Sealing ability of different adhesive restorative materials

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Abstract: The purpose of this study was to evaluate the sealing ability of different adhesive restorative materials to bovine enamel and dentin. Ninety standard sauce-shaped Class V cavities with 3 mm of diameter × 2 mm of depth were prepared in the buccal and lingual faces of 45 bovine incisors. The gingival margin was located in dentin and the incisal margin in enamel. Teeth were randomly divided in 9 groups (n = 10) and restored with the following materials: five flowable composites, one microfilled composite, one microhybrid composite, one compomer; and one resin-modified glass ionomer cement (RMGIC). The restorations were made based on the manufacturer's instructions for adhesive treatment and restorative procedure. After polishing, the teeth were thermocycled and immersed in 2% basic fuchsin for 24 hours. Teeth were, then, serially sectioned generating 3 slices of 1 mm that were observed in a stereomicroscope under × 40 magnification. The degree of dye leakage was recorded as follows: 0 – no leakage; 1 – leakage up to half the cavity; 2 – leakage in more than half of the cavity; 3 – extensive dye leakage, reaching the deepest portion of the cavity. Data was statistically analyzed using Kruskal-Wallis non-parametric test complemented with Bonferroni's test when the difference between means was significant (α = 0,05). Extensive dye leakage was observed in dentin margins. The results were statistically higher than in enamel margins (Mann-Whitney *U* test ($p < 0.001$)). Compomer restorations produced the highest marginal sealing in dentin, differing from all other groups. The highest degree of dye leakage in enamel was produced by the microfilled composite. The majority of the materials exhibited leakage-free margins in up to 70% of the specimens. Both, materials and substrate significantly influenced the sealing ability.

Keywords: *Compomer; composite resin; microkeakage; resin modified glass ionomer cement.*

Resumo: O objetivo deste estudo foi avaliar o selamento marginal de materiais restauradores adesivos diferentes ao esmalte e à dentina bovina. Noventa cavidades Classe V, padronizadas na forma de pires, com 3 mm de diâmetro × 2 mm de profundidade foram preparadas nas superficies vestibular e palatina de 45 incisivos bovinos, com margem gengival localizada em dentina e margem incisal em esmalte. Os dentes foram aleatoriamente divididos em 9 grupos (n = 10) e restaurados com os seguintes materiais: cinco resinas *flow*, uma resina composta microparticulada, uma resina composta microhíbrida, um compômero e um CIVMR. As restaurações foram confeccionadas com base nas instruções dos fabricantes para tratamento adesivo e procedimento restaurador. Depois do polimento, os dentes foram termociclados e imersos em fucsina básica a 2% por 24 horas. Os dentes foram seccionados seriadamente gerando 3 fatias de 1 mm que foram observadas em estereomicroscópio sob magnificação de 40×. O grau de penetração do corante foi registrado conforme segue: 0 – sem infiltração; 1 – infiltração atingindo metade da cavidade; 2 – infiltração em mais da metade da cavidade; 3 – infiltração extensa, atingindo a porção mais profunda da cavidade. Os dados foram submetidos ao teste não paramétrico de Kruskal-Wallis complementado com o teste de Bonferroni quando a diferença entre as médias foi significante (α = 0,05). Infiltração extensa foi observada nas margens dentinárias. Os resultados foram estatisticamente superiores aos produzidos em margens em esmalte (Mann-Whitney *U* ($p < 0,001$)). Restaurações de compômero produziram o maior selamento marginal em dentina, diferindo de todos os outros grupos. O maior grau de infiltração do corante em esmalte foi produzido pela resina composta microparticulada. A maioria dos materiais apresentou margens livres de infiltração em até 70% dos espécimes. Ambos, materiais e substratos influenciaram significativamente no selamento das restaurações.

