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Comparative Analysis of Different Methods of Marginal Microleakage Evaluation for Restored Teeth by Composite Resin

Análise Comparativa Entre Métodos de Avaliação da Microinfiltração Marginal de Dentes Restaurados com Resina Composta

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Abstract

Polymerization contraction of composite resin can cause marginal microleakage resulting in hypersensitivity, discoloration, secondary caries, pulpal involvement, and restoration failure. Different methods are used to assess these leaks. This study compared two methods of assessing marginal infiltration using dye penetration. Class V preparations were made in 45 fragments of bovine teeth, which were restored in composite resin. After finishing and polishing, the samples were randomized into 3 groups: GI (control, no sealing); GII (Fortify surface sealant (Bisco, Schaumburg, IL, United States of America); GIII (Biscover surface sealant Bisco, Schaumburg, IL, United States of America). The restorations were thermocycled and immersed in 2% methylene blue. For the qualitative infiltration assessment, the samples were analyzed under a stereomicroscope and classified between 0 and 3. The quantitative evaluation was carried out by analyzing the absorbance of the solution obtained by grinding the sample. The qualitative results were analyzed using the Kappa and Kruskal-Wallis tests, and the quantitative results using the Tukey test. Group II and III showed less marginal infiltration than the Control Group, although they did not differ statistically. It was concluded that there was no difference between the two methods tested.

Keywords: Dental Leakage. Dental Bonding. Composite Resins. Adhesiveness. Dental Sealants.

Resumo

A contração de polimerização da resina composta pode causar microinfiltração marginal, resultando em hipersensibilidade, descoloração, cáries secundárias, comprometimento pulpar e insucesso da restauração. Este estudo comparou dois métodos de avaliação da infiltração marginal através da penetração de corante. Foram realizados preparos classe V em 45 fragmentos de dentes bovinos que foram restaurados em resina composta. Após o acabamento e polimento, as amostras foram randomizadas em 3 grupos: GI (controle, sem selamento); GII (selante de superfície Fortify (Bisco, Schaumburg, IL, Estados Unidos da América); GIII (selante de superfície Biscover Bisco, Schaumburg, IL, Estados Unidos da América). As restaurações foram termocicladas e imersas em azul de metileno a 2%. Para a avaliação qualitativa da infiltração, as amostras foram analisadas sob um estereomicroscópio e classificadas entre 0 e 3. A avaliação quantitativa foi realizada através da análise da absorbância da solução obtida pela trituração da amostra. Os resultados qualitativos foram analisados pelos testes de Kappa e Kruskal-Wallis, e os quantitativos pelo teste de Tukey. Os grupos II e III apresentaram menor infiltração marginal do que o grupo controle, embora não diferissem estatisticamente entre si. Concluiu-se que não houve diferença entre os dois métodos testados.

Palavras-chave: Infiltração Dentária. Adesividade Dentária. Resina Composta. Adesividade. Selantes Dentários.

1 Introduction

The use of composite resins has been popularized in restorative dentistry due to its longevity, excellent aesthetics, and satisfactory physical-mechanical properties[1]. Despite this, the inherent polymerization contraction can cause microleakage[2], and the incremental insertion technique, the increase of the polymerization time and cycles represent strategies capable of mitigating this disadvantage[3]. However, even if the material is sensitive to strategies, the occurrence of gaps, microleakage and failures in the tooth-restoration interface can appear and cause dental hypersensitivity and marginal discoloration[4], secondary caries, pulp involvement and restoration failure[2].

The magnitude of marginal infiltration is related to the modulus of elasticity, the degree of conversion, insertion techniques and the cavity configuration factor (Factor C)[5]. Since the longevity of the restoration depends on the integrity of the marginal seal[2], compensatory mechanisms such as the application of surface sealants have been proposed to protect the retention, sealing the tooth/restoration interface[6] and fill in the marginal gaps by infiltrating internally[2]. However, not all resin agents can be used as surface sealants due to their different viscosities, diluents, and polymerization mechanisms[7]. Therefore, this study aimed to compare two

methodologies for evaluating marginal infiltration by dye penetration.

2 Material and Methods

2.1 Preparation of specimens

For this study, 50 bovine incisors were initially collected and stored buffered in a 0.1% thymol solution. After removing the debris manually with scalpel blades, the teeth were polished with rubber cups and pumice stone to proceed with the surface analysis under 4x magnifying lens. Teeth with cracks and fracture lines were discarded not to influence dye penetration.

After selection, 85 fragments with surface area of 5x5 mm were extracted from the buccal surface of the teeth by separating the crown and the root portion with a double-sided diamond disk (KG Soresen, Ind. Com. Ltda, Barueri, SP, Brazil) under water jet irrigation at low speed, and then cuts in the coronary portion in the mesio-distal and inciso-cervical directions were made using a metallographic cutter (Isomet 1000, Buehler) with a high-concentration diamond blade (Extec 4" x 012 x ½).

