

Effect of mechanical loading on microleakage of resin composite restorations lined with low modulus materials

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ABSTRACT - The aim of this study was to evaluate the effect of mechanical loading on marginal leakage of simulated class I composite restorations with adhesive layers of different thickness or in association with a low viscosity composite liner. Sixty bovine incisors, selected for the study, were prepared with round cavities (4mm diameter X 2mm depth) on a flattened enamel area. The teeth were randomly assigned into three groups according to the liner used: Group 1: (control) Single Bond adhesive system (SB), according to manufacturer instructions; Group 2: SB, applied in three layers individually photocured; Group 3: SB, followed by the application of liner with the flowable composite Protect Liner F. All cavities were restored using a single bulk (Z250) composite. Half of the specimens of each group were submitted to mechanical loading (100,000 cycles, 60 N, 2,3 Hz). The specimens were then prepared for the microleakage test and immersed in a buffered 2% methylene blue solution for 2 hours. The specimens were next longitudinally sectioned through the center of each restoration using a slow-speed diamond saw and evaluated using a stereomicroscope at magnification x40, according to ISO (TR11405) scores. Data were analyzed with the Kruskal-Wallis test ($p>0.05$). There were no differences between the restorative techniques; all of them were capable of producing some sealed restorations and the microleakage levels were low. After the mechanical loading, the microleakage levels increased for all groups, however it was significant only for group 3. The use of resin liners with flowable composites does not reduce microleakage levels, and after mechanical loading the microleakage levels increase. The restorative technique with flowable liners is not recommended for high occlusal stress situations.

KEYWORDS - Mechanical loading, microleakage, resin composite restorations

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Introduction

Light cured resin composites are commonly used in daily clinical practice to restore anterior and posterior teeth, because of their aesthetic advantages, improved bonding to tooth structure, and enhanced mechanical properties. However, polymerization shrinkage is still a major problem in light curing restorations (1-3). The polymerization shrinkage of resin composites can create contraction forces that may disrupt the bond to cavity walls (2-3). The competition between mechanical stress in polymerizing resin composites and the bonding to the walls is one of the main causes of early marginal failure and subsequent microleakage observed in composite restorations (1-3).

In an attempt to minimize the deleterious effects of polymerization shrinkage, compensatory mechanisms, such as thicker adhesive layers of unfilled adhesives (4), have been proposed. The main purpose is to act as a relatively flexible stress-absorbing layer, or "elastic buffer" between the shrinking resin composite and the rigid substrate. The high stress induced by rigid composite polymerization shrinkage could be relieved by a more elastic interface (4,5) According to Ausiello *et al.* (6), the adhesive layer would go through an elastic deformation and the outcome could be uniform stress distribution.

Liners with flowable composite have also been used (7-9). The elastic modulus of flowable composites is approximately 50% or less than the modulus of traditional hybrid composites,

which indicates high flexibility (10,11). Several authors have verified the efficiency of liners with flowable composites in decreasing microleakage (9,12), improvement of marginal adaptation (13), and reduction in shrinkage stress (14) immediately after polymerization.

However, even if marginal integrity could be established during and immediately after the restorative procedure, leakage may occur after some time due to chemical, thermal, and mechanical stress on the adhesive interface (15). Deformations in the restoration may occur due to mechanical loading. This could lead to microcracks on the adhesive interface or in the plastic deformation of that interface (depending on its modulus of elasticity). In 1970, Jorgensen (16) introduced "mechanical percolation" to indicate mechanical factors in the oral environment that could produce asymmetric pressure on fillings, resulting in temporary or permanent marginal gaps. According to Nakayama *et al.* (17), a Young's modulus equal to or greater than that of dentin, 10.3 GPa (18), is required for resin composites to resist deformation by occlusal stress. Thus, adhesive layer thickness and composite rigidity are important variables in defining the restored tooth's mechanical behavior. When shrinkage and occlusal loading stress occur simultaneously, studies have shown that composite rigidity and adhesive interface resilience have opposing effects. The more rigid the composite used in the restoration, the higher the polymerization shrinkage stress, but the lower the cusp movement under occlusal loading.

The restorative technique with low modulus liners seems to be a reliable alternative for reducing the shrinkage stress due to the elastic characteristics of the liner (10,11) and avoiding deformations under occlusal loading, since the restorative composite presents a greater elastic modulus than dentin (19).

Based on the literature concerning adhesive restorative techniques and their restrictions, the purpose of this study was to evaluate the influence of mechanical loading on microleakage of simulated class I resin

composite restorations prepared in bovine teeth using low modulus resin liners.