Palavras-chave: *Compômero; resina composta; microinfiltração; cimento de ionômero de vidro modificado por resina.*

Introduction

Dental restorations attempt to restore the shape, function and aesthetics caused by the loss of dental tissue. In order to choose the most adequate restorative material the clinician must take into account factors such as biological, optical, mechanical and manipulative properties. Also, the adhesiveness and sealing ability of the material should come to mind when selecting the restorative material[1]. Problems in marginal adaptation related to resin-based materials have been extensively described in literature as a consequence of the shrinkage stress caused by the polymerization of the composites. This stress usually causes the breakdown of the adhesive interface, forming microgaps[1,2] that allow the penetration of microorganisms, fluids and chemical substances from the oral environment along the tooth/restoration interface[2,3]. The marginal leakage, mainly in restorations with cervical margin in dentin[1,4,5], is considered responsible for hypersensitivity, secondary caries, marginal discoloration and pulpal pathologies[6].

Marginal sealing is known to influence the longevity of dental restorations[7]. The most common method of assessing the sealing efficiency of a restorative material is by microleakage evaluation[8]. In the last ten years, hundreds of studies on microleakage were published. However, these studies have generally given contradictory results, probably due to differences in technical procedures and lack of standardization[7,8].

Class V cavities are characteristic for presenting little or no enamel at the cervical margins, which has been considered a great challenge for the achievement of an adequate adhesion[9-11]. Furthermore, not rarely, chemical and microstructural changes in dentin, like sclerosis, are present in this cavity configuration.

Restorative alternatives to the use of composites in such situations have been considered. The application of glass ionomer cement (GIC), whose mechanism of adhesion is based on the ion exchange with the calcium of the tooth structure[12], has been considered, especially in the presence of sclerotic dentin. However, the low wear resistance and the high solubility have limited the exposure of chemically cured GICs to the oral environment. These limitations were overcome by the addition of resin monomers into the conventional GICs and enlarged their clinical application[13]. Besides, some resin modified glass ionomer cements (RMGIC) present a trial mechanism of cure, warranting an efficient setting. Adhesion of RMGICs relies into two mechanisms: the chemical quelation reaction between the material and the tooth and a resinous primer that penetrates and creates micromechanical retention with the tooth structure. The presence of a resinous component, though, induces polymerization shrinkage to RMGICs, and this effect on the marginal sealing of the restorations must be evaluated.

Flowable composites present low viscosity due to the low filler content. These materials, therefore, flow and adapt closely to the cavity preparations[14,15]. The low filler content (about 30 to 50%) also determines a low elastic modulus that allows the flowable composites to deflect with the tooth[16,17]. Based on that, one could consider Class V cavities as an indication of use for these materials. Flowable composites, however, shrink proportionally more than conventional composites, due to the higher amount of matrix, raising doubts about the effect of the stress generated on the long term marginal sealing of cavities, especially in dentin margins[16].

Compomers, or polyacid-modified resin composites, do not present acid-base reaction, setting only when exposed to light. Due to better mechanical properties, handling properties and aesthetic appearance comparing to RMGIC, compomers have also been indicated for non-carious Class V.[18]

Several restorative possibilities are available for cervical restorations and expectations are that, due to different compositions, mechanical properties and adhesive characteristics, the results of marginal sealing may be different. Therefore, the purpose of this study was to evaluate the sealing ability of different adhesive restorative materials to bovine substrates in Class V cavities, testing the hypothesis that both, material and substrate affect the marginal sealing of the restorations.

Material and method

Forty-five freshly extracted bovine incisors, free of cracks, were selected and used in the study.

Cavity preparation

Class V cavities were prepared on both buccal and lingual surfaces of each tooth. Preparations were made by a single operator, using a high-speed handpiece with air-water spray and a # 4 spherical carbide burs (Jet, Ontario, Canada) and # 2082 diamond burs (KG Sorensen, Barueri, SP, Brazil). Burs were replaced after 4 cavity preparations to ensure cutting efficacy. The cavities were sauce-shaped, with 3 mm of diameter and 2 mm of depth. Cervical margins were located in dentin and incisal margins in enamel. Teeth were stored in distilled water and randomly assigned into 9 groups (n = 10) and restored with the following materials: five flowable composites, one microfilled composite, one microhybrid composite, one compomer; and one resin-modified glass ionomer cement (RMGIC) (Table 1).