The dental fragments were embedded in polystyrene resin to facilitate handling during the restorative and dye-dipping procedures. For this, sheets of wax 7 were placed on glass plates, the fragments were poured onto the matrix and positioned on the wax so that the dentin was covered in resin and the enamel surface was free. After 12 hours, the polystyrene resin cylinder was removed from the matrix and the enamel surface was treated with #600 and #1200 grit silicon carbide (Sic) sandpaper under constant irrigation in a rotary polisher (Maxigrind) to flatten the surface.

Forty-five cavities free of any marginal defects with dimensions of 2x2x1.5 mm were made using a cavity preparation standardizing machine with nº 3100 diamond tips. (KG Sorensen Ind. Com. Ltda, Barueri, SP, Brazil), under constant refrigeration, which were replaced every five preparations. Each cavity was rinsed with water, dried and etched with 35% phosphoric acid (3M ESPE, St. Paul, MN, United States of America) for 15 seconds. After this, the samples were washed for 10 seconds and dried with absorbent paper to receive a double layer of the Single Bond adhesive system (3M ESPE, St. Paul MN, United States of America) which was photoactivated with the DMC KM-200R light-curing device for 10 seconds. The equipment was calibrated before use and marked a light intensity of 800mW/cm^2. The Z250 composite resin in B2 color (3M ESPE, St. Paul, MN, United States of America) was inserted in a single increment using a resin spatula and photoactivated for 20 seconds, following the manufacturer's instructions.

The samples were stored in distilled water and kept in an oven at 37±2ºC for 24 hours before being finished and polished with medium-grit disks, fine and superfine Sof-Lex system (3M ESPE, St. Paul, MN, United States of America) for 10 seconds each. The samples were then randomized into 3 groups (n=15) according to surface treatment:

Group I: control group (no surface treatment),

Group II: the samples were conditioned with 32% Uni-Etch phosphoric acid (Bisco, Schaumburg, IL, United States of America), for 15 seconds, washed, dried and covered with Fortify surface sealant (Bisco, Shaumburg, IL, United States of America), on which a jet of air was applied for 3 seconds to ensure better distribution of the sealant and photoactivated for 10 seconds.

Group III: the samples were conditioned with 32% Uni-Etch phosphoric acid for 15 seconds, washed, dried and covered with Biscover surface sealant (Bisco, Schaumburg, IL, United States of America), on which a jet of air was applied for 3 seconds to ensure better distribution of the sealant, and photoactivated for 15 seconds.

2.2 Thermal Cycling

All the samples, properly identified, were kept in an oven at 37±2 ºC for 12 hours to be subjected to 1000 thermal cycles, which represents 2 baths of 1 minute at temperatures of 5±2 ºC and 55±2 ºC with a transfer time of 5 seconds in a thermal cycling machine (MCT 2 AMM *Instrumental).

2.3 Qualitative Analysis of Marginal Infiltration

After thermal cycling, the interface between the fragment and the polystyrene resin was protected by a layer of cyanoacrylate-based adhesive (Superbond, Henkel Loctite Adesivos Ltda, Itapevi, SP, Brazil) to prevent staining. The samples were then stored in a 2% methylene blue solution for 4 hours, pH 7.08-11, washed in running water for 2 minutes and dried.

The samples were sectioned in the center of the restoration using a metallographic cutter and a high-concentration diamond blade, so that two units were obtained for each tooth fragment. Each unit was analyzed for degree of infiltration by calibrated evaluators using a stereoscopic magnifying glass (Meiji Techino 2000) at 40X magnification, according to the following scores: 0 (no leakage); 1 (Leakage up to half of the gingival wall); 2 (Leakage beyond the gingival half, without reaching the axial wall); 3 (Leakage with involvement of the axial wall or beyond).

2.4 Quantitative Analysis of Marginal Infiltration

After qualitative analysis, the specimens were removed from the polystyrene cylinder so that only the tooth fragment and restoration could be ground in a hard tissue mill (Maconi Equip. Ltda, Piracicaba/São Paulo, Brasil), to obtain a powder and facilitate the dilution of the infiltrated methylene blue in alcohol. Each sample was weighed before and after grinding on a high-precision analytical balance (0,0001 g) and did not

represent a loss of more than 10% of the initial weight.

The powder obtained for each group was immersed separately in a test tube with 4 ml of pro-analysis ethyl alcohol (Merck, CA, United States of America) for 24 hours to dissolve the methylene blue infiltrated at the tooth/restoration interface. After the time had elapsed, all the solutions were centrifuged in a centrifuge (C-15N, Tomy Seiko Co) set at 3000 rpm for 3 minutes, for the powder and impurities decant and the supernatant to be analyzed by spectrophotometer (DU 65, Beckman).

For the absorbance reading, the device was adjusted to the wavelength of maximum spectral absorbance for the methylene blue dye. The value was obtained from the spectral scan of standard solutions at concentrations of 0,03125; 0,0625; 0,125; 0,25; 0,5; 1; 2; 4 µg/ml. The wavelength of 668 nm was used to read the solutions.

