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Restorative Dentistry

The effect of insertion and photopolymerization techniques on microleakage of Class V cavities – a quantitative evaluation

Efeito de diferentes técnicas de inserção e fotopolimerização na microinfiltração de cavidades Classe V – avaliação quantitativa

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ABSTRACT: The aim of this *in vitro* study was to evaluate by spectrophotometry the influence of the incremental technique and progressive light curing in the microleakage of Class V cavities. Forty samples were prepared with class V cylindrical cavities on the buccal root surface of bovine incisive teeth and filled with composite resin (Z250). The samples were divided into four groups: I: cavity was bulk filled and the composite was light cured for 40 seconds; Group II: cavity was bulk filled and a "soft-start" polymerization was used; Group III: cavity was filled with the incremental technique in two coats and light cured for 40 seconds; Group IV: cavity was filled with the incremental technique in two coats and light cured with "soft-start" polymerization. After the restoration, the specimens were thermally stressed for 3,000 cycles in bath at 5 ± 2°C and 55 ± 2°C, protected with nail enamel, colored with 2% methylene blue and cut into sections. These sections were triturated and the dye was recovered with PA ethanol and the supernatant was evaluated. The data were submitted to ANOVA and the results showed the following averages: bulk filled and conventional photopolymerization (I) 0.06075 μg/ml; bulk filled and progressive photopolymerization (II) 0.04030 μg/ml; incremental insertion and conventional photopolymerization (III) 0.04648 μg/ml; incremental insertion and progressive photopolymerization (IV) 0.04339 μg/ml. No significant statistic differences were observed among the mean values. The Degulux "soft-start" equipment probably emits too high initial light intensity to promote progressive photopolymerization.
DESCRIPTORS: Dental leakage; Dentin-bonding agents; Composite resins.

RESUMO: O objetivo deste estudo *in vitro* foi avaliar através de espectrofotometria a influência das técnicas de inserção incremental e de fotopolimerização progressiva na microinfiltração de cavidades Classe V. Foram preparadas 40 cavidades cilíndricas na superfície radicular vestibular de incisivos bovinos e preenchidas com resina composta (Z250). Os espécimes foram divididos em quatro grupos: I: a resina foi inserida em camada única e fotopolimerizada por 40 segundos; II: a resina foi inserida em camada única e fotopolimerizada progressivamente com um aparelho "soft-start"; III: a resina foi inserida em duas camadas e fotopolimerizada por 40 segundos; IV: a resina foi inserida em duas camadas e fotopolimerizada progressivamente. Em seguida os espécimes foram submetidos a 3.000 ciclos térmicos a 5 ± 2°C e 55 ± 2°C, preparados, corados com azul de metileno a 2%, seccionados, triturados e avaliados em espectrofotometria para se quantificar o corante infiltrado. Os dados foram submetidos a ANOVA. Os resultados demonstraram as seguintes médias: inserção única e fotopolimerização convencional (I): 0,06075 μg/ml; inserção única e fotopolimerização progressiva (II): 0,04030 μg/ml; inserção incremental e fotopolimerização convencional (III): 0,04648 μg/ml; inserção incremental e fotopolimerização progressiva (IV): 0,04339 μg/ml. Não foram encontradas diferenças estatísticas significativas entre as médias. Observou-se que o aparelho Degulux "soft-start" emite uma intensidade de luz inicial muito alta para promover fotopolimerização progressiva.
DESCRITORES: Infiltração dentária; Adesivos dentinários; Resinas compostas.

INTRODUCTION

Light-activated resin composite restorative material has revolutionized clinical dentistry, and modern advanced technology continues to develop resin composites[15]. As a result, new resin composites have become widely used for many purposes in restorative dentistry[2]. Light cured materials offer

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the practitioner the freedom to time the initiation of polymerization, so that the restoration can be placed and shaped with ease[4]. The most commonly used monomer for both anterior and posterior resins is Bis-GMA, which has a higher molecular weight than methyl methacrylate, and helps to reduce the polymerization shrinkage. Two physical phenomena invariably accompany the polymerization of resins of dental interest such as: the development of heat and the volumetric shrinkage of the cured material compared with the prepolymer[18].

The polymerization shrinkage of a resin composite can create contraction forces that may disrupt the bond to cavity walls. This competition between the mechanical stress in polymerizing resin composites and the bonds of adhesive resins to the walls of restorations is one of the main causes of marginal failure and subsequent microleakage, leading to secondary caries[2,22]. The shrinkage of the cured resin can be usefully divided into two parts which are: the pre-gel shrinkage (in which volumetric change can be compensated by continued flow of the material) and the post-gel shrinkage (in which the shrinkage of the polymer is accompanied by the development of a modulus of elasticity)[18]. As a result, the stresses begin to grow and can cause adhesion failure[10] or deformation of the surrounding tooth structure resulting in microcracks in the cervical enamel that predispose the tooth to fracture[22].

