Class I and Class V composite restorations: Influence of light-curing techniques on microleakage

Restaurações de Classes I e V: influência das técnicas de fotoativação na microinfiltração

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Abstract

Purpose: To evaluate the effect of light-curing techniques on *in vitro* microleakage of class I and class V composite restorations.

Methods: Sixty human premolars were used to prepare 30 class I and 30 class V cavities, which were cleaned and treated with one step self-etching adhesive (Xeno III – Dentsply). A resin composite (TPH 3 – Dentsply) was inserted in two layers and light-cured using two protocols (n=15 each): conventional curing (500 mW/cm², 30 s each increment) and pulse delay technique (first increment similar to the conventional technique and the last increment initially cured with 200 mW/cm² for 3 s and after 5 min light-cured again with 500 mW/cm² for 30 s). The specimens were polished, submitted to 800 thermal cycles, sealed, and immersed in a 2% basic fuchsin solution. The teeth were cleaned, sliced, and scored according to the dye penetration. Data were analyzed by Mann-Whitney U test.

Results: In class I cavities the pulse delay light-curing technique showed statistically significant better sealing than the conventional technique. In class V restorations no difference was detected between the two techniques in enamel and dentin.

Conclusion: Light-curing technique affected the microleakage in class I composite restorations but not in class V.

Key words: Microleakage; composite; dentin adhesive

Resumo

Objetivo: Avaliar o efeito da técnica de fotoativação na microinfiltração *in vitro* em cavidades de classes I e V restauradas com resina composta.

Metodologia: Em 60 pré-molares humanos, foram confeccionadas cavidades de classe I em 30 dentes e de classe V nos demais 30 dentes. As cavidades foram limpas e tratadas com o sistema adesivo autocondicionante de um passo (Xeno III – Dentsply). A resina composta (TPH 3 – Dentsply) foi inserida em dois incrementos e fotoativada de dois modos (n=15 cada): A) Convencional, sendo cada incremento fotoativado com intensidade de 500 mW/cm² por 30 s; B) Pulso tardio, sendo o primeiro incremento fotoativado da mesma forma que o grupo convencional e o último incremento inicialmente fotoativado com 200 mW/cm², durante 3 s, 5 min de espera e fotoativação final com 500 mW/cm² por 30 s. Os espécimes foram polidos, submetidos a 800 ciclos térmicos, impermeabilizados e imersos em fucsina básica a 2%. Os dentes foram limpos, seccionados e avaliados quanto à penetração do corante usando-se escores de 0 a 5. Os dados foram analisados por teste U de Mann-Whitney.

Resultados: Nas cavidades de classe I houve diferença estatisticamente significativa entre os grupos. Nas cavidades de classe V não houve diferença entre os dois métodos de fotoativação, tanto em margem de esmalte quanto em dentina.

Conclusão: Em cavidades de classe I a fotoativação por pulso tardio proporcionou maior vedamento marginal que a fotoativação convencional. Em cavidades de classe V não houve diferença de penetração do corante.

Palavras-chave: Infiltração dentária; adesivos dentinários; resinas compostas

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Introduction

Several advances in mechanical properties and esthetics of resin composites have resulted in increasing use of these materials in posterior teeth (1). However, resin composites still present a number of limitations, such as polymerization shrinkage and internal stresses, which can lead to cusp deflection, postoperative sensitivity, marginal integrity loss, and recurrent caries (1-4). Previous studies (3,5-7) reported that the internal generated stress during composite polymerization shrinkage can be greater than the bonding of the adhesive to the dental substrate, which may result in marginal and interface failure of the restoration, with subsequent possibility of penetration of fluids and bacteria.

Some procedures were suggested to reduce polymerization stress such as changes in material composition and restoration techniques, as well as different light intensity during photo-activation (8). The stress value depends on the resin composite composition, *i.e.*, percentage of load and matrix composition, which influence the amount of polymerization shrinkage, modulus of elasticity, and composite flow before the gel point (5). The gel point is defined when the material no longer shows viscous flow during the polymerization shrinkage, which varies with the intensity of the light-curing units (9).

During the polymerization shrinkage of the resin composite restoration, the development of stresses is related to the cavity configuration (c-factor) (2), which is defined as the quotient between bonded and unbonded composite surface resulting in higher values for deeper cavities (10). Therefore, the smaller the unbonded area, the lower the material flow and the larger the stress generated by polymerization shrinkage on the bonded surface (11). On the other hand, in a large surface area the composite more easily deforms, thus generating less stress on the bonded surfaces. A recently established method to reduce the stress shrinkage consists in an initial reduction of monomer conversion into polymer, which controls the flow capacity of the resin composite (1). Increasing the time of curing by diminishing the light-curing intensity slows the polymerization reaction, which influences the material flow characteristics and can be useful in moderating the shrinkage stress development, thus improving marginal adaptation.