A line graph was drawn on a cartesian axis system with the dye concentration values in µg/ml on the abscissa axis and the optical density on the ordinate. The linear regression of y as a function of x was obtained to form the equation of the line in the polynomial regression (r=0.9997), which was used to calculate the dye concentration.

2.5 Statistical analysis

For assess the degree of marginalization using the qualitative method, the Kappa test was initially used to verify the agreement between the examiners. The values obtained, between 7.3 and 8.0, indicated good agreement. The Kruskal-Wallis test was applied with a significance level of 5%. In the quantitative method, the results were submitted to Tukey's non-parametric test.

3 Results and Discussion

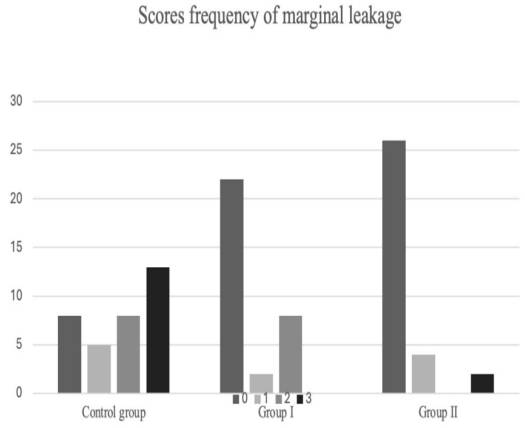
Initially, for the qualitative method, the median scores were calculated for each sectioned unit, and the Kruskall-Wallis non-parametric statistical test (α=0.05) was applied to detect differences between the groups, as shown in Table 1. The Forfity and Biscover groups had the lowest marginal infiltration averages, with no statistical difference between them, but with a difference to the control group (Table 1 and Figure 1).

Table 1 - Results of dye penetration into the gingival wall of class V cavities with or without surface sealant application using the qualitative method.

	Median	Arithmetic Average	
Control	2	633,333	A
Fortify	0	396	B
Biscover	0	335,667	B

Kruskal-Wallis Test, Non-parametric Multiple Comparisons Test ($p<0.05$). Different letters indicate a statistically significant difference.
Source: research data.

Figure 1 - Measures occurrence of marginal leakage.



Source: research data.

For the quantitative method, groups II and III also showed less marginal infiltration, with no significant differences between them, but with a statistical difference to the control group (Table 2).

Table 2 - Quantitative analysis of dye penetration at the gingival wall of Class V cavities with and without the application of a surface sealant

Group	Arithmetic Average	
Control	0,2273	A
Fortify	0,1975	B
Biscover	0.1919	B

Tukey test = 0,0297. Different letters indicate a statistically significant difference.
Source: research data;

The study reviewed the aspects related to marginal infiltration in composite resin restorations and the results indicated no difference between the two methods evaluated. In addition, it was possible to observe that the different surface sealing materials did not differ in marginal sealing capacity.

Microcracks at the tooth-restoration interface can develop due to polymerization shrinkage, mismatched thermal expansion coefficients, non-incremental insertion techniques, and stresses from finishing and polishing[8,9]. The occurrence of microcracks challenges the preservation of the marginal sealing at the interface[10] and may be the source of marginal discoloration[11,12], sensibility[13], bacterial colonization, and compromise clinical longevity[14]. The use of surface sealants over the restoration has been proposed to mitigate marginal leakage and treatment impairment[15]. High values of marginal infiltration in composite resin restorations are related to polymerization stress and the C factor, combined with an ineffective adhesive system[16]. Factor C is inversely proportional to the treatment predictability. Class II restorations have a value between 1 and 2, while class I restorations can reach up

to 5[17–19]. In this study, Class V cavities with a rating of 4 were prepared, indicating higher polymerization stress at the tooth-restoration interface and an increased likelihood of marginal infiltration.

Overall, all groups in this study exhibited some degree of marginal leakage (Table 1). The groups treated with surface sealants showed reduced infiltration compared to the control group, though the difference was not statistically significant. While no sealant fully prevents marginal infiltration, the reduced leakage rate suggests that sealants may slow down the degradation of the tooth-restoration interface by saliva.

The effectiveness of a sealant in improving marginal integrity depends on its viscosity, as deeper penetration into the tooth-restoration interface can enhance sealing[10,20]. When restoration walls are limited to enamel, marginal leakage is reduced or eliminated[21] which aligns with the findings of this study. Although surface sealants can fill structural defects at the interface[22], their marginal sealing capacity is not flawless, consistent with other study[23]. This limitation, along with the material's limited longevity, necessitates reapplication over time[24].

The use of surface sealants is not a common clinical practice, likely due to added costs, longer procedure times, and limited awareness of their benefits. However, the results of this study suggest that, given the simplicity of application, ease of handling, and minimal procedure time, marginal sealing could be recommended as a follow-up procedure after composite resin restoration.

4 Conclusion

Based on the results obtained:

- All groups treated with surface sealants exhibited reduced marginal infiltration compared to the unsealed restoration group;

- There was no significant difference between the two methods used to evaluate surface sealants concerning marginal infiltration.

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