Restorative proceeding

The different restorative procedures also are described in Table 1. All materials were used according to manufacturers' instructions (Table 1). Activation of the light-cured materials was performed using a quartz-tungsten-halogen light curing unit (XL-3000, 3M/ESPE, St Paul, MN, USA) with irradiance higher than 450 mW.cm^{-2}.

After restored, teeth were stored in distilled water for 7 days at room temperature. Finishing and polishing were made with Sof-Lex discs (3M/ESPE, St Paul, MN, USA) and polishing paste Poligloss (TDV Dental Ltda., Pomerode, SC, Brazil)[19].

Thermocycling

The samples were submitted to thermocycling with 500 cycles from 5 to 55 °C, with a dwell time of 30 seconds.

Microleakage evaluation

Root apexes were sealed with a chemical curing epoxi resin (Durepoxi – Alba Química Indústria e Comércio Ltda., São Paulo, SP, Brazil). Following, two layers of nail varnish were applied over the teeth, excepting the restoration and a 1 mm perimeter around it. The specimens were immersed in a 2% basic fuchsin solution for 24 hours[18] and washed in tap water for the same time.

The specimens were serially sectioned buccal-lingually in order to obtain three thick slices of 1 mm. Leakage was evaluated by two previously calibrated and blinded examiners using a stereomicroscope (Tecnival, Biosystems Ltda., Curitiba, PR, Brazil) under x40 magnification, and classified based as follows:

0 – No dye leakage;
1 – Dye leakage up to half the cavity;
2 – Dye leakage in more than half of the cavity depth;
3 – Extensive dye leakage, reaching the deepest portion of the cavity.

Table 1. Restorative materials used in the study

Restorative material	Material type	Manufacturer	Batch #	Dentin pretreatment	Insertion	Light curing §
Wave	Flowable composite	SDI[1]	002312	Stae	Flowable composite syringe*	40 seconds
Flow It	Flowable composite	Jeneric/Pentron[2]	25072	Bond 1	Flowable composite syringe*	40 seconds
Filtek Flow	Flowable composite	3M/ESPE[3]	1CF	Single Bond	Flowable composite syringe*	40 seconds
Fill Magic Flow	Flowable composite	Vigodent[4]	00199	Fill Magic Bond	Flowable composite syringe*	40 seconds
Tetric Flow	Flowable composite	Vivadent[5]	B11078	Excite	Flowable composite syringe*	40 seconds
Filtek A-110	Microfill composite	3M/ESPE[3]	0AM	Single Bond	Teflon spatulas*	40 seconds
Filtek P-60	Hybrid composite	3M/ESPE[3]	2ME	Single Bond	Teflon spatulas*	40 seconds
Freedom	Compomer	SDI[1]	002173	Stae	Compomer syringe*	40 seconds
Vitremer	RMGIC (a)	3M/ESPE[3]	20010914	Vitremer primer	Centrix syringe*	40 seconds

Resin modified glass ionomer cement; [1]Southern Dental Industries Ltda., São Paulo, SP, Brazil; [2]Pentron Clinical Technologies, Wallingford, CT, USA; [3]3M/ESPE, St Paul, MN, USA; [4]Vigodent S.A. Indústria e Comércio, Rio de Janeiro, RJ, Brazil; [5]Ivoclar Vivadent Ltda., São Paulo, SP, Brazil; *Inserted in 2 increments (the first in the cervical half and the second in the incisal half of the cavity preparation); and § XL-3000 (3M Dental Products).

Whenever disagreement between examiners occurred, consensus was reached.

Statistical analysis

Data were submitted to non-parametric Kruskal-Wallis test complemented with Bonferroni's test ($p < 0.05$). To evaluate the difference between the substrates (enamel and dentin) the Mann-Whitney *U* test was used ($p < 0.05$). The data were analyzed with SigmaStat 3.0 (SPSS, Chicago, IL, USA) statistics program for Windows.

