Penetration and Microleakage of Dental Sealants in Artificial Fissures

Dominique Droz, PhD   Marie-Josee Schiele, DDS   Marc M. Panighi, PhD

ABSTRACT

This study investigated sealant penetration and dye microleakage of a resin composite system, a compomer system, and a resin-modified glass-ionomer cement in artificially grooved fissures in human molars. Ionosit Seal penetrated 99% of the artificial crevices, whereas Dyract Seal penetrated 97%. The penetration of Helioseal F at 90% was statistically different ($P<.0001$) from the other 2 materials. Microleakage dye penetration occurred in 22% of the Dyract Seal samples, while it occurred in 5% of Healioseal F and 7% of Ionosit Seal samples. The viscosity and flow properties of the 3 sealants allowed the materials to penetrate the artificial grooves, but they did not seem to affect their sealing capacity. (*J Dent Child*. 2004;71:41-44)

KEYWORDS: SEALANTS, MICROLEAKAGE

Pits and fissures account for more than 85% of the affected surfaces for all dental caries.[1,2] To minimize caries in these areas, pit and fissure sealing is an effective method.[3,4] Since the work of Buonocore,[5] it was well known that polymers bonded to enamel with a micromechanical process established by resin tags into microporosities created in the etched enamel. Sealants prevented occlusal caries depending on their retention to enamel, which impeded not only partial or total loss of material, but also microleakage that leads to bacterial invasion and subsequent development of caries.

Variations occur among different resin systems used as fissure sealants.[6] These problems can be related to:

1. technical errors, such as salivary contamination of the etched enamel or improper sealant handling;
2. particular material characteristics like viscosity or surface tension,[7] polymerization shrinkage, or thermal expansion;[8]
3. complex morphology of fissures,[9] which harbor microorganisms and protein debris inhibiting sealant penetration.[10]

Microscopic investigations[11,12] have shown that about 60% of occlusal fissures actually presented deep and/or complex grooves. Consequently, the possibility that the sealant obturated fissures varied, particularly with anatomical variations.[13] Comparison of the intrinsic ability of several materials to seal fissures hermetically appeared to be difficult when using the occlusal fissures of human teeth.

To overcome such difficulties and compare without bias the aptitude of sealants to tightly plug fissures, the present investigation compared penetration and microleakage of 3 sealants in artificially prepared fissures.

METHODS

SAMPLE PRESENTATION

Fifteen extracted noncarious third molars with intact buccal and lingual surfaces were selected. The teeth were cleaned of debris or soft tissue remnants and stored at 4°C in a 0.5% chloramine T solution, then used within a 4-month period. A flat enamel surface was ground wet with 180-600 grit silicon carbide abrasive papers, perpendicular to buccal and lingual surfaces on 1 of the proximal surfaces.

From the flat proximal surface, 2 standardized V-shaped channels were carefully performed on the occlusal third of the buccal and lingual surfaces with a water-cooled 853-008 diamond flame bur (Diatech Dental, Heerbrugg, Germany) without reaching the opposite side and crossing the natural groove. These grooves simulated V-type fissure morphology, which actually represented 34% of all the occlusal fissure types.[11] For each of the V-shaped channels, the dimensions were approximately 5 mm long, 0.9±0.05 mm wide at the top, and gradually narrowed toward the bottom of the 1.5 mm high artificial fissure.

Dr. Droz is associate professor and Dr. Schiele is associate assistant, Departement Odontologie Pédiatrique, Université Nancy I, Cedex, France; Dr. Panighi is dental professor, Laboratoire de Physique des Matériaux, Nancy I Cedex, France.
Correspond with Dr. Droz at dominique.droz@odonto.uhp-nancy.fr

SEALING PROCEDURES

To have 4 surrounding walls, a piece of metal matrix ribbon that was long enough to cover the proximal surface was bonded on the flat one. After the specimens were randomly distributed, artificial fissures were filled with 3 commercially available sealants and adhesive systems:

1. Dyract Seal (Compomer)/Primer Bond;
2. Helioseal F (Resin Composite)/Scotch Bond;
3. Ionosit Seal (RMGC)/Solist.

Furthermore, to fairly compare each material, the buccal grooves of a sample were sealed with 1 material and the lingual grooves with another. In this way, each sealant was used in 20 artificial fissures and compared to each of the others: 10 on the buccal surface and 10 on the lingual surface. These fissures were conditioned and sealed strictly according to manufacturers' instructions with an explorer without pressure.

In the group HF/SB (Helioseal F/ScotchBond), artificial fissures were conditioned with 35% H_3PO_4 gel for 30 seconds, rinsed for the same amount of time, and dried with air-spray until enamel became dull white. Two layers of ScotchBond 1 were thoroughly microbrushed and light-cured for 10 seconds. One minute after placement of Helioseal F, the sealant was photopolymerized (Visilux 2, 3M Dental Products Co) for 40 seconds.

