

Effect of Photoactivation Systems and Resin Composites on the Microleakage of Esthetic Restorations

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Abstract

Aim: The aim of this study was to evaluate the influence of four photoactivation systems [quartz tungsten halogen (QTH), light-emitting diode (LED), argon ion laser (AL), and plasma arc curing PAC] on cementum/dentin and enamel microleakage of Class II restorations using a microhybrid [Z250 – 3M ESPE] and two packable composites [(SureFil - Dentsply and Tetric Ceram HB – Ivoclar/Vivadent)].

Methods and Materials: Three hundred sixty “vertical-slot Class II cavities” were prepared at the mesial surface of bovine incisors using a 245 carbide bur in a highspeed handpiece. Specimens were divided into twelve groups (composite-photoactivation systems). Half of the specimens had the gingival margin placed in enamel (n=15) and the other half in cementum/dentin (n=15). Composites were inserted and cured in 2 mm increments according to manufacturers’ recommended exposure times. After polishing, the samples were immersed in 2% methylene blue solution, sectioned, and evaluated at the gingival margins. Data were submitted to statistical analysis using the Kruskal–Wallis and Mann-Whitney tests.

Results: No significant differences were found among the photoactivation systems and among resin composites ($p>0.05$). Microleakage was not significantly affected by location (enamel vs. cementum/dentin,

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p>0.05). These findings suggested neither the photoactivation systems nor the resin composite types might have an effect on the microleakage at gingival margins Class II cavities.

Keywords: Microleakage, photoactivation system, resin composite, marginal sealing, packable resin composites

Citation: Cavalcante LMA, Peris AR, Ambrosano GMB, Ritter AV, Pimenta LAF. Effect of Photoactivation Systems and Resin Composites on the Microleakage of Esthetic Restorations. J Contemp Dent Pract 2007 February;(8)2:070-079.

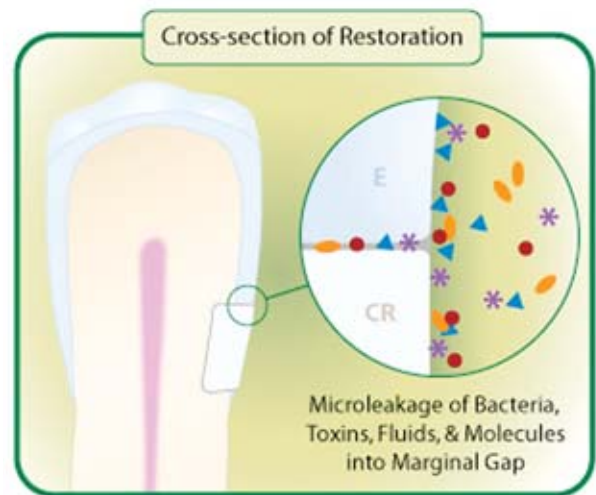
Introduction

Despite advances to resolve problems with composite technology, such as wear and technique sensitivity, microleakage can occur when resin composite restorations are placed.

Stress arising from polymerization shrinkage is one of the most critical problems associated with light-activated composites.¹ The competition between contracting forces built up in the polymerizing resin and the bonds of adhesive resins to the wall of the restoration can lead to marginal failure and subsequent microleakage.^{2,3} For this reason, bond strength must be greater than contraction stress in order to obtain stable marginal adaptation.

One of the major factors which decreases the integrity and clinical life expectancy of the esthetic restorations is gap formation and microleakage, especially when the gingival margin is in dentin.⁴ This is a problem of clinical significance because microleakage allows the passage of bacteria, fluids, molecules, and toxins and could lead to dentinal hypersensitivity, pulp inflammation, secondary caries, and even pulp necrosis.^{5,6}

Curing a composite is dependent on the composite (photoinitiator, filler type, shade, and translucency), the intensity and spectral output of curing unit, and possibly the curing mode.⁷ Because of this relationship; different light units have been developed. Currently, there are basically four different types of lights available for polymerizing resin composites: quartz tungsten halogen (QTH), plasma arc (PAC), argon ion lasers (AL), and light-emitting diodes (LED). The main objectives of these photoactivation systems are minimizing and controlling polymerization shrinkage, to provide better physical properties,



and, some of them, to reduce the time required for curing resin composites.

