Microleakage evaluation of resin composite restorations polymerized with different blue light-emitting diode units (LED)

Avaliação da microinfiltração marginal de restaurações de resina composta polimerizadas com diferentes aparelhos de LEDs

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ABSTRACT

The aim of this study was to evaluate the microleakage of class II resin composite restorations polymerized with light-emitting diodes (LEDs) with different numbers of blue diodes. One hundred sixty-eight class II cavities were prepared in bovine teeth. A one-bottle adhesive system (Single Bond/3M ESPE) was applied. The microhybrid or packable resin composites were inserted in three horizontal increments and cured for 40 seconds each, according to the following groups (n=21): G1- Z250 + LED light curing unit with 19 LEDs (3M ESPE); G2- Surefil + LED light curing unit with 19 LEDs; G3- Z250 + LED light curing unit with 7 LEDs (DMC); G4- Surefil + LED light curing unit with 7 LEDs; G5- Z250 + LED light curing unit with 6 LEDs (MM Optics); G6- Surefil + LED light curing unit with 6 LEDs; G7- Z250 + conventional halogen light curing unit (Demetron-Kerr); G8- Surefil + conventional halogen light curing unit. After thermocycling, the specimens were immersed in 2% methylene blue solution and then evaluated for microleakage. The Kruskal-Wallis and non-parametric Multiple Comparison tests ($p<0.05$) showed statistically significant differences among groups median: G1: 1(d); G2: 4(a); G3: 1(cd); G4: 4(a); G5: 2(bc); G6: 4(a); G7: 1(cd); G8: 4(ab). The blue light-emitting diode units (LEDs) demonstrated similar results to the conventional halogen lamp unit and the microleakage of the packable resin composite was significantly more severe than that of the microhybrid resin composite.

UNITERMS

Dental leakage; composite resins; light; animal; in vitro; dental equipment.

Introduction

In recent years, the popularity of esthetic tooth-colored restorations has resulted a rapidly increasing use of resin composites [3,13]. However, resin composites still present a number of limitations such as polymerization shrinkage [7,20], which has been associated with lack of marginal integrity, deflection of cusps, production of internal stress and postoperative sensitivity [3,7-8].

Many techniques have been studied to control the polymerization shrinkage, such as soft-start polymerization[15,18,22-3], pulse delay[23], and reduced rate polymerization [10,21], which employ halogen lamps. High-intensity curing lights are also commercially attractive to clinicians because the time spent polymerizing resin composite restorations can be reduced to up to 75% [4]. Belonging to this category are the argon laser light curing units and plasma arc light units [4].

Despite their popularity, halogen technology light curing units have several drawbacks. For example, halogen bulbs have a limited effective lifetime of approximately 100 hours, and the bulb, the reflector and the filter can degrade over time due to the high operating temperatures and the large quantity of heat that is oduced during the operating cycles[11,19].

To overcome the problems inherent to halogen light curing units, solid-state light emitting diode (LED) technology has been proposed for curing light-activated dental materials[2,11,19].

LEDs have an expected lifetime of several thousand hours without significant degradation of light flux over time [2,11,17]. In addition, LEDs require no filters to produce blue light [17]. The most frequently employed resin composites have camphorquinone as photoinitiator, which has an absorption peak of 467 nm that approximately coincides with the emission peak of the LEDs light curing units, at 465 nm [2,13,19]. The spectral purity of LEDs light curing units make the polymerization process of resin composite more efficient [2], with the advantage of preventing overheating [2,12].

Several studies have reported that composites cured with LED units showed some inferior physical properties[11,13,19] and an inferior degree of conversion [12] when compared with halogen lamps. However, the LED units exceeded by far the minimum composite depth of cure according to ISO 4049 [11,19] and, when the halogen lamps compared had equal irradiance to LED light curing unit, the depth of cure is greater for composites cured by LED light curing unit [17].