Davidson *et al.*[3] (1984) reported the influence of contraction stresses, generated during polymerization shrinkage, on adhesion of light-cured and chemically cured resin composite to dentin, in both two-dimensional and three-dimensional models. In the two-dimensional model, the bond strength could withstand the contraction forces because the adhesion of the resin composite was performed on a flat dentin surface. This configuration allowed a large, free, and unbounded surface, which permitted the flow of the resin across the free surface during its polymerization shrinkage, thereby minimizing stresses at the bonded surface. In the three-dimensional cavity models, the composite was bonded to two or more cavity walls[2]. In such situations, the resin flow was limited or restricted, leading to an increase in the stress generated at bonded surfaces.

Techniques are used to minimize the effect of shrinkage polymerization, like progressive photopolymerization and incremental insertion technique. In the progressive photopolymerization, the composite is irradiated by a low initial light intensity followed by normal light intensity. With a low initial light intensity, the resin stays for a longer period in the pre-gel stage of contraction, in which volumetric change can be compensated by the continuous flow of the material[18]. The aim of "soft-start" polymerization is to prolong the time span before reaching the gel point by low light-curing intensities and to increase the flow capability of the material. Afterwards, high light intensities are necessary for a complete polymerization and optimal mechanical properties[12].

The purpose of the incremental techniques is to minimize the stress generated by polymerization contraction, inserting resin layers in the cavity and reducing the bonded areas. As a result, we have a lower C-factor, which allows the resin to flow at the free surfaces[2].

It is necessary to verify if the variation methods of photopolymerization intensity and incremental technique are being effective in preventing marginal microleakage; therefore, the aim of this study was to evaluate in quantity by spectrophotometry the influence of the incremental technique and progressive light curing in the microleakage of class V cavities.

MATERIAL AND METHODS

In this study, forty bovine incisors were used. After being extracted, the teeth were cleaned of gross debris, polished and examined under a microscope (4 X) (Carl Zeiss, Gottingen, Germany) in order to discard damaged teeth. All teeth were stored in distilled water at 5°C for three months. Cylindrical class V cavities of 1.85 ± 0.05 mm in diameter and 1.5 mm in depth were prepared 4 mm below the cemento-enamel junction at the buccal root surface with a special diamond bur (KG Sorensen Ind. Com. Ltda., Barueri, São Paulo, Brazil) at high speed and adequate water cooling. Each diamond bur was replaced after every five cavity preparations. The cavities were restored with Single Bond (3M – ESPE, St. Paul, MN, USA) and a microhybrid resin (Z250, 3M – ESPE, St. Paul, MN, USA), and light cured with a Degulux "soft-start" Curing Light unit (Degussa-Hüls AG, Hanau, Germany). Before beginning the experiment, the light intensity of the light-curing unit was assessed with a radiometer (Demetron Research Corporation, Danbury, CT, USA); the initial low light intensity was 400 mW/cm^2 for 10 seconds and the high intensity was 600 mW/cm^2 for 30 seconds. The light intensity for continuous photopolymerization was 600 mW/cm^2. The root apices were removed with a diamond disc (KG Sorensen Ind. e Com. Ltda., Barueri, SP, Brazil) and sealed with composite resin (Z250, 3M – ESPE, St. Paul, MN, USA) and Super Bonder cyanoacrylate adhesive (Henkel Loctite Adhesives Ltda., Itapevi, São Paulo, Brazil).

After the preparation, the teeth were randomly assigned to four test groups of 10 specimens each (Table 1). Group I: The cavity was bulk filled and the composite was light cured for 40 seconds; Group II: The cavity was bulk filled and a "soft-start" polymerization was used with an appropriate light curing unit (Degussa-Hüls AG, Hanau, Germany); Group III: The cavity was filled with the incremental technique in two coats and light cured for 40 seconds; Group IV: The cavity was filled with the incremental technique in two coats and light cured with "soft-start" polymerization. After the restorations, all specimens were immersed in distilled water for 24 hours; after that, the restorations were polished with SofLex aluminum oxide discs (3M – ESPE, St. Paul, MN, USA).

The restored teeth were subjected to 3,000 temperature cycles between 5°C and 55°C. The cycles consisted of 60 seconds in each bath with an exchange time of 15 seconds between baths. After cycling, the whole tooth surface except a 1 mm window around the restoration was covered with two coats of nail varnish (Risqué, Niasi, SP, Brazil), and immersed in 2% methylene blue solution (Merck, Darmstadt, Germany) for 12 hours at 37°C. After this time, the samples were rinsed in tap water and dried. The specimens were cut with diamond discs and 5 mm sections of the root including the restorations were removed. The nail varnish and superficial stain were removed from each specimen with a graded series of SofLex aluminum oxide discs (3M – ESPE, St. Paul, MN, USA).