The magnitude of the stress generated in polymerizing a resin composite restoration also seems to be influenced by numerous factors related to the material's composition, technique, and cavity preparation. The relationship among these factors dictates the magnitude of the shrinkage for a given restoration.⁷

This study evaluated the marginal seal (measured as microleakage at enamel and cementum/dentin margins) of Class II composite restorations using four photoactivation systems: QTH LED, AL and PAC and three different composites – a microhybrid Filtek Z250 and two packable resin composites SureFil and Tetric Ceram HB, polymerized according to the manufacturers' recommended exposure times.

Methods and Materials

Three hundred and sixty extracted bovine incisor teeth were selected, debrided, and stored in a 1% thymol solution for one week. The

specimens were then cut either 3 mm apical to the cementum-enamel junction or 4 mm coronal to the cementum-enamel junction, depending on gingival margin location, with a double-faced diamond disk (KG Sorensen Ind. Com. Ltda, Barueri, SP, Brazil) as illustrated in Figure 1.

In each specimen a “vertical-slot” resembling a Class II cavity was prepared at the mesial surface with a #245 carbide bur (KG Sorensen Ind. Com. Ltda, Barueri, SP, Brazil) in a highspeed water-cooled handpiece (Kavo do Brasil AS, Joinville, SC, Brazil). The burs were replaced after every ten preparations to maintain uniformity. The butt-joint cavities had the following dimensions: 1.5 mm of axial depth by 3 mm of bucco-lingual width, with the gingival margin located either 1 mm apical (enamel) to or 1 mm coronal (cementum/dentin) to the cementum-enamel junction corresponding 4 mm cervico-incisal (Figure 1).

Specimens were randomly divided into twelve groups (n=30), and each group was the result of the combination of the resin composites and

light-curing units used. Within each group, 15 specimens had gingival margins on enamel and 15 had gingival margins on cementum/dentin (Figure 1).

In all groups the enamel and dentin were etched with 35% phosphoric acid (3M ESPE, St. Paul, MN, USA) for 15 seconds, rinsed for 15 seconds, and blot dried. Two coats of Single Bond adhesive (3M ESPE, St. Paul, MN, USA) were applied with a brush tip, lightly dried, and polymerized for ten seconds following the manufacturer’s directions.

The resin composites (Table 1) SureFil (Dentsply/Caulk, Milford, DE, USA), Filtek Z250 (3M ESPE, St. Paul, MN, USA), and Tetric Ceram HB (Ivoclar/Vivadent INC, Liechtstein) were inserted in 2 mm horizontal increments, and each increment was polymerized on the occlusal surface according to the following groups:

Group 1: SureFil resin composite and AL photoactivation system (Accucure 3000, Lasermed, West Jordan, UT, USA) for 20 seconds;