Adequate polymerization is a crucial factor in obtaining optimal physical properties and clinical performance of resin composites. Problems associated with inadequate polymerization include inferior physical properties, solubility in the oral environment, and increased Microleakage [12]. The aim of this study was to evaluate the marginal microleakage of class II resin composite restorations polymerized with blue light-emitting diode units (LEDs), with different numbers of blue diodes, in comparison with the conventional halogen lamp.

Material and Method

Eighty-four extracted bovine incisor teeth were initially stored in a saline solution containing 0.5% sodium azide, after which the debris was removed from the teeth. The crowns of the teeth were cut off 5 mm above the cemento-enamel junction (CEJ), with a double-faced diamond disk (KG Sorensen, Brazil).

Simulated "Slot" type Class II cavities at the mesial and lingual surfaces were prepared with carbide burs (Jet Brand, Canada) in a high-speed water-cooled hand piece. Burs were replaced after every 8 preparations to maintain uniformity. Butt-joint cavities had the following dimensions: 1.5mm axial deep by 3mm bucco-lingual wide and the gingival margin was located 1mm apical to the CEJ.

In all groups, enamel and dentin etching with 35% phosphoric acid (3M ESPE) was performed for 15 seconds. Single Bond (3M ESPE) adhesive system was applied following manufacturer's instructions. Z250 microhybrid resin composite (3M ESPE) and Surefil packable resin composite (Dentsply Caulk, USA) were inserted in three horizontal increments and each increment was cured for 40 seconds, according to the following groups (n=21):

G1: microhybrid resin composite cured with LED light curing unit (Elipar™ FreeLight, 3M ESPE, USA), which has nineteen LEDs;

G2: packable resin composite cured with LED light curing unit (Elipar ™ FreeLight, 3M ESPE, USA);

G3: microhybrid resin composite cured with LED light curing unit (Ultrablue III, DMC, Brazil), which has seven LEDs;

G4: packable resin composite cured with LED light curing unit (Ultrablue III, DMC, Brazil);

G5: microhybrid resin composite cured with LED light curing unit (LEC-470 I, MM Optics, Brazil), which has six LEDs;

G6: packable resin composite cured with LED light curing unit (LEC-470 I, MM Optics, Brazil);

G7 (control 1): microhybrid resin composite cured with conventional halogen light curing unit (Optilux 501, Demetron-Kerr, USA);

G8 (control 2): packable resin composite cured with conventional halogen light curing unit (Optilux 501, Demetron-Kerr, USA).

The intensity of the light curing units was measured with a radiometer and they are summarized in Picture 1.

Picture 1 – Light curing units used in this study and their intensities

Light Source	Light curing unit/manufacturer	Light intensity
19 LEDs	Elipar™ FreeLight, 3M ESPE, USA	280 mW/cm^2
7 LEDs	Ultrablue III, DMC, Brazil	140 mW/cm^2
6 LEDs	LEC-470 I, MM Optics, Brazil	100 mW/cm^2
Halogen Lamp	Optilux 501, Demetron-Kerr, USA	850 mW/cm^2

Following the restorative procedure, the teeth were stored in a humid environment at 37°C for 48 hours. After this time, all restorations were finished with aluminium oxide discs (Sof-Lex, 3M ESPE, USA) medium, fine and ultrafine finishing disks. All specimens were then thermocycled in a thermal cycling machine (MCT2 AMM, Instrumental, Brazil) for 1,000 cycles at 5 ± 2°C and 55 ± 2 °C with a dwell time of 60 seconds in distilled water with a 5-second transfer time. Next, the apices and coronal surfaces were sealed with epoxy resin (Araldite, Brascola Ltda, Brazil) and the teeth were coated with two applications of fingernail polish up to 1mm from the gingival margins. All teeth were immersed in a freshly prepared aqueous solution of 2% methylene blue (pH 7.0) for 4 hours at 37°C and then washed in water. Finally, each tooth was sectioned vertically through the center of the restoration with a diamond disk at low-speed.