Previous studies evaluated the influence of curing methods on the mechanical properties of resin composites and the generated stress during polymerization shrinkage. For example, Suh et al. (12) showed that the pulse delay curing technique yielded a reduction of up to 34% in the residual stress of composites, and Luo et al. (13) concluded that the pulse delay technique improved marginal integrity. On the other hand, Pereira et al. (14) found that the internal adaptation of composite in class V restorations was not influenced by the curing technique.

Therefore, the purpose of the present *in vitro* study was to evaluate the influence of conventional and pulse delay polymerization techniques on the microleakage of class I and class V cavities restored with resin composite.

Methods

The research project was approved by the University Committee of Ethics and Research in Human Beings (Protocol No 141/06). The materials used in this study were described in Table 1.

Sixty premolars extracted for orthodontic reasons were selected and stored in 0.1% thymol solution in 0.9% saline, for up 6 months. The teeth were cleaned with pumice and water. Class I cavities (dimensions: 2 mm-deep, 3 mm-long and 2 mm-wide) were prepared on the occlusal surfaces of 30 teeth, using 245 tungsten carbide drills (KG Sorensen, Ind. e Com Ltda. Baurueri, SP, Brazil) and high-speed, water-cooled hand piece. Burs were replaced after every five preparations. Class V cavities were prepared on the buccal surfaces of the other 30 teeth, using 4054 diamond burs (KG Sorensen, Ind. e Com Ltda. Barueri, Brazil) and 245 tungsten carbide drill (KG Sorensen) to standardize the cavity depth (2 mm) and provide wall finishing. The occlusal margin was located in enamel, and the gingival margin in dentin, being 1.0 mm apart from the cement-enamel junction. Therefore, the occlusal-gingival height and axial depth were 2 mm. A probe was used to check the dimensions of the cavity preparations in millimeters. Figure 1 shows a schematic drawing of the class I and class V cavities.

Table 1. Materials evaluated in this study.

Material	Manufacturer	Composition*
Composite resin TPH 3	Dentsply CaulK, Milford, DE	Bis-GMA adduct, Bis-EMA adduct, canphorquinone (CQ), triethylene glycol dimethacrylate, stabilizer, pigments
Adhesive Xeno III	(Dentsply DeTrey GmbH, Konstanz, Germany)	Bottle A: HEMA, purified water, ethanol, BHT, highly dispersed silicon dioxide Bottle B: Pyro-EMA, PEM-F, UDMA, BHT, CQ, ethyl-4-dimethylaminobenzoate

* Composition description according to the manufacturers.
Abbreviations: UDMA - urethane dimethacrylate; Bis-GMA - bis-phenol A-glycidyl dimethacrylate; CQ - canphorquinone; HEMA - hydroxyethyl methacrylate; BHT - butylated hydroxyl toluene; Pyro-Ema - tetra-methacryl-ethyl-pyrophosphate; PEM-F - penta-methacryl-oxy-ethyl-cyclo-phosphazenmonofluoride.

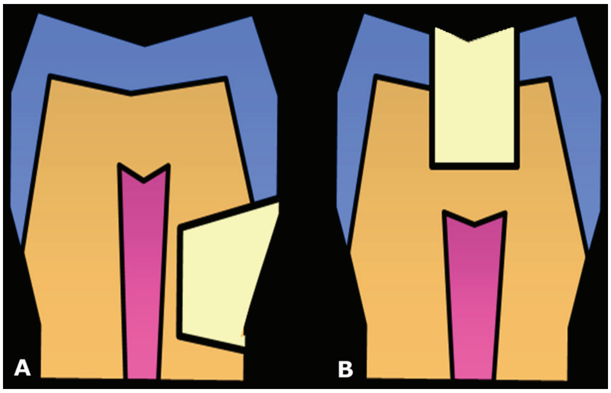

Fig. 1. Schematic illustration of class V (A) and class I (B) cavity preparations.