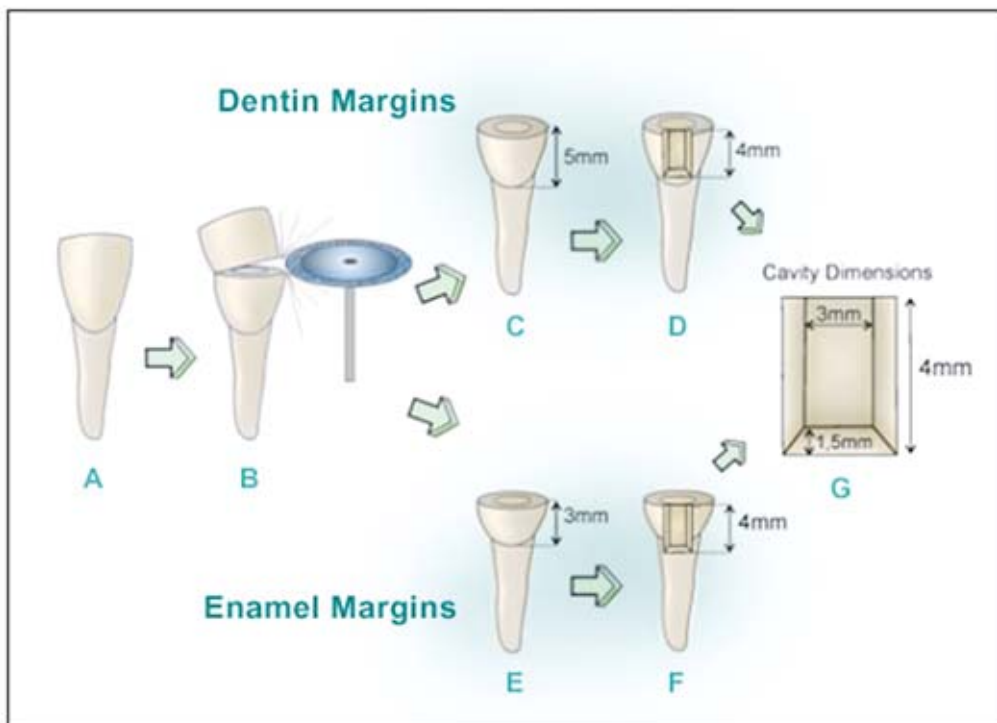


Figure 1. Diagram of cavity preparations. (a) Bovine incisor teeth; (b) sectioning of the crown; (c) section at 5 mm for enamel margins; (d) cavity preparation at enamel margins (1 mm upper enamel-cementum junction); (e) section at 3 mm for cementum margins; (f) cavity preparation at cementum margins (1 mm lower enamel-cementum junction); and (g) cavity dimensions.

Table 1. Resin composites evaluated.

Material	Type	Shade	Composition	Manufacturer (Batch n ^o)
FILTEK Z250	Microhybrid	A2	Bis-GMA, UDMA, Bis-EMA, TEGDMA, filler: 60% by volume zirconia/silica	3M ESPE – St. Paul, MN, USA (2PW)
SUREFIL	Packable	A	Bis-GMA, UDMA, filler: 66% by volume aluminium-fluoride- boro silicate barium, silica	Dentsply/Caulk – Milford, DE, USA (010626)
TETRIC CERAM HB	Packable	A2	Bis-GMA, UDMA, filler: 63% by volume barium-glass, ytterbium trifluoride, Ba-Al-fluorsilicate glass, silica.	Ivoclar/Vivadent – Liechtestein (E45007)

Group 2: SureFil resin composite and QTH photoactivation system (Optilux 501, Demetrom, Danbury, CT, USA) for 40 seconds;

Group 3: SureFil resin composite and LED photoactivation system (EliparTM FreeLight, 3M ESPE, St. Paul, MN, USA) for 40 seconds;

Group 4: SureFil resin composite using PAC photoactivation system (APOLLO 95E Elite, DMD Corp., Westlake Village, CA, USA) for 6 seconds;

Group 5: Tetric Ceram HB resin composite with AL photoactivation system (Accucure 3000, Lasermed, West Jordan, UT, USA) for 10 seconds;

Group 6: Tetric Ceram HB resin composite and QTH photoactivation system (Optilux 501, Demetrom, Danbury, CT, USA) for 20 seconds;

Group 7: Tetric Ceram HB resin composite and LED photoactivation system (EliparTM FreeLight, 3M ESPE, St. Paul, MN, USA) for 20 seconds; each increment;

Group 8: Tetric Ceram HB resin composite and PAC photoactivation system (APOLLO 95E Elite, DMD Corp., Westlake Village, CA, USA) for 3 seconds;

Group 9: Filtek Z250 resin composite with AL photoactivation system (Accucure 3000, Lasermed, West Jordan, UT, USA) for 10 seconds;

Group 10: Filtek Z250 resin composite and QTH photoactivation system (Optilux 501, Demetrom, Danbury, CT, USA) for 20 seconds;

Group 11: Filtek Z250 resin composite and LED photoactivation system (EliparTM FreeLight, 3M ESPE, St. Paul, MN, USA) for 20 seconds each increment;

Group 12: Filtek Z250 resin composite and PAC photoactivation system (APOLLO 95E Elite, DMD Corp., Westlake Village, CA, USA) for 3 seconds.