In the group DS/PB (Dyract Seal/Primer Bond), grooves were conditioned with nonrinse conditioner rubbed for 20 seconds and dried with a gentle air flow. Prime and Bond was applied and left undisturbed for 30 seconds. Excess solvent was removed by gentle air flow and cured for 10 seconds. After that, Dyract Seal was placed in the channel, and 1 minute after its placement, Dyract was light-cured for 40 seconds (Visilux 2, 3M Dental Products Co).

In the group IS/SO (Ionosit Seal/Solist), artificial fissures were conditioned as in group HF/SB. Two layers of Solist were successively rubbed for 30 seconds, gently dried by air flow and photopolymerized for 10 seconds. Ionosit Seal was placed in the groove, left undisturbed for 1 minute and light-cured for 40 seconds (Visilux 2, 3M Dental Products Co).

EXPERIMENTAL MEASUREMENTS

After the sealing, teeth were covered with 2 layers of nail varnish, excepted 1mm around the grooves, and stored for 24 hours at 100%. Following an immersion for 48 hours in a 1% methylene blue solution, samples were thoroughly rinsed in tap water. Longitudinal sections across the artificial grooves were ground, using wet silicon carbide disks from 180 to 1200 grit every 300 μm along the whole length of the fissures. Each section was examined under a stereomicroscope (Olympus SZH, OM System, Japan) at ×10 magnification.

The penetration of the sealant into the fissure was determined as the ratio of the sealant penetration height divided by the total height of the fissure, using image analyzer softwares (Matrox Inspector, MES Ltd, Montreal, Canada and Photomagic, Micrografx). The degree of marginal dye leakage along the artificial groove margins was scored as follows:

Table 1. Mean, Standard Deviation, and Coefficient of Variation of Dye Penetration Depth Ratio

Materials tested	Mean	Standard Deviation	Coefficient of Variation (%)
Helioseal F^A	0.90	0.14	16
Dyract Seal^B	0.97	0.10	10
Ionosit Seal^B	0.99	0.03	3

The different superscript letters indicate a significant difference among materials at P<.0001.

- 0 no dye penetration;
- 1 dye penetration up to one third of fissure total height;
- 2 dye penetration between one third and two thirds of fissure total height;
- 3 dye penetration between two thirds and the total height of the fissure.

STATISTICAL ANALYSIS

The *t* test and chi-square tests at 5% confidence level were performed to determine any significant difference among the 3 sealants in their penetration into artificial fissures microleakage.

RESULTS

A total of 472 sections were examined for depth of penetration and microleakage. Sealant penetration depth was expressed as the ratio of sealant penetration relative to the fissure depth (Table 1).

Ionosit Seal (resin-modified glass-ionomer material) penetrated 99% of the artificial fissure depth. The very low coefficient of variation (3%) demonstrated that this phenomenon occurred regularly throughout the experiment. Dyract Seal (compomer material) also filled the fissures almost completely with a coefficient of variation higher (10%) than that of Ionosit Seal. There was no statistical difference between these materials. The penetration depth of Helioseal F (a resin composite material) was lower and the difference with other materials was highly significant ($P<.0001$). This sealant exhibited also the highest coefficient of variation (16%) giving evidence of scattered data (Table 1).

The leakage behavior of the sealants is represented in Table 2. The lowest microleakage values were measured in fissures with Helioseal F or Ionosit Seal, which displayed respectively 5% and 7% of samples with dye penetration. No statistical difference was detected between both materials, but dye penetration was deeper with Helioseal F than with Ionosit Seal (Table 2). In fissures sealed with Dyract Seal, dye penetration occurred in 22% of the samples. These fissures exhibited a higher level of dye penetration, and the difference was highly significant when compared with other sealants ($P<.001$).

DISCUSSION

Pit and fissure sealing technique is largely accepted as an effective treatment to prevent occlusal caries,[14,15] and clinical

Table 2. Microleakage Frequency Score (%)

Materials tested	Score 0	1	2	3	Sum of microleakage
Helioseal F[A]	95	0	5	0	5
Dyract Seal[B]	78	6	10	6	22
Ionosit Seal[A]	93	6	1	0	7

The different superscript letters indicate a significant difference among materials at P<.001.

evaluations show a strong correlation between sealant retention and absence of caries. Occlusal fissures present a complex anatomical configuration, which prevents the etching and sealing materials from reaching the bottom and penetrating beyond the region of the fissure constriction.[10] In addition, although clinically sound, occlusal fissures may already have carious lesions visible only histologically,[16] even if caries settled on both sides of the fissure.[17] For these reasons, mechanical enlargement of occlusal fissures is advocated and numerous studies[15,18-21] reported a better retention of the sealant, deeper penetration, and thicker layer of the sealing materials than in unprepared occlusal fissures.[22] Because of the complexity of fissure anatomy and difficulty of materials to reach the fissure bottom, in vivo experimental parameters were not easily reproducible, and comparison of different sealants was a problem. In this respect, artificial grooves appeared to be a good process for carrying out reproducible fissure shapes where penetration and retention of different sealants might fairly be compared.