Materials and Methods

The following materials were used in this study: Single Bond adhesive system, Protect Liner F flowable composite, and Filtek Z250 hybrid restorative composite. The description and composition of these materials are presented in the Table 1.

Sixty freshly extracted bovine incisors were selected. These teeth were cleaned and submitted to scratching with a periodontal curette to remove the tissular remains. Prophylaxis was provided using pumice-stone paste on the Robinson brush, at a low rotational speed. The roots and incisal thirds of the teeth were sectioned off using a diamond disc assembled on a ISOMET 1000 machine (Buheler, UK LTD, Lake Bluff, IL 60044 - USA). The specimens were embedded in acrylic resin in ½ inch PVC tubes. The specimens were then ground on a water-cooled mechanical polisher (Minimet 1000, Buheler, UK LTD, Lake Bluff, IL 60044 - USA) using 320-, 400- and 600-grit silicon carbide (SiC) abrasive paper (Carbimet Disc Set, #305178180, Buheler, UK LTD, Lake Bluff, IL 60044 - USA) to expose a flat enamel area of at least 6 mm in diameter on the buccal surfaces.

After the specimens were ground, they were observed in a stereomicroscope (Zeis, Manaus, AM, Brazil), at magnification x25, to verify if the enamel remained on the surface and to detect possible cracks or structural alterations in the enamel that could interfere in the results of the study.

Standard cavity preparations (2 mm in depth and 4 mm in diameter) were performed on the central area of flattened surfaces, using a diamond tip FG 3053 (KG Sorensen Indústria e Comércio Ltda, São Paulo, SP, Brazil) 4 mm in diameter and 1,5 mm in height, assembled in a high-speed hand piece (Kavo, Joinville, SC, Brazil), under constant

Table 1- Description of the restorative materials and bonding systems used in this study.

Material	Type	Manufacturer
Filtek Z 250	Hybrid resin composite	3M/Espe
Protect Liner F	Flowable resin composite	Kuraray Co.
Single Bond	Adhesive system	3M/Espe

cooling air-water. The tips were substituted every 10 preparations.

The cavity walls were made at a 90° angle to the surface (entirely located in enamel) and rounded internal angles accompanying the drawing of the diamond point used. During the preparation of the cavities, specimens were discarded if pulp exposure was detected.

The teeth were randomly assigned into three groups of 20 teeth each, according to the restorative technique used:

- **Group 1 (SB - control)**– Application of the Single Bond adhesive system according to manufacturer's instructions (35% phosphoric acid gel was applied to enamel and dentin for 15 seconds and rinsed for 10 seconds. The water excess water was removed using an air syringe, leaving the surface slightly moist. The Single Bond adhesive was applied in two consecutive coats and light cured for 10 s).
- **Group 2 (SB/3L)** – Application of the same procedure used in Group 1, and in addition, two extra adhesive layers were applied and light-activated individually.
- **Group 3 (SB/PLF)** – Application of the same procedure used in Group 1, with the difference that Protect Liner F was applied after the bonding procedure.

The application of the flowable composite as a resin liner was standardized by volume: half centimeter of the material was applied on a glass slab, using a microbrush in spiral movement starting from the bottom of the cavity. The resin liner was photoactivated using the photocuring unit Elipar Tri-light (ESPE – America Co., Seefeld 82229 - Germany) during 20 s with an intensity of 800 mW/cm². The cavities were then filled with the Filtek Z250 composite, shade A3, in a single increment and light-cured for 20 seconds with the same unit mentioned above.

The specimens were stored in distilled water at 37°C for 24 hours, then finished and polished under running water using 600- wet paper and 1200- grid SiC paper.

Each group was randomly subdivided into two groups (n=10), according to mechanical loading:

Subgroup A – The specimens were not submitted to mechanical loading and they were immediately prepared for the microleakage test.

Subgroup B – The specimens were submitted to 100000 mechanical cycles. The 60N load was perpendicularly applied to the center of the restoration with a frequency of 2.3 Hz. Cavities were prepared on the buccal side of the teeth as class V restorations, however, as load was applied to the center of the restorations, they simulated class I restorations under occlusal stress.

For the microleakage test, the specimens were entirely covered with two layers of nail varnish, except for the filling, and one millimeter beyond the margins. Then, they were immersed in a buffered 2% methylene blue dye solution. After 2 hours in this solution, the specimens were rinsed in tap water for 10 minutes and all the coating was removed.

After cleaning, the specimens were longitudinally sectioned in halves through the center of each restoration using a slow-speed diamond saw at low speed under liquid cooling. Three independent examiners using a stereomicroscope at magnification x40 to verify the dye penetration evaluated the sections. The following criteria were used to score the extent of leakage at the dentin margins:

0. no dye penetration;
1. dye penetration only in enamel
2. dye penetration into dentin, without reaching the axial wall;
3. dye penetration including the axial wall.