The exposure time(s) and energy density for each photoactivation system were used according to the manufacturer's recommendations (Table 2). The power (mW) of the four light units was measured using a power meter (Ophir Optonics Inc., Danvers, MA, USA). The diameters of the tips were measured with a digital caliper (Mitutoyo Corp., Tokyo, Japan) to determine the tip areas. By dividing the power by the area, the total intensity was calculated (mW/cm²). The spectral distributions of the light units were obtained using a USB 2000 spectrometer (Ocean Optics, Dunedin, FL, USA). The total intensity data and the spectral distributions of the units were tabulated in the software, Origin 6.1 (OriginLab Corp. Northampton, MA, USA) to obtain, by integrate calculus, the specific light intensity at the 450-490 nm wavelength range (Table 3).

Following the restorative procedure, the teeth were stored in water at 37°C for 48 hours. After this time, all restorations were finished with Sof-Lex discs (3M ESPE, St. Paul, MN, USA). Finishing and polishing were done in only one direction with a low-speed handpiece without any water coolant.

After the polishing, the apices and coronal surfaces were sealed with Araldite epoxy resin (Brascola Ltda, São Bernardo do Campo, SP,

Table 2. Exposure times and energy density based on total intensity values* or based on the intensity values at 450-490 nm wavelength range.**

Sources	Exposure Time – Total* and at 450-490 nm** Energy Density (J/cm ²)		
	FILTEK Z250	SUREFIL	TETRIC HB
QTH	20 sec – 10.8*/5.0**	40 sec – 21.6*/10.0**	20 sec – 10.8*/5.0**
LED	20 sec – 5.4*/3.0**	40 sec – 10.8*/6.1**	20 sec – 5.4*/3.0**
PAC	3 sec – 5.4*/4.5**	6 sec – 10.9*/9.0**	3 sec – 5.4*/4.5**
AL	10 sec – 2.8*/2.0**	20 sec – 6.1*/4.1**	10 sec – 2.8*/2.0**

*Time of exposure indicated by manufacturers

Table 3. Curing units tested – total light intensity and intensity at the 450-490 nm wavelength range.

Curing Units	Source	Total Intensity (mW/cm ²)	Intensity at the 450-490 nm wavelength range(mW/cm ²)
Optilux 501- Demetrom, USA	QTH	541	251
EliparFreelight -3M ESPE, USA	LED	270	152
Apollo 95E - DMD Corporation, USA	PAC	1818	1516
Accucure 3000 - LaserMed, USA	AL	*277 *306	*204 *205

* 150 mW – used for Fitek Z250 and Tetric Ceram HB ** 200 mW – used for Surefil according to manufactures' indication

Brazil), and the teeth were coated with two applications of fingernail polish up to 1 mm from the gingival margins. All teeth were immersed in a freshly prepared aqueous 2% methylene blue solution (pH=7.0) for four hours at 37°C and then washed in tap water. Finally, each tooth was sectioned vertically through the center of the restoration with a diamond disk (KG Sorensen Ind. Com. Ltda, Barueri, SP, Brazil) at low-speed, obtaining two sections.

Dye penetration at the gingival margin was evaluated by two previously calibrated examiners with an optical stereomicroscope (Meiji Techno Co., LTD., Iruma-gun Saitana, Japan) at 70x magnification and scored using the following criteria:

0=No dye penetration

1=dye penetration that extended for less than 1/3 of preparation depth

2=dye penetration greater than 1/3 and up to 1/2 of preparation depth

3=dye penetration greater than 1/2 but not reaching the axial wall and

4=dye penetration reaching or pasting the axial wall (Figure 2)

Each evaluator scored the microleakage of the two halves of the restoration; thus, each restoration was scored four times by the two examiners. For statistical analysis, each restoration was given the highest score obtained from any of the two surfaces examined. The Weighted Kappa Test of Reproducibility evaluated the agreement among examiners. The median of the microleakage evaluation of the two examiners was submitted to the Kruskal–Wallis and Mann-Whitney tests at 5% level of significance in order to evaluate the differences among the experimental groups.