Each specimen was weighed and ground into powder in a mill for hard tissues (Marconi Equip. Ltda., Piracicaba, São Paulo, Brazil). The powder specimen was weighed again, and if the difference between the initial and the final weight was greater than 10%, the sample would be discarded. The powder of each sample was individually immersed in a glass tube containing 4 ml of absolute alcohol PA (Merck, Darmstadt, Germany), for 24 hours, in order to dilute the methylene blue solution. After this procedure, the solutions were centrifuged (Tomy – IC 15NA, Tomy Ind., Tokyo, Japan) at 3,000 rpm for 3 min. The supernatant was analyzed using a spectrophotometer (Beckman DU 65, Instruments, Inc., Fullerton, CA, USA) adjusted with a wavelength of 565 ηm. In order to determine the absorbency, the spectrophotometer was adjusted with appropriate wavelength for the methylene blue, corresponding to the maximum absorbency for the dye. To calibrate the spectrophotometer, the absorbency of the standard solutions (containing from 0 to 4 μg of dye/mL) was determined at wavelengths ranging from 400 to 700 ηm, and the maximum value was obtained at 565 ηm. In this wavelength, the absorbencies for the standard solutions were obtained. With these values, a coefficient of linear correlation ($r = 0.9998$) and a straight-line equation ($y = 0.2714\,x + 0.0071$) were determined. To calculate the quantity of dye in the dye concentration (μg/ml) that infiltrated between the tooth and the restoration, the "y" was changed for the absorbency value of each sample in linear equation. The microleakage of each specimen was expressed as μg of dye/mL, lower values indicating lower microleakage. Data were statistically analyzed by two-way ANOVA and Tukey-Kramer test.

TABLE 1 - Division of each group according to photopolymerization and insertion technique.

Groups	Treatments
I	Bulk insertion; conventional polymerization
II	Bulk insertion; "soft-start" polymerization
III	Incremental insertion; conventional polymerization
IV	Incremental insertion; "soft-start" polymerization

RESULTS

The results of the analysis of variance (two-way ANOVA) expressed in Table 2 and Graph 1 revealed no significant differences in mean microleakage based on two independent variables ($p > 0.05$). The incremental technique and the "soft-start" polymerization did not influence the microleakage around class V cavities in root surfaces of bovine teeth. The general variation coefficient of the experiment (in percentage) was 19.44. No differences were detected when the means of microleakage were compared between groups.

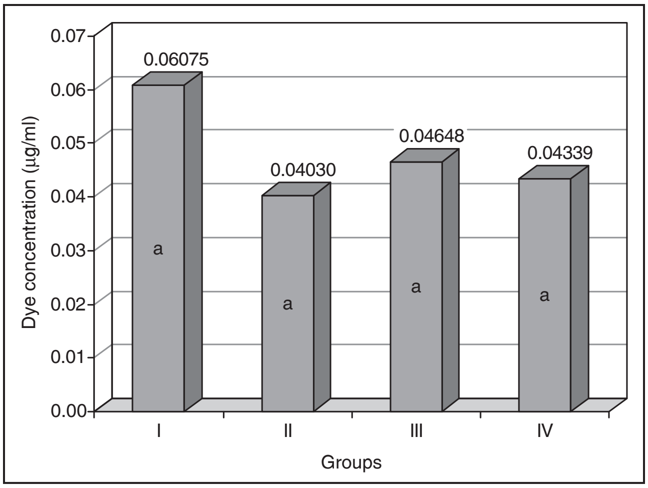
DISCUSSION

Secondary caries at the tooth/restoration interface and particularly at the dentin or cementum/restoration interface is the main reason for the replacement of resin composite restorations[12]. It has been demonstrated that the ingress of bac-

TABLE 2 - Means and Standard Deviations (SD) of microleakage (μg/ml).

Groups	n	Mean and SD	Tukey
I - Bulk filling/conventional photopolymerization	10	0.06075 (± 0.033205)	a
II - Bulk filling/“soft-start” photopolymerization	10	0.04030 (± 0.00762)	a
III - Incremental filling/conventional photopolymerization	10	0.04648 (± 0.013266)	a
IV - Incremental filling/“soft-start” photopolymerization	10	0.04339 (± 0.01968)	a

Same letters indicate no significant difference.



GRAPH 1 - Comparison between means of dye concentration according to the different insertion and photopolymerization techniques. Same letters indicate no significant difference.

teria at the tooth/restoration interface is the main reason for secondary caries and related pulpal reactions[1,14]. In most laboratory studies in which microleakage is evaluated, linear measurements of the extent of dye penetration at the tooth/restoration interface are performed[5]. These two-dimensional linear measurements do not take into account the density of the leakage in a three-dimensional leakage-pattern. The spectrophotometric dye-recovery method used in the present study allows for the direct and quantitative measurement of leakage volumetrically[19].