The method and the microleakage quantification were based on ISO TR 11405, 2003.

The Kruskal-Wallis test was used to examine the data for microleakage in the four groups. The computation of significant differences was assigned a p<0.05 level.

Results

The results from dye penetration of loaded and unloaded restorations are shown in Graph I. Without loading procedures, all restorative groups showed low levels of leakage. There were no statistical differences for the restorative techniques with or without resin liners. With loading, there was numerical increase of the microleakage levels for all groups, however it was only statistically significant for group 3 (with flowable composite liner).

Discussion

Microleakage is defined as the clinically undetectable passage of bacteria, fluids, molecules, or ions between a cavity wall and the restorative material applied to it (21). Microleakage evaluation is the most commonly used method for assessing the seal efficiency of a restorative material.

The most important factor that causes immediate marginal failure and subsequent microleakage is stress generated during polymerization (1-3). Marginal gap formation in composite restorations is directly related to the polymerization shrinkage stress, which is inversely correlated with Young's module of the restorative composite (5). Therefore, the more rigid the restorative composite, the more stressed the interface. In contrast, it is also important that the restorative materials have a rigid characteristic to resist occlusal loading.

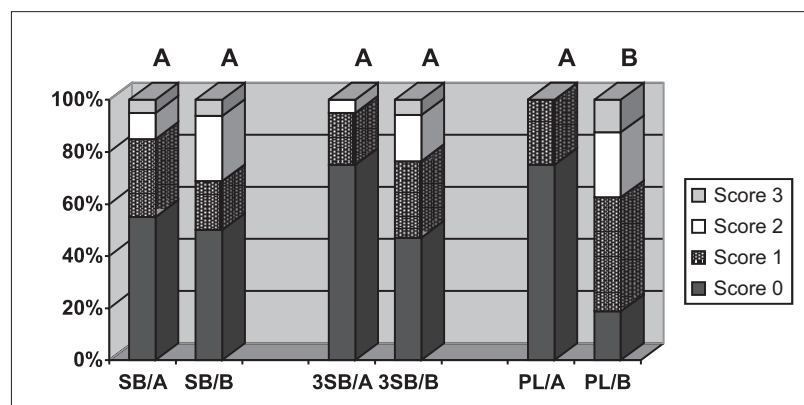
Restorative techniques with low modulus resin liners have thus been proposed (4,7-9,12). This technique, which adds flexibility of liner to rigidity of restorative material, may make it possible to produce sealed restorations. These authors observed the advantages of this technique in reducing microleakage, marginal gap formation, and polymerization shrinkage stress. However, in this study, neither the use of flowable composite lining nor the use of a thicker layer of a low stiffness adhesive completely eliminated microleakage. When compared to the conventional restorative technique, the use of low modulus liners showed similar microleakage levels.

In 2000, Choi *et al.* (4) demonstrated that polymerization contraction stress was significantly absorbed and relieved by the application of an increased thickness of a low

stiffness adhesive, reducing microleakage. However, this was not observed in this study, because group 2 (three adhesive layers) was not statistically different from the control group. Considering that stress absorption is directly related to liner thickness and elastic modulus, it can be concluded that the adhesive layer was not thick enough to effectively reduce stress by elastic elongation. Also, the large volume of restorative composite may generate great stress at the interface, and, in this case, the adhesive layer was not able to relieve this stress. In addition, it should be noted that the application of thicker layers of adhesive has some drawbacks. A thick layer of unfilled adhesive at the margin of a restoration may lead to enhanced wear in this region. The adhesive is radiolucent, which may pose diagnostic problems at subsequent examinations (4,7). And, long-term, the use of three layers of Single Bond may be inappropriate. The high hydrophilic condition added residual water (solvent normally insufficiently removed), allowing for more hydrolytic degeneration (22). This restorative technique with three adhesive layers may be even worse for class II restorations with margins ending in dentin.

Although several authors have found better results with the flowable composite lining, in this case the flowable composite lining in class I restorations did not effectively reduce marginal leakage. There are two possible explanations for this. First, despite their low elastic modulus, the contraction stress produced by the flowable composite may be high enough, because of the high volumetric shrinkage, to produce adhesive failure at the interface between the tooth and the composite when the material is used as a liner. Second, the elastic modulus of the Protect Liner F may not be low enough to provide significant stress

Graphic 1. Frequency of microleakage scores



relief (23). According to Chuang *et al.* (24) the use of flowable liners may result in the reduction of internal voids, but not in evident improvement of marginal sealing because of greater polymerization shrinkage. Our results corroborate with those of Chuang *et al.* (24); Jain, Belcher (25); and Jang *et al.* (26).