The self-etch adhesive was applied on the surfaces using a disposable applicator, left undisturbed for 20 s, air-blasted for 2 s, and light-cured for 15 s using a LED equipment (Radii – SDI Limited, Bayswater, Victoria, Austria) at 500 mW/cm² as measured by a radiometer (Gnatus, Ribeirão Preto, SP, Brazil). The specimens were divided into six groups according to the cavity type, margin to be evaluated, method of curing, and light-curing intensity (Table 2). The composite was packed inside the cavity in two layers (approximately 1 mm each), with a titanium spatula, firstly at the cavity bottom, followed by the pulp or axial wall, and finally filling the entire cavity. The curing of each layer was performed with the LED with controlled light intensity, as follows:

- Group 1 (class I – conventional light-curing): 30 s light-curing for each layer at 500 mW/cm² (Fig. 2).
- Group 2 (class I – pulse delay curing): the first layer was inserted at the cement-enamel area and light-cured for 30 s at 500 mW/cm². The second layer was packed and cured initially at 200 mW/cm² for 3 s. Initial finishing was performed with a diamond bur for 5 min, and final curing was performed for 30 s at 500 mW/cm².
- Groups 3 and 5 (class V – conventional light-curing): each layer was cured for 30 s at 500 mW/cm².
- Groups 4 and 6 (class V – pulse delay curing): the first layer was cured at 500 mW/cm² for 30 s. The second layer was cured initially at 200 mW/cm² for 3 s; the initial finishing was carried out for 5 min, and then a final curing was performed for 30 s at 500 mW/cm².

The restored teeth were immersed in distilled water and stored at 37 °C for 24 h before the restorations were finished and polished with rubber cups (TDV Dental Ltda. Pomerode, SC, Brazil). In sequence, all specimens were thermocycled (Ética Equipamentos Científicos S/A, São Paulo, SP, Brazil) for 800 cycles at 5±2 ºC and 55±2 ºC. The dwell-time was 30 s with a 5-s transfer time. After thermocycling, the coronal and root surfaces were sealed with sticky wax and two layers of nail polish, except for the restoration and 1 mm around it.

The specimens were immersed in 2% basic fuchsin solution at 37 ºC for 24 h, washed in running water, dried with absorbent paper, and sectioned in the buccal-lingual direction (Isomet 1000, Buehler, Lake Bluff, IL, USA) under water refrigeration. The analysis of microleakage was performed by a qualitative method. Two examiners visually assessed the degree of dye penetration using a stereoscope and assigned scores (1) as follows:

- For Class I cavities: Score 0 – No dye penetration; Score 1 – Infiltration to half of any surrounding walls; Score 2 – Infiltration beyond half of any surrounding walls without reaching the pulp wall; Score 3 – Infiltration up to the pulp wall; Score 4 – Infiltration in any surrounding walls and in the pulp direction.
- For Class V cavities: Score 0 – No dye penetration; Score 1 – Infiltration up to half of any surrounding wall; Score 2 – Infiltration beyond half of any surrounding wall without reaching the pulp wall; Score 3 – Infiltration in any surrounding wall and in pulp wall; Score 4 – Infiltration in any surrounding wall and axial wall towards the pulp. Enamel and dentin margins were evaluated independently.

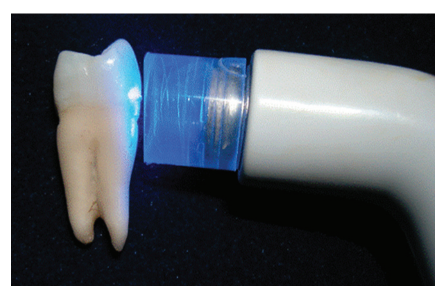

Fig. 2. Plastic spacer used to standardize the position of the light-curing tip.

Table 2. Description of the experimental groups according to the type of cavity, dental margin to be evaluated, and light-curing technique.

Group	Cavity	Margin	Photo-activation methods	Intensity of the photo-activation	
				200 mW/cm²	500 mW/cm²
1	Class I	Enamel	Conventional	_	30 s
2	Class I	Enamel	Pulse delay	3 s*	30 s
3	Class V	Enamel	Conventional	_	30 s
4	Class V	Enamel	Pulse delay	3 s*	30 s
5	Class V	Dentin	Conventional	_	30 s
6	Class V	Dentin	Pulse delay	3 s*	30 s

* The light-curing was performed by pulse delay in the last composite layer; the time period between curing by pulse delay and last curing by conventional technique was 5 minutes.

Figure 3 shows examples of the scores of dye penetration in the cavities. In case of disagreement between examiners a new analysis was performed, and any differences were discussed until reaching mutual agreement. To compare groups in pairs according to the light-curing technique (conventional *vs* pulse-delay curing), data were analyzed by Mann-Whitney U test at the significance level of 0.05.