Microleakage at the gingival margin was evaluated by two observers with an optical stereomicroscope (Meiji 2000, Meiji, China) at 60x magnification and scored using the following criteria:

0 - No dye penetration
1 - Dye penetration that extended for less than or up to 1/3 of preparation depth
2 - Dye penetration greater than 1/3 or up to 2/3 of preparation depth
3 - Dye penetration greater than 2/3 of preparation depth
4 - Dye penetration reaching or passing the axial wall.

The scores evaluation was submitted to the Kruskal-Wallis and non-parametric Multiple Comparison tests at 5% level of significance (α= 0.05) in order to evaluate the differences among the experimental groups.

Results

The microleakage of packable resin composite was significantly more severe than the microhybrid resin composite under any light curing unit. For both resin composites, blue light-emitting diode units (LEDs) presented similar behavior to conventional halogen lamp unit (Table 1. For microhybrid resin composite, the LEDs light curing unit with six LEDs resulted in significantly more microleakage than the LEDs light curing unit composed of nineteen LEDs.

Table 1– Results (Median and Rank Sum) of microleakage for each group

Resin composite/ Light Curing Unit	Median	Rank Sum	
Microhybrid / 19 LEDs	1	37.60	d
Microhybrid / 7 LEDs	1	57.17	cd
Microhybrid / 6 LEDs	2	68.53	bc
Microhybrid / Conventional	1	57.14	cd
Packable / 19 LEDs	4	98.87	a
Packable / 7 LEDs	4	104.38	a
Packable / 6 LEDs	4	104.53	a
Packable / Conventional	4	91.85	ab

Means followed by different letters were statistically different in the Kruskal-Wallis test and non-parametric Multiple Comparison test ($p < 0.05$).

Discussion

The results of this study showed good comportment for LEDs light curing units. The LEDs light curing unit with nineteen LEDs presented the least amount of microleakage for the microhybrid resin composite, but it was statistically lower than the group cured with six LEDs only.

Although the light intensity of the LEDs light curing units was considerably low, it probably resulted in adequate polymerization, since the microleakage did not increase for groups polimerized with LEDs. This is possible because the LED emission spectrum fits the maximum absorption of camphorquinone[1], making the polymerization process of resin composite more efficient [1-2,11,19]. In comparison, the emission spectrum of a halogen light is considerably broader, exhibiting larger irradiance in all other regions, although the wavelength range is already adjusted by filters [1,11,19].

Some other studies demonstrated a decrease of physical and mechanical properties when the resin composite was cured with LEDs light curing units. Stahl et al. [19] (2000) showed that mean flexural strength and mean flexural modulus are significantly greater for specimens polymerized with the halogen light curing unit than for those specimens polymerized with LEDs light curing unit with seventeen LEDs, although both fulfill the ISO 4049 requirement in terms of flexural strength.

Jandt et al. [11] (2000) also showed that the conventional halogen light curing unit cured composites significantly deeper than the LEDs light curing unit. However, both units cured the composite deeper than required by both ISO 4049 and the manufacturer. For compressive strengths, there were no significant differences between samples produced with LEDs or conventional light curing units[11].

Kurachi et al. [13] (2001) observed inferior hardness for resin composite polymerized with LEDs light curing units (with two, three, four, five or six LEDs) than that polymerized with the halogen lamp. The authors suggested that longer exposure times or a thinner resin layer are required to achieve reasonable hardness values due to their reduced irradiance. Medeiros[14] (2001) also suggested that longer exposure time (sixty seconds) is necessary to polymerize increments of 2mm.

The degree of conversion for four hybrid resin composites was higher for all materials polymerized with halogen curing units. Great differences of curing intensity were also observed in which the low curing energy of blue LEDs enables a slower polymerization reaction in composite material [12].

This slow polymerization reaction influences flow characteristics and may be useful in moderating the development of shrinkage stress and improving marginal sealing [10]. Therefore, in this study, less microleakage could be caused by decrease of shrinkage stress for specimens cured by LEDs light curing units.