The effect of mechanical loading on restorations with low modulus linings has not been reported. Fatigue load stress on a restored cavity tends to weaken the bond especially to dentin in those areas with the lowest strength, as pulp floors and angles. Deformation of the restoration can occur due to loading and thermal cycling, and perhaps evolve into gaps between the cavity floor and the adhesive or to plastic deformation of the adhesive interface (27). In addition, the mineralized dentin was reported to have become weaker after load cycling (28).

The mechanical fatigue distinguishes the sealing quality of a restorative technique in a more expressive way. According to Abdalla, Davidson (15), mechanical loading cycling can adversely affect the interface of adhesive class I composite restorations.

However, the results of this present study showed that the effect of mechanical loading is dependent on the restorative technique employed to each restoration. The marginal sealing of the restoration using only the hybrid restorative composite (Z250) was not affected by the mechanical loading, regardless of the thickness of the adhesive layer. Conversely, exposure of the restorations lined with Protect Liner F to the load cycling significantly increased the marginal leakage. The low modulus resin liner may have reduced the mechanical resistance of the restoration and could have altered its behavior when the mechanical load was applied, culminating in an increase of microleakage levels.

The restorative technique using resin elastic liners and rigid restorative composites seems not to be a suitable alternative for reducing stress at the dentin/composite interface; in addition, the low modulus liner can alter the rigidity of the restoration allowing greater deformation by occlusal loading as compared to a restoration without a flowable liner.

Despite the results found for class I restorations under high occlusal loading, the use of flowable liners or thicker adhesive layers may be an adequate choice in low stress situations, as class V restorations.

In conclusion, low modulus resin liners should be applied only in low occlusal stress situations; otherwise, they can reduce the mechanical resistance of the restoration, allowing for abnormal stress distribution and increased marginal gap formation.

Resumo

ALONSO, Roberta Caroline Bruschi, VIEIRA, Érica Brenoe, CORRER, Gisele Maria, CUNHA, Leonardo Gonçalves, CORRER-SOBRINHO, Lourenço e SINHORETI, Mário Alexandre Coelho. Efeito da ciclagem mecânica na microinfiltração de restaurações de resina composta associadas com materiais de baixo módulo de elasticidade. *Oral Sci.*, mai./ago. 2005, vol.1, no.1, p.23-28.

O objetivo desse estudo foi avaliar o efeito da ciclagem mecânica na infiltração marginal de restaurações de resina composta classe I simuladas, com camadas de adesivo de diferentes espessuras ou em associação com base de baixo módulo de elasticidade. Sessenta incisivos bovinos selecionados para esse estudo, foram preparados com cavidades com formato circular (4mm de diâmetro X 2mm de profundidade) em uma área de esmalte planificada. Os dentes foram aleatoriamente divididos em três grupos de acordo com a base utilizada: Grupo 1: (controle) sistema adesivo Single Bond (SB), de acordo com as instruções do fabricante; Grupo 2: SB, aplicado em três camadas e individualmente fotoativadas; Grupo 3: SB, seguido pela aplicação de base com resina fluída, Protect Liner F. Todas as cavidades foram restauradas usando volume único com a resina composta Z250. Metade dos corpos-de-prova de cada grupo foi submetido à ciclagem mecânica (100.000 ciclos, 60 N, 2,3 Hz). Os corpos-de-prova foram preparados para o teste de microinfiltração e imersos em solução tamponada de azul de metileno a 2% por 2 horas. Os corpos-de-prova foram seccionados longitudinalmente no centro de cada restauração usando um disco diamantado em baixa velocidade e avaliados usando lupa estereoscópica (40X de aumento), de acordo com a especificação ISO (TR11405). Os dados foram analisados por meio do teste de Kruskal-Wallis ($p>0,05$). Não houve diferença estatística significativa entre as técnicas restauradoras; todas foram capazes de

produzir algum selamento e os níveis de microinfiltração foram baixos. Após a ciclagem mecânica, os níveis de microinfiltração aumentaram para todos os grupos, porém apenas o Grupo 3 apresentou diferença significativa. A utilização de base resinosa de resina composta *flow* não reduziu os níveis de microinfiltração, e após a ciclagem mecânica,

os níveis de microinfiltração aumentaram. A técnica de restauração com base resinosa de resina composta *flow* não é recomendada para situações de grande força oclusal.

PALAVRAS-CHAVE: Ciclagem mecânica, microinfiltração, restaurações em resina composta.

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