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Original Article

Micro-CT assessment of sealant penetration in different types of fissures in primary molars