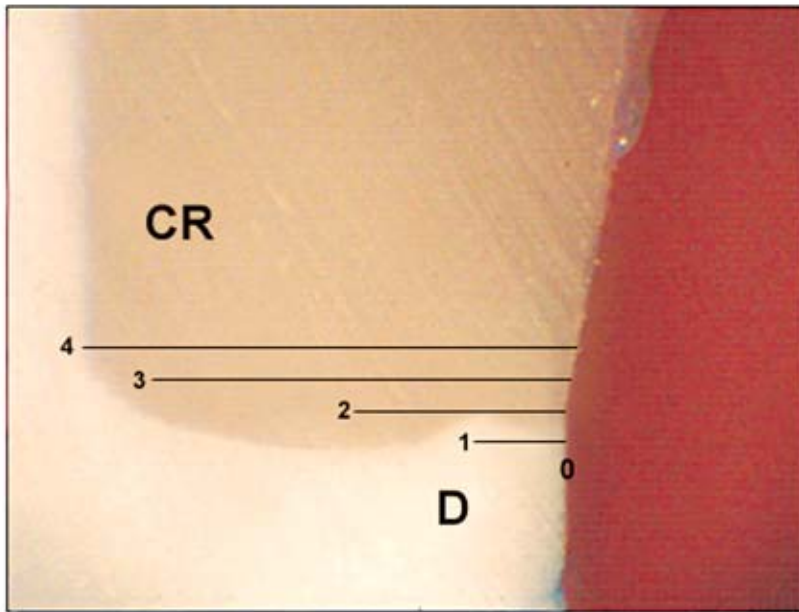


Figure 2. Diagram of microleakage evaluation criteria. Legend: **0**=No dye penetration; **1**=dye penetration that extended for less than 1/3 of preparation depth; **2**=dye penetration greater than 1/3 and up to 1/2 of preparation depth; **3**=dye penetration greater than 1/2 but not reaching the axial wall; and **4**=dye penetration reaching or pasting the axial wall.

Results

The overall inter observer agreement was excellent (Kappa value of 0.87) with a weighted Kappa estimator of 0.86.

The distribution of microleakage scores for each group – at cementum/dentin and enamel margin – is summarized in Tables 4 and 5.

None of the groups showed complete prevention of dye penetration. At the cementum/dentin ($H=16.43$; $p=0.1256$) or enamel ($H=17.5760$; $p=0.0920$) margins, the Kruskal-Wallis test showed there were no statistically significant differences observed among the four light sources and the three resin composites used in this experiment.

The Kruskal-Wallis test revealed no statistically significant difference among margin location: enamel, cementum/dentin $p=0.7344$.

Discussion

In vitro microleakage tests are numerous, and diverse methods have been used to access the leakage of restorative materials.⁸ The most commonly used methodology involves exposure of the samples to a dye solution and then viewing

cross sections under a stereomicroscope.^{5,9,10} A dye such as methylene blue is a realistic agent to identify the presence of a clinically relevant gap.^{11,12}

The influence of using different kinds of light-curing systems with varying intensities during the polymerization on microleakage was evaluated in this study using a microhybrid (Z250) and two packable resin composites (Surefil) and (Tetric Cream HB). According to the results, none of the four photoactivation systems – QTH, AL, LED, and PAC - used in this study were capable of eliminating marginal leakage and no differences were observed among them in the resin composite restorations.

According to some studies, the rapid rate of curing using units with high light intensities, like PAC and AL, can produce an increase in contraction forces and the magnitude of strain associated with the polymerization shrinkage.^{13,14,15,16} These stresses and strains can consequently increase the incidence and the magnitude of interfacial gaps, resulting in inferior marginal integrity.^{13,14,15,16} However, for these curing units, no increase in marginal leakage

Table 4. Distribution of microleakage scores and medians for each group – dentin margins.

Light Unit	Resin composite	SCORES					Median
		0	1	2	3	4	
LAS	SureFil	8	6	12	2	2	2.0 A
	Tetric HB	0	9	8	6	7	1.0 A
	Filtek Z250	14	7	5	4	0	2.0 A
QTH	SureFil	10	8	6	2	0	0.5 A
	Tetric HB	8	10	4	5	3	2.0 A
	Filtek Z250	12	1	10	6	0	1.0 A
LED	SureFil	5	8	6	7	4	1.0 A
	Tetric HB	7	12	9	0	0	1.2 A
	Filtek Z250	12	2	11	5	0	1.0 A
PAC	SureFil	16	3	1	10	0	2.0 A
	Tetric HB	2	14	4	6	2	2.0 A
	Filtek Z250	11	5	9	3	2	1.0 A

H=16.43 p=0.1256

Medians followed by same letters are not statistically different when analyzed by Kruskal-Wallis test (alfa=0.05)

Table 5. Distribution of microleakage scores and medians for each group – enamel margins.