The shrinkage that occurs during the conversion of the monomer to the polymer of the adhesive and of the composite resin certainly works against the formation of an adhesive bond between the resin and the dentin and also contributes to the breakdown of the composite resin itself *in vivo* over time[8]. Many factors have a direct effect on the polymerization shrinkage of composite resin: size of the restoration, cavity configuration, placement technique (incremental or bulk), and curing method (chemical or light-curing).

The role of cavity configuration on the development of polymerization stresses with a resin composite was demonstrated by Feilzer *et al.*[6] (1987).

Davidson *et al.*[3] (1984) reported that when polymerization is restricted to one direction only, a substantial marginal bond that withstands contraction forces occurs, because the resin composite still flows. When the composite was restricted to three dimensions rather than one, almost no bonds withstood the polymerization shrinkage. Generally, the fewer the free, unbonded areas present in a cavity, the less the resin is able to flow, and therefore the greater the contraction stress at the bonded surfaces[2].

In this study, Class V cavities were used with high C-factor (4.8) to evaluate the role of the incremental technique and “soft-start” polymerization in diminishing the effect of cavity configuration in composite polymerization shrinkage.

Another important factor that influences the bond quality is the light intensity. An ideal light intensity (233 mW/cm^2 for 1 mm increments) is necessary to achieve a deep and complete polymerization of the material and good mechanical properties[8,16]. However, previous studies have shown that the marginal adaptation of light-curing composites can be improved by light curing the material slowly with low intensity light[10].

Pires *et al.*[13] (1993) described that light intensity diminishes as the curing tip is moved farther from the composite resin restorative material. Davidson-Kaban *et al.*[4] (1997) demonstrated that exposure time and light intensity positively affects the degree of conversion, while sample thickness negatively influences the cure. When the conversion rate on the top surface was taken as a reference, the curing at a depth of 2 mm became critical[16]. For that reason, approximately 1.0 mm was chosen as the incremental layer thickness and also to guarantee good mechanical properties. However, cavity depth was 1.5 mm; because of that, the bulk-filled groups also had small layers, perhaps causing no differences among means of microleakage.

According to Versluis *et al.*[20] (1996), in a finite element study, the total amount of composite necessary to fill a cavity becomes lower for an incremental filling technique compared with the single bulk filling technique in the same occlusal contour. This results in higher residual shrinkage stresses for the incremental filling method. The polymerization contraction of each individual filling increment will cause some deformation to the cavity, decreasing its volume. Such situation must result in a higher stress state of the tooth-restoration complex. Also, the type of incremental technique affects the amount of applied restorative material, and therefore cusp displacement. These findings are in contrast with some studies that stated that the incremental technique reduces the polymerization shrinkage effects[2,21].

In spite of this study's results, the incremental techniques should be used to achieve both good mechanical properties associated with a high rate of conversion and close adaptation of the resin composites to the cavity wall.

Previous studies have demonstrated that it is actually possible to reduce marginal gap of resin composite by starting the light polymerization reaction gradually and progressively[4,9].

Mehl *et al.*[11] (1995) showed that hardness is not changed by using a pre-polymerization step with light intensity reduced to about 50% of the final curing intensity values, if the specimens are post cured for at least 20 seconds with the full intensity. The initial light intensity reported in the related literature ranges from 150 to 250 mW/cm^2; and the final intensity is around 800 mW/cm^2.[7,10] It is known that the Degulux "soft-start", the equipment used in this study, emits initial light intensity of 400 mW/cm^2 and final light intensity of 600 mW/cm^2. Contrasting the values of light intensity emitted by the Degulux "soft-start" with the values showed by Sakaguchi, Berge[17] (1998) (low intensity values vary from 116 to 241 mW/cm^2) and Friedl *et al.*[8] (2000) (150 mW/cm^2 - low intensity and 800 mW/cm^2 - high intensity), we can conclude that the initial light intensity emitted by this equipment might be too high to promote progressive photopolymerization.

A combination of factors such as shrinkage rate, flow capacity, completeness of polymerization and bond strength may affect the resulting shrinkage and its impact upon the integrity of the tooth-restoration complexes, and influence the clinical success of restorations. However, this study shows that in small Class V cavities with high C-factor the incremental filling technique and progressive photopolymerization (initial light intensity – 400 mW/cm^2 and final – 600 mW/cm^2) did not reduce the microleakage compared to the bulk filling technique and conventional light cure (600 mW/cm^2).

CONCLUSIONS

- The incremental technique and the "soft-start" polymerization did not influence the microleakage in class V cavities in root surfaces of bovine teeth.
- The Degulux "soft-start" equipment probably emits initial light intensity too high to promote progressive photopolymerization.

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