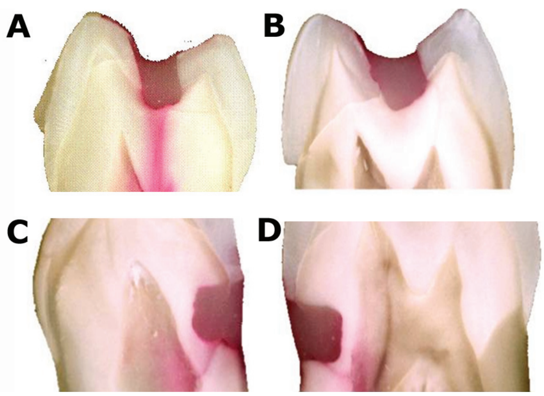

Fig. 3. Examples of dye penetration: **(A)** Score 4 for class I with conventional curing. **(B)** Score 3 for class I with pulse delay curing. **(C)** Score 1 (enamel) and Score 4 (dentin) for class V with conventional curing. **(D)** Score 1 (enamel) and Score 4 (dentin) for class V with pulse delay curing.

Results

The scores of microleakage for class I cavities in enamel margins and for class V cavities, in enamel and dentin margins, are shown in Figure 4. A statistically significant difference of microleakage was seen between Groups 1 and 2 (P=0.01). In class I cavities, pulse delay light-curing (Group 2) provided better marginal sealing when compared to conventional light-curing (Group 1). In class V cavities, there was no difference in scores between the two types of curing in enamel margins (Group 3 × Group 4) (P=0.75) and in dentin margins (Group 5 × Group 6) (P=0.69).
The conventional (Group 3 × Group 5, P<0.001) and the pulse delay (Group 4 × Group 6, P=0.002) light-curing techniques showed better marginal sealing in enamel than in dentin margins.

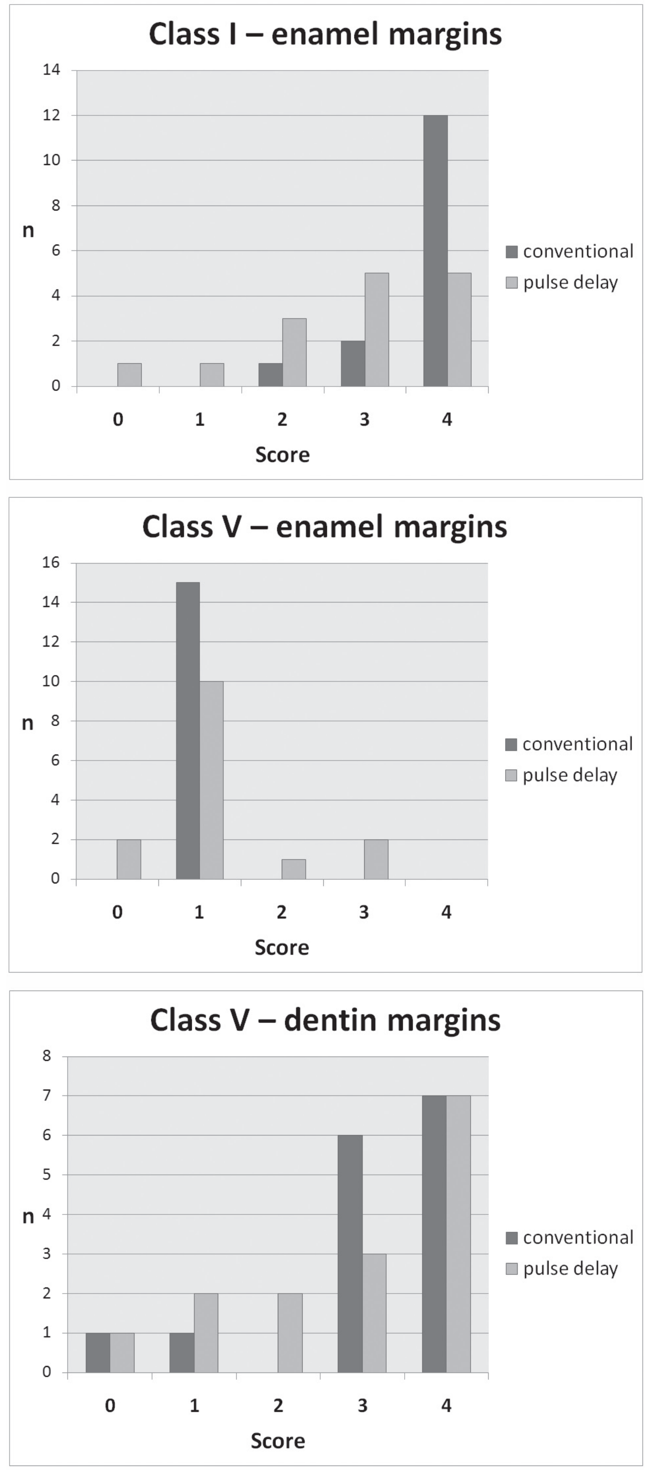

Fig. 4. Microleakage scores of the experimental groups according to dental margins, type of cavity restoration, and light-curing technique.