Results

Microleakage scores in enamel are reported in Table 2. Bonferroni's test showed statistically significant differences between groups for microleakage at enamel margins ($p < 0.05$). Cavities restored with the microfill composite exhibited significantly higher leakage than the other groups. Higher rates of leakage-free margins were observed in Class V cavities restored with Filtek Flow (100%), Wave (70%), Flow it (90%), P60 (90%), Freedom (80%) and Vitremer (70%), with no statistically significant difference among them. Intermediate leakage results were observed for Tetric Flow and Fill Magic Flow, which were also similar to other groups (Freedom, Vitremer and Wave).

Microleakage scores in dentin are shown in Table 3. Significant differences were observed regarding the sealing ability in dentin margins ($p < 0.05$). Excepting the compomer group (Freedom), which exhibited the higher marginal sealing ability in dentin, the overall results were similar, disclosing a high degree of dye leakage, mainly expressed by the high number of score 3.

Comparison of leakage results in enamel and dentin margins pointed out a statistically lower leakage in enamel than in dentin margins (Mann-Whitney *U* test $p < 0.001$).

Discussion

In vitro tests remain an indispensable method for initial screening of dental materials and set a theoretical maximum

Table 2. Microleakage scores observed for different restorative materials in enamel margin

	Scores					
	0	1	2	3	Median	Statistical grouping*
Wave	7	2	-	1	0	AB
Flow It	9	-	-	1	0	A
Filtek Flow	10	-	-	-	0	A
Fill Magic Flow	5	5	-	-	0.5	B
Tetric Flow	4	3	3	-	1	B
Filtek A-110	2	1	1	6	3	C
Filtek P-60	9	1	-	-	0	A
Freedom	8	1	-	1	0	AB
Vitremer	7	1	1	1	0	AB

*Same letters indicate no significant difference (Bonferroni's test at $p < 0.05$)

Table 3. Microleakage scores observed for different restorative materials in dentin margin

	Scores					
	0	1	2	3	Median	Statistical grouping*
Wave	-	-	-	10	3	C
Flow It	-	3	-	7	3	BC
Filtek Flow	-	-	-	10	3	C
Fill Magic Flow	-	2	-	8	3	BC
Tetric Flow	-	2	2	6	3	B
Filtek A-110	-	-	1	9	3	C
Filtek P-60	-	2	1	7	3	BC
Freedom	6	4	-	-	0	A
Vitremer	-	3	-	7	3	BC

*Same letters indicate no significant difference (Bonferroni's test at $p = 0.05$)

amount of leakage that could be present in vivo[20]. Microleakage tests are the cheapest and fastest method to evaluate the sealing ability of restorative materials[6]. Some drawbacks, however, are associated to the test. It is hard to reproduce all the challenges restorations face in the oral environment through this in vitro method. Besides, microleakage tests present a huge methodological variation, impairing a reliable comparison between studies[8]. Different dyes and tracers with different composition, pH, molecular weight and concentration have been used in literature[20,21]. Also, different immersion times are reported, oscillating from 4 hours to 72 hours[6]. In this study, immersion in 2% basic fuchsine solution for 24 hours was adopted. These parameters were indicated in a systematic review about microleakage tests as the most commonly used parameters[8].

As opposed to other cavity configurations, such as Class II cavities, Class V cavities are especially useful for in vitro/in vivo comparisons due to the easy access of the restoration margins for clinical inspection and evaluation. Furthermore, the operational technique for the placement of Class V restorations presents less variability compared to Class II restorations, taking into account the cavity size, application of the adhesive, layering technique, curing protocol, matrix technique, removal of excess, etc.[22]

Results of the present study were significantly affected by the tooth substrate present in the restoration margins. The higher marginal sealing observed in enamel margins could be attributed to the well-know stability of bond of recent adhesive systems to conventionally etched enamel margins[23]. Acid etching with phosphoric acid produces micro retentions in enamel that are filled by fluid resin producing tags, resulting in adequate and long-lasting adhesion between the restorative material (usually composites and compomers) and this tissue[8]. Enamel is also prone to be etched by the self-conditioning primer of the RMGIC, whose function is to modify the smear layer. Conversely, dentin is a challenging substrate for adhesion since it is heterogeneous, less mineralized and moist, affecting the durability of the bond and the marginal sealing of the restorations[7,15].

