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Wear and superficial roughness of glass ionomer cements used as sealants, after simulated toothbrushing

Desgaste e rugosidade superficial de cimentos de ionômero de vidro utilizados como selantes, após escovação simulada

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ABSTRACT: The purpose of this study was to evaluate, *in vitro*, the properties (wear and roughness) of glass ionomer cements that could influence their indication as pit and fissure sealants. The utilized materials were Fuji Plus, Ketac-Molar and Vitremer (in two different proportions: 1:1 and ¼:1). The resin-based sealant Delton was used as control. By means of an electronic balance (precision of 10^{-4} g), wear was measured in function of weight loss after simulated toothbrushing. Superficial roughness was determined by means of a surface roughness-measuring apparatus. The results revealed that diluted Vitremer and Fuji Plus were less resistant to toothbrushing abrasion and had the greatest increase in superficial roughness. Although in clinical situations luting or diluted ionomer cements are often utilized as alternatives to resin-based sealants, the results of this study revealed that the properties of those cements are worse than those of restorative ionomers, which presented results similar to those of the evaluated resin sealant.
DESCRIPTORS: Pit and fissure sealants; Dental restoration wear; Dental materials.

RESUMO: O presente estudo foi conduzido *in vitro* com o intuito de constatar as propriedades (desgaste e rugosidade) dos CIV, as quais influenciam na sua indicação como material selador de fossas e fissuras. Os materiais empregados foram Fuji Plus, Ketac-Molar e Vitremer (duas proporções: 1:1 e ¼:1). O selante Delton foi controle. A determinação do desgaste foi obtida através da quantidade de massa perdida após a escovação e a rugosidade através da análise quantitativa da superfície. Os resultados mostraram que o Vitremer diluído e o Fuji Plus apresentaram maior grau de desgaste e maior aumento de rugosidade. Apesar de clinicamente se encontrar um maior uso dos ionômeros de vidro cimentantes ou diluídos como forma alternativa para material selador; este trabalho permitiu concluir que estes possuem propriedades bastante inferiores quando comparados aos ionômeros restauradores que, por sua vez, possuem resultados semelhantes ao selante resinoso.
DESCRITORES: Selantes de fossas e fissuras; Desgaste de restauração dentária; Materiais dentários.

INTRODUCTION

Occlusal caries constitute approximately 80 percent of the primary lesions in permanent teeth[3]. Although fluoride has reduced the prevalence of dental caries, it has been demonstrated that its protective effect is greater on smooth surfaces than on pit and fissures[21].

Sealing of pits and fissures is a clinical preventive procedure used to limit occlusal caries [21]. Most of the types of sealant available in the marketplace are resin-based. The preventive effects of this type of sealant are obtained and maintained as long as the material remains completely intact and bonded to the dental surface[6]. Micromechanical retention is provided by the acidic conditioning of enamel prior to the application of sealants. For the adequate retention of the resin-based sealant, at the time of placement the enamel must be clean, free of salivary contamination and dry[7,19]. However, these conditions are rarely possible on recently erupted permanent molars, for which the sealing procedure is indicated.

The glass ionomer cement is an alternative material that may be utilized as a sealant. It presents the desirable property of long-term fluoride release and was introduced in 1974 by McLean, Wilson[13], who reported 84% of complete clinical retention after 1 year, and 78% after 2 years. In their study, wide fissures were selected to allow the placement of thick bulk portions of cement. So far, studies on

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the efficacy of GICs (Glass Ionomer Cements) have been carried out, and their results have been conflicting. Some clinical trials reported high success rates[12,16] (measured through sealant retention), while others report much poorer success rates[1,4,17]. However, an interesting finding is that, as to the reduction of the incidence of caries, the glass ionomer sealant is successful in all studies – it seems to exert a cariostatic effect even after macroscopically removed from the fissure. Long-term retention might not be necessary if the material has anticariogenic properties that increase the resistance of newly erupted fissures to caries[1].