Light Unit	Resin composite	SCORES					Median
		0	1	2	3	4	
LAS	SureFil	10	5	11	2	2	1.5 A
	Tetric HB	0	9	9	6	6	2.0 A
	Filtek Z250	14	8	6	2	0	1.0 A
QTH	SureFil	11	9	6	0	0	0.5 A
	Tetric HB	8	11	3	6	2	1.0 A
	Filtek Z250	11	1	11	7	0	2.0 A
LED	SureFil	6	6	8	6	4	2.0 A
	Tetric HB	7	12	9	0	0	1.0 A
	Filtek Z250	13	1	12	4	0	2.0 A
PAC	SureFil	15	3	2	10	0	0.5 A
	Tetric HB	2	15	3	6	2	1.0 A
	Filtek Z250	11	5	10	2	2	1.0 A

H=17.5760 p=0.0920

Medians followed by same letters are not statistically different when analyzed by Kruskal-Wallis test (alfa=0.05)

was observed in this study as demonstrated in previous reports.^{17,18,19} In spite of some studies which attribute this similar marginal seal to a relatively small degree of conversion, evaluations using the Knoop hardness test confirmed PAC and AL irradiations provided an equivalent degree of polymerization compared to the other curing protocols.^{17,19} Consequently, the margin quality of PAC and AL irradiated restorations seems to have been achieved without compromising mechanical properties and biocompatibility.

A strong and positive correlation between polymerization shrinkage stress values and microleakage has been reported in some studies.^{20,21} However, other studies affirm the amount of linear shrinkage is not influenced by the light source.^{22,23,24,25} The lack of relationship between polymerization shrinkage and the photoactivation systems used was confirmed in the present study. There are no statistically significant differences among the four light-curing systems when microleakage was evaluated at the cementum/dentin and enamel margins. These results were also described in previous studies that evaluated the marginal seal of composite restorations.^{4,17,18,26,27,28}

The energy density has demonstrated to be an important indicator of the total light to which composite material is exposed. Calculations of energy density as the product of light intensity (in mW/cm²) and time (in s) showed the energy density for AL were lower than LED, PAC, and QTH which showed a higher value (Table 3). However, based on the results of this study these variations in energy density were probably insufficient to influence the gap formation.

Characteristics of the restorative material are additional factors that can influence the marginal seal in resin composite restorations. Such characteristics as volumetric polymerization shrinkage, filler contents, elastic modulus, the photoinitiator, as well as the matrix resin can greatly affect the stress formation at the composite-tooth interface.^{1,13,14,17}

The flow and polymerization shrinkage were found to be significant determinants of gap formation around resin composite restorations *in vitro*.¹ The resin composite formulation has also been shown to be the most important factor in polymerization problems rather than light type or curing mode.²⁹ Even though this influence is reported in several studies, the results of the present study showed both packable composites (SureFil and Tetric Cream HB) and the microhybrid (Z250) resin composites did not show differences with regard to dye penetration at cementum/dentin nor at enamel margins.

Evaluation of interfacial integrity using a microleakage test seems to be limited, since only one parameter was used to express the overall quality of the interface (dye penetration depth, evaluated at specific sites).²⁰ These restrictions may provide a lack of precise results when different materials are analyzed. As a result, differences due to the material in microleakage tests may not be revealed. No differences were detected among photoactivation systems in this experiment. This means the AL, PAC, and LED based units presented the same behavior when compared to the QTH based unit used as control. Also, there were no differences observed with regard to the composite resin formulation in this study. However, further studies must be conducted in order to evaluate the long-term behavior of this composite resin restorations associated with the actual available light sources.

Conclusion

Under the conditions of this *in vitro* study:

- None of the photoactivation methods eliminated microleakage.
- No significant differences in the microleakage scores were found among the light units used – AL, PAC, QTH, and LED.
- For enamel and cementum/dentin margins, neither the resin composite formulation nor the light sources affect microleakage.

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Acknowledgements

This investigation was supported by FAPESP # 02/11601-0 and # 02/11602-7 (Fundação de Apoio à Pesquisa do Estado de São Paulo).