Good marginal sealing was observed with the RMGIC restorations in enamel. These materials present a good interaction with the calcium-based tooth structure[12]. Add to that, a resin-based primer is available to enhance the sealing through bonding of the resinous portion[24,25]. In dentin, however, the same material presented a higher marginal leakage. Because the bond mechanisms of the RMGIC rely on the presence of calcium, one could expect the dentin margins to present weaker marginal sealing and higher leakage.

The higher marginal sealing in dentin was produced by the compomer. Compomers have been developed to improve the physical and mechanical properties of conventional glass ionomer cements.[18] These light-cured materials do not contain water, however, some manufacturers claim that the water is absorbed by the hydrophilic monomers when the material is in contact with saliva, allowing a weak acid-basic reaction, which is characteristically present in true glass ionomer cements.[18] In fact, compomers behave more like a composite than a GIC, requiring acid etching and application of adhesive system. These procedures have been shown to enhance the sealing ability and retention of compomers.[18]

Overall results of marginal sealing for flowable, hybrid and microfilled composites were poor, in spite of the differences in composition and mechanical properties between them. The highest degree of dye leakage (score 3) was observed in up to 60% of the specimens, demonstrating that adhesion of resin-based composites to cervical margin in the absence of enamel still remains a challenge. In a recent study, Sensi et al.[11] observed good marginal sealing for cervical margins in dentin using flowable composites, when they were not light cured together with the adhesive system. In the present study, regardless of the flowable composites were light cured separately from the adhesive system, the marginal sealing observed was poor. In a 1-year clinical evaluation of non-carious cervical restorations, Loguercio et al.[26] were not able to identify any significant improvement in restorations performed with a microhybrid composites lined with a flowable composite in comparison with restorations performed without flowable lining. Corroborating these findings, Tyas, Burrow[27] did not observe difference in clinical performance of microfill composite and flowable resins in cervical lesions after three years.

In enamel, only the group restored with the microfill composite exhibited extensive leakage. This was a surprising finding, since two other composites from the same manufacturer (Filtek Flow and Filtek P-60) were used with the same adhesive system and showed improved resistance to dye leakage. The different matrix/filler ratio explains this behavior, since it determines both the polymerization shrinkage and the elastic modulus of the materials.

Yazici et al.[28], using different types of composite (packable, hybrid, and flow), observed similar sealing ability in Class V restorations. These results are in agreement with our results in enamel, which revealed minimal or no leakage. The performance was similar for six materials (3 flowable composites, the compomer, the RMGIC and the hybrid composite). Even though, there are contradictory results in literature about improvements in marginal sealing using flowable composites[4,6,14]. Chimello et al.[29] found similar microleakage using a flowable composite in comparison with a hybrid composite in both occlusal and cervical margins.

The post-gel phase of composites polymerization is characterized by an increase in the composite stiffness, which may induce stress during the rest of the process[29]. It is believed that flowable composites, due to their low elastic modulus, are likely to absorb the stress generated by the polymerization shrinkage[15,16,29]. Flow characteristics of such composites are clearly related to the different microleakage results. They depend upon the type of monomers used and their ratio, as well as on the size and amount of the filler content. These characteristics may vary from one material to another, making difficult the extrapolation of the properties to a whole composite category[16]. Behle[30] remembers that the majority of flowable composites available nowadays are hybrid materials, presenting microfiller or macrofiller particles. The variation in the filler content and viscosity determines different polymerization shrinkage behaviors[28,31].

Conclusion

Based on the method used in the present study one could conclude that the work hypothesis was accepted, since both substrates and materials tested influenced the marginal sealing of the restorations. Enamel margins were more likely to resist dye leakage than dentin margins. The materials tested exhibited different performances regarding microleakage in both margins.

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