However, it has been observed that the filling cement could not penetrate fissures narrower than 100 μm[10]. As it occurs with other dental restorative materials, the powder-liquid ratio plays an important role in the ultimate physical properties. For glass ionomer cements, the greater the amount of powder, the greater the abrasion resistance and viscosity, and the lower the solubility. High viscosity could negatively affect the ability of the material to flow adequately into the pit or fissure, therefore reducing its sealing ability. To solve this problem, the utilization of flowable GICs has been recommended, in the form of a luting cement or a diluted filling cement. A flowable material penetrates deeper into the fissures, improves retention and also provides longer protection. Machado et al.[9] carried out a study to examine the effect of diluting a resin-modified glass ionomer (Vitremer with 1:4 powder-liquid ratio) on its clinical performance as a pit and fissure sealant. They reported high success rates after a period of one year, but further research on the physical properties obtained with this different ratio is necessary.

Another factor that should be considered is the low wear resistance of GICs, which may contribute to faster disintegration and thinning of the sealant and, eventually, to its fracture and displacement[1].

The characteristics of the surface of glass ionomers are also important, since an increase in roughness might result in faster colonization of the surface and faster maturation of plaque, thereby increasing the risk of caries[22].

The purpose of the present study was to compare, *in vitro*, the resistance to abrasion and the surface roughness of different forms of glass-ionomer cements used as pit and fissure sealants: filling (conventional and resin-modified), luting and diluted (modified powder-liquid ratio) forms. Simulated toothbrushing with toothpaste was carried out to predict brushing abrasion.

MATERIALS AND METHODS

Experimental design

The studied materials were glass ionomer cements in four different forms, and a resin sealant was used as control. The experimental sample was composed of 60 specimens randomly assigned to five groups of 12. The order in which the 12 specimens were prepared was randomly determined. The response variables were wear and superficial roughness, respectively evaluated by means of weight loss and roughness measurements after a toothbrush-dentifrice test.

Specimen preparation

The materials utilized in this study are presented in Table 1. The instructions of manufacturers were followed for handling the materials, except for Vitremer, which was prepared in a diluted form, with ¼ of the recommended amount of powder for each drop of liquid. The matrixes (with a 5.0-mm inner diameter and 3.0 mm of thickness) were slightly overfilled with the materials in a single increment, covered with a polyester strip and a glass slab, and pressed to extrude any ex-

TABLE 1 - Tested materials.

Brand	Manufacturer	Type	Powder:liquid ratio	Batch number
Delton	Dentsply	-	-	49861
Ketac-Molar	ESPE	Conventional GIC filling	3.0 g:1.0 g	SW0048756
Fuji Plus	GC-Corp	Resin-modified luting GIC	2.0 g:1.0 g	160781
Vitremer	3M Dental Products	Resin-modified filling GIC	2.5 g:1.0 g	19990519
Vitremer ¼	3M Dental Products	Resin-modified GIC diluted for sealing	0.625 g:1.0 g	19990519

GIC = glass ionomer cement.

cess. When necessary, the specimens were cured by means of a visible light-curing unit, following the exposure time recommended by the manufacturers. Ketac-Molar and Fuji Plus were immediately protected using nail polish (Maybelline), and the Finishing Gloss (3M) was used on the Vitremer and ¼ Vitremer groups. After one hour all the specimens were stored at 37º in 100% relative humidity

Initial measurements

Weighing was carried out by means of an electronic balance (Mettler Toledo – AB 204) every 24 hours until the specimens had a stable weight on five serial measurements, and this value was considered the initial weight. At this time, the analysis surface roughness was quantitatively carried out by means of a surface roughness-measuring instrument (Hommel Tester T1000). Surface roughness was characterized by the height parameter, Ra (μm), defined as the arithmetical average of the absolute values of profile departures in relation to length. The definite initial surface roughness was an average of five initial random measurements of each sample. The cut-off value was set at 0.25 mm.