To date, adhesion to enamel with polymers has been achieved by etching the substrate to such an extent that adhesive bond strengths approached the tensile strength of enamel. Nevertheless, all the materials used in this experiment exhibited some degree of leakage, and this finding agreed with numerous previous studies.[21-24] According to Moore et al,[25] microleakage between tooth substrate and restorative materials could be expected on all restorative polymers. One of the likely explanations for this was that the adhesive bond was weakened or broken by the dimensional changes occurring inevitably when materials set. However, polymerization contraction was only 1 of the parameters that intervened in the adhesion mechanisms. The principal factors governing adhesion are micromorphology, surface energy of the substrate, surface tension (which is the surface energy of a liquid), and viscosity of the adhesive materials.

After etching the enamel, the surface energy, which corresponded to the number of ionic bonds broken around the atoms of the surface, increased proportionally to the real area created by the acid at a microscopic level. The etched depth with 35% phosphoric acid solution for 60 seconds reached 8-13 µm.[26] According to van Noort[27] the ideal adhesive would have a surface tension just below the surface energy of the substrate. In this case, the surface microroughness can be advantageous in improving the adhesive bond strength by increasing the process of micromechanical interlocking. The penetration of sealants in narrow cracks, like occlusal fissures or microscopic spaces occurring after etching, is led by capillary action which involves the rate of penetration of a fluid in a crevice. The surface tension and viscosity are the most important factors that influence the coefficient of penetration of the adhesives.[28] Sealants can fill narrow occlusal fissures almost completely if the penetration coefficient value is at least 1.3 $cm.s^{-1}$, and if the sealant is allowed to flow from 1 edge of the fissure to the other.[29] Current commercial sealing materials present a penetration coefficient between 4 $cm.s^{-1}$ and 12 $cm.s^{-1}$. These low viscosity sealants were able to penetrate microirregularities of etched enamel and form resin tags up to 10 µm depth.[26]

Less viscous sealants presented better flow and thus penetrated more deeply into fissures. With these sealants, faster penetration rates should also be found with larger crevices while more viscous fluids should exhibit slower rates. For this reason, a filled sealant would be less prone to completely fill a fissure than an unfilled material. Helioseal F is a filled resin composite consisting principally of Bis-GMA (rigid molecule because of 2 aromatic rings) and triethyleneglycol dimethacrylate (low molecular weight monomer used as viscosity controller). This type of material is more viscous than a resin-modified glass-ionomer or compomer,[22] thus poorer penetration might be anticipated with this material. In this study (Table 1) Helioseal F penetrated significantly less than both Dyract Seal and Ionosit Seal. On the other hand, the difference between Dyract Seal and Ionosit Seal (P=.03) cannot be considered clinically important. Nevertheless, the viscosity of Ionosit Seal allowed the material to penetrate deeply in the experimental fissures in a very regular manner, as attested by the coefficient of variation equal to 3% (Table 1).

In microleakage experiments, fissure sealing is successful when dye fails to penetrate along the sealant-enamel interface. In this investigation, the extent of the dye penetration underwent statistically significant variations between materials (Table 2): Helioseal F and Ionosit Seal presented less leakage than Dyract Seal. Ionosit Seal showed the best fissure penetration (Table 1) and not much leakage, and this finding agreed with the assertion of Geiger et al[15] who stated that the deeper the penetration level, the lower the probability of microleakage. However in this study, Helioseal F exhibited both the least marginal leakage and least penetration level. In this study, viscosity and the flow properties of the 3 sealants did not affect their sealing capacity, which was in good agreement with the study of Barnes et al[30] But the present study found significant interfacial leakage with the compomer sealant (Dyract Seal) and this observation was consistent with the one of Salama and Al-Hammad[22] and Puckett et al[24] who demonstrated that compomer samples exhibited greater leakage than the other materials used. After placement of a compomer, a dual reaction occurs: first the light-cure leads to a polymerized acidic-monomer frame inside which a second long-termed acid-base reaction occurs with the penetration of hydrous fluids into the material. A possible explanation for the higher leakage may be the 2 reaction mechanisms, which might lead to a greater polymerization contraction that opens a gap at the enamel-sealant interface.

Future experimental work should evaluate the quality of sealing and sealant retention in relation to material physico-chemical characteristics. Artificial fissures seem to be a good procedure to discriminate the penetration and bonding ability of different materials.

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