The slower polymerization reaction of LEDs light curing units also causes less temperature increases than conventional halogen lamp[12,14]. Furthermore, the LEDs light curing units have the advantage of being small and wireless, improving handling properties [1], as the units with nineteen and seven LEDs used in this study.

Statistical difference was observed between hybrid and packable resin composites for all light curing units. Along with the polymerization process, shrinkage stress build-up occurs after the material acquires stiffness[6]. The amount of contraction stress has been determined to be dependent on the extent of the reaction, the stiffness of composite and its ability to flow[6-7,9]. Less rigid materials were observed to be better capable of reducing the contraction stresses than rigid materials and the packable resin composite is more rigid than microhybrid resin composite [7].

The highly filled small-sized interlocking filler particles of Surefil packable resin composite may, to some extent, obstruct the composite to change shape during polymerization, resulting in an overall higher stress build-up than the hybrid composite[6]. This technology can also decrease the capacity of flow [16], and the lower the capacity of flow, the greater will be the shrinkage stress, which can be decisive for the success of the bonding procedure[5]. Chen et al.[6] (2001) observed that packable resin composites exhibited significantly higher maximum contraction stress and a higher rate of contraction force than a conventional hybrid resin composite. In this study, the hybrid resin composite can also have benefited the bond with the cavity walls.

Due to their inherent advantages and the positive results of this study, LEDs light curing units appear to promise a good perspective for future clinical use.

Conclusion

This *"in vitro"* study, in bovine teeth, allowed us to conclude:

1. The LEDs light curing units present similar results in controlling the microleakage when compared to conventional halogen lamps for both resin composites used.
2. For the microhybrid resin composite (Z250), the LEDs light curing unit composed of six LEDs presented significantly more microleakage than the LEDs light curing unit composed of nineteen LEDs.
3. The microleakage of packable resin composite (Surefil) was significantly more severe than the microhybrid resin composite for all light curing units.

Resumo

O objetivo deste estudo foi avaliar a microinfiltração marginal de restaurações classe II de resina composta polimerizadas com aparelhos de diferentes números de LEDs. Foram preparadas 168 cavidades classe II em incisivos bovinos seccionados e o sistema adesivo de frasco único (Single Bond/3M ESPE) foi aplicado. As resinas compostas microhíbrida (Z250/3M ESPE) ou condensável (Surefil/Dentisply) foram inseridas em três incrementos horizontais, que foram polimerizados por 40 segundos cada, de acordo com os grupos (n=21): G1- Z250 + polimerização com aparelho de 19 LEDs (3M ESPE); G2- Surefil + polimerização com aparelho de 19 LEDs; G3- Z250 + polimerização com aparelho de 7 LEDs (DMC); G4- Surefil + polimerização com aparelho de 7 LEDs; G5- Z250 + polimerização com aparelho de 6 LEDs (MM Optics); G6- Surefil + polimerização com aparelho de 6 LEDs G7- Z250 + polimerização convencional com luz halógena (Demetron-Kerr); G8- Surefil + polimerização convencional com luz halógena. Após termociclagem, *os espécimes foram imersos em solução aquosa de azul de metileno a 2% e a microinfiltração foi avaliada. Os testes Kruskal-Wallis e de Comparações Múltiplas (p<0,05) mostraram diferenças estatisticamente significantes entre os grupos (mediana): G1: 1(d); G2: 4(a); G3: 1(cd); G4: 4(a); G5: 2(bc); G6: 4(a); G7: 1(cd); G8: 4(ab). Os aparelhos fotopolimerizadores de LEDs apresentaram resultados similares ao aparelho de fotopolimerização convencional, mas a microinfiltração das restaurações de resina composta condensável foi significantemente mais severa que das restaurações de resina composta microhíbrida.*

Unitermos

Infiltração dentária; resinas compostas; luz; animal; in vitro; equipamento odontológico.

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