Toothbrush abrasion

Subsequently, the specimens were submitted to brushing abrasion in an abrasion testing machine (similar to Pepsodent, made by the Department of Dental Materials, School of Dentistry of Bauru, University of São Paulo). Ten thousand strokes were performed at a speed of 374 strokes (complete forward and reverse movement) per minute, with a load of 200 g, with soft bristles tips (Colgate Classic Infantil - Colgate Palmolive, Division of Kolynos do Brasil Ltda., Osasco, São Paulo, Brazil), in the presence of an abrasive slurry composed of calcium carbonate dentifrice (Sorriso - Kolynos do Brasil Ltda., Osasco, São Paulo, Brazil) and distilled de-ionized water in the rate of 1:2 in weight. After brushing abrasion, the specimens were subjected to a new storage period, carried out like the first one.

Final measurements

Final weight and final surface roughness measurements were obtained after toothbrushing, as described for the initial measurements.

Analysis of wear and superficial roughness

Wear was measured based on the level of weight loss. It was calculated based on the difference between the initial weight (before tooth brushing) and the final weight (after tooth brushing), for each specimen. The variation of surface roughness was based on the difference between initial and final means, for each specimen.

Statistical analysis

The results were analyzed by means of the one-way ANOVA criterion and Tukey's test at $p < 0.05$.

RESULTS

The adjusted mean values (standard error) of the percentage of weight loss (%) of each one of the five groups are presented in Table 2. The one-way ANOVA criterion, followed by Tukey's test, revealed differences between the tested materials as to wear resistance.

Vitremer ¼ presented the highest percentage of weight loss, followed by Fuji Plus and Delton, which did not statistically differ from Ketac-Molar. Vitremer showed the greatest wear resistance and presented no statistically significant difference when compared to Ketac-Molar (Table 2).

ANOVA and Tukey's tests were utilized to evaluate the increase of surface roughness of the materials after the toothbrushing test. The averages between initial and final values of surface roughness of each material are presented in Table 3. An increase in surface roughness was observed in all tested materials after brushing simulation. Vitremer ¼ exhibited the greatest surface roughness increase, followed by Fuji Plus (Table 3). The other groups did not statistically differ from each other, except for the baseline ($p < 0.05$).

TABLE 2 - Averages and standard deviations for percentage of weight loss. Results from Tukey's test.

Material	Mean weight loss (%)	Standard deviation
Vitremer ¼	5.41333	1.034574
Fuji Plus	4.12227	0.690283
Delton	2.28319 ┐	1.105618
Ketac-Molar	1.52472 ┤	0.420329
Vitremer	1.26285 ┘	0.138136

Values connected by vertical brackets did not statistically differ from each other ($p < 0.05$).

TABLE 3 - Averages of inicial (Ra_i) and final (Ra_f) superficial roughness (μm), averages and standard deviations for the increase of superficial roughness ($Ra_f - Ra_i$) and results from Tukey's test.

Material	Ra_i (μm)	Ra_f (μm)	$Ra_f - Ra_i$ (μm)	Standard deviation
Vitremer ¼	0.31	0.92	0.609667	0.309945
Fuji Plus	0.27	0.65	0.383667	0.080326
Delton	0.18	0.33	0.150667	0.139777
Vitremer	0.21	0.30	0.088500	0.116401
Ketac-Molar	0.37	0.41	0.044833	0.107664

Values connected by vertical brackets did not statistically differ from each other ($p < 0.05$).

DISCUSSION

The obtained results could not be compared with those of other studies, since no one else has evaluated wear and roughness of materials used as pit and fissure sealants with a comparable methodology.

The rate of abrasion depends on several factors such as the type of dentifrice, the water/dentifrice ratio, the type of brush, and the speed and pressure employed during brushing[8]. However, since in this investigation these parameters were standardized for all groups, the abrasion resistance of the studied materials seems to depend on their inherent properties[10]. Actually, the differences between the materials regarding wear have been reported as the result of a combination of factors[18]. One of such factors is the characteristics of the matrix, which is formed by an acid-base cross-linking reaction of the metal ion-polyacid (conventional GIC), by an interpenetrating polymer network combining the acid-base cross-linking reaction with the cross-linking polymerization of the monomer system, or by an additive action of polymers (resin-modified glass-ionomer cements). Other factors are the ratio and size of glass inorganic particles and the formation of air bubbles while the material is prepared.