Discussion

The marginal gap formation in resin composite restorations often is related to multiple factors, such as polymerization shrinkage of the restorative material (6-7), quality and strength of the adhesive bond, and cavity configuration (7), which require different clinical strategies and techniques to minimize marginal microleakage.
Some studies (1,4,9,15) have suggested that the speed modulation of the polymerization reaction lengthen the composite pre-gel phase inducing material flow and greater stress relief. This condition can be developed by using the pulse delay light-curing technique (small energy pulses) or a soft-start light-curing technique (pre-polymerization with low intensity light followed by a final cure with high intensity light). As a result, there is a tendency to minimize the marginal gap formation (13), with no compromise of the polymerization degree of conversion (16).

The present study evaluated if different light-curing techniques (conventional or pulse delay) resulted in different microleakage around class I and class V cavities restored with resin composite. Additionally, it was examined whether there were differences between enamel and dentin margins in both the conventional and the pulse delay light-curing techniques. The results showed a significant advantage for the pulse delay technique, which had improved marginal sealing. Kanca and Suh (17) also reported that the enamel margins are vulnerable to stresses generated by polymerization shrinkage of composites, especially in restorations where the cavity configuration factor is high, and the use of the pulse delay protocol to cure the composite occlusal layer improved the marginal quality of class I cavities. Suh et al. (12) also reported that the initial reduction of light power to 200 mW/cm^2, followed by a waiting period of 3-5 minutes, and then exposure to high light intensity (600 mW/cm^2) would result in a significant reduction of the final shrinkage stress, which ranged from 4 to 34% for the composites tested.

Regarding class V cavities, no statistically significant differences were observed between the different light-curing techniques in enamel and dentin margins. The absence of visible differences of microleakage in class V cavities also was observed by Pereira et al. (14), which found similar internal adaptation of class V restorations to the cavity wall using three light-curing methods (pulse delay, soft-start, and conventional technique). Krejci et al. (18) found that the pulse delay technique reduced the composite contraction and linear displacement during polymerization, but there was no improvement in marginal adaptation of class V restorations.

This present study found better sealing in enamel than in dentin margins using both the conventional and pulse delay light-curing techniques. Bonding to dentin is more difficult to achieve than bonding to enamel due to inherent characteristics of the dentin substrate, such as humidity, structural changes over time, dentin tubules and permeability, intratubular fluid movement, calcification, etc (19).

Other factors may have influenced the results of the present study, such as the composite insertion technique, cavity geometry and position, dental substrate, and adhesive system. Two layers of composite were used to minimize the polymerization contraction effects of the cavity filling (11). The self-etching adhesive system contains acidic monomer that acts over and into the smear layer, causing dentin demineralization and penetration simultaneously (20). The effectiveness of self-etching systems on enamel surfaces has been questioned and evaluated against total etching systems. Martins et al. (21) found greater marginal microleakage in enamel margins of class V cavities with a self-etching adhesive in comparison with a total etching adhesive. As the present study did not assess a total etching adhesive, it was not possible to compare its effect at the enamel margins.

The pulse delay technique involves the light-curing modulation, initially with low intensity, followed by a waiting period (3 to 5 min), and a final cure with high light intensity. The waiting period is fundamental because the polymerization reaction continues after the light-curing unit is off, but at a slower speed (12). The restoration protocol with this technique is simple and easy to perform even with a conventional light-curing unit, but the longer total polymerization time (because of the waiting period of 3-5 min) may be the main obstacle to popularize the pulse delay technique in routine dental practice.

In summary, this study showed a positive effect in marginal sealing for class I cavities using the pulse delay technique. However, no difference was observed for class V cavities. Longitudinal clinical studies should add evidences on the possible beneficial use of light-curing techniques to promote better adaptation and interface sealing between composite restoration and dental substrate.

Conclusions

Based on the results of this study it can be concluded that:

1. For enamel margins in class I cavities, the pulse delay light-curing technique yielded lower microleakage than the conventional light-curing.
2. For enamel and dentin margins of class V cavities, no statistically significant differences in microleakage were found between the conventional and pulse delay light-curing techniques.
3. For class V cavities, dentin margins had greater dye penetration than enamel margins independently from the light-curing technique.

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