41} have found no differences in microleakage when LEDs or halogen lamps were used to photo-activate class II composite restorations. Small (2001)⁴¹ stated that although many improvements have been made, any material or method can ensure the effectiveness of the restoration if certain principles are respected, while another study³⁰ found better overall results when 2nd generation LEDs and halogen lamps are used compared with 1st generation LEDs.

On the other hand, differently from this study, Fernandes et al. (2002)⁴² reported that the use of LED units contributes to a better interface integrity, which is an extremely essential factor in procedures that utilize light-curing materials. Studies have found that using a LED²⁰ or a halogen lamp¹⁸ in soft start mode reduces polymerization shrinkage and microleakage. All the discrepancies between these studies probably occur due to the different experimental designs of each study, especially the cavity size, polymerization

method²², light intensity of LCUs and energy density *per* increment. Accurate knowledge of the polymerization process and control techniques may also contribute to the clinical performance of the restorative procedure and better marginal adaptation, hence, decreasing marginal gap formation¹⁷.

It is important to emphasize that this *in vitro* study used different LCUs with the same curing time (according to the manufacturer's instructions), with no influence of other factors, such as energy density or power intensity. It is also known that the stress caused by polymerization shrinkage of composites has a multifactorial nature⁷. Therefore, select an appropriate restorative material, follow correct handling and placement techniques and use an appropriate LCU may allow for controlling polymerization shrinkage and having more aesthetic and durable Class II restorations due to reduction of marginal discoloration, recurrent caries and postoperative sensitivity¹⁷.

Within the limitations of this *in vitro* study, it may be concluded that there were no differences among the LCUs tested with respect to gap formation and marginal microleakage of Class II composite restorations. Further studies should be done to verify the interaction between the different factors that characterize gap formation and marginal microleakage, as well as ensure a better marginal adaptation at tooth/restoration interface.

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