Diluted Vitremer was the material most susceptible to abrasion, followed by Fuji Plus, both presenting a flowable constitution. This behavior was already expected because the particles of glass present in the powder determine, to a large extent, the wear resistance of the material[15], and these materials presented a reduced amount of particles, since they have more liquid. Fuji Plus is originally produced in a diluted form. The manufacturer tried to compensate this dilution by reducing the size of the glass particles, since smaller particles have a larger contact surface area and are consequently more reactive with their admixed acidic polymer. This avoids formation of multiple in-mixed air bubbles[5,20], justifying its best behavior in relation to the experimental hand-diluted Vitremer ¼ ionomer.

The resin sealant Delton, in spite of presenting minimum amount of inorganic particles, has a matrix of polymer chains more resistant when compared to the polyalkenoate network, presenting better wear resistance than Fuji Plus. Delton showed no statistically significant difference as to brushing abrasion in comparison with Ketac Molar, which had a wear behavior similar to that of Vitremer. On the other hand, Delton presented wear resistance values that were statistically lower than those of Vitremer.

Resin-modified glass ionomers are reported to have improved mechanical properties[11]. However, there is some controversy regarding the relative abrasion resistance of resin-modified and conventional glass ionomers[2]. Wilson[23] stated that the hydrogel salt from ionomers and poly-HEMA would be unlikely to interpenetrate, thus forming separate phases, which is not desirable. Moreover, Momoi *et al.*[14] reported lower abrasion resistance for the resin-modified material than for the conventional material. However, according to the results obtained in this study, which are in agreement with the results reported by Xie *et al.*[24], the conventional and resin-modified GIC presented similar behaviors as to wear resistance.

Since resin-based sealants, which are referential materials concerning retention, present wear resistance similar to or even worse than that of ionomers, one can conclude that brushing abrasion resistance is not the property responsible for the poor retention of ionomer-based materials applied on partially erupted teeth. Other factors, such as poor adhesion to teeth and low resistance to occlusal forces, when teeth are already erupted,

may contribute to the loss of glass ionomer sealants.

The porosity caused by the presence of air bubbles, as well as the filler particles exposed due to abrasion, result on higher roughness. Surface roughness is also influenced by the characteristics of the materials in interaction with several factors, which have been previously explained.

Similarly to what was observed regarding wear, the materials that comparatively presented worse roughness results were the cements containing more liquid than powder (Vitremer ¼, preceded by Fuji Plus). A possible explanation is that the decrease of glass particles, in these materials, increases their susceptibility to erosion, causing more pronounced displacement of inorganic particles and greater exposure of air bubbles incorporated during mixture[5].

It is expected that an increase in surface roughness results in faster colonization of the surfaces and faster maturation of dental plaque, thereby increasing the risk of caries, although glass ionomer cements present anticariogenic action due to fluoride release[22]. However, it seems that higher abrasion may provoke loss of surface integrity and the formation of anatomical sites that would encourage the accumulation and stagnation of substrates and microorganisms[1].

Changes in surface roughness and wear rate cannot entirely predict the clinical behavior of the studied materials. Other aspects, such as depth of penetration, adhesion and marginal microleakage, can more positively account for their clinical performance. Therefore, *in vitro* models may not necessarily give a full realistic indication of what happens in the mouth. However, considering the high turnover of new materials, the obtained results are important, as well as the results of other laboratorial studies, for predicting the behavior of sealing materials.

CONCLUSIONS

Under the conditions in which this study was carried out, it may be concluded that:

- The glass ionomer cements which presented flowable consistency (Vitremer ¼ and Fuji Plus) presented worse properties (wear and roughness) than the restorative ionomers (Ketac-Molar and Vitremer) and the resin-based sealant (Delton).
- Vitremer and Ketac-Molar (restorative ionomers) revealed similar wear resistance and increased surface roughness when compared to the evaluated resin-based sealant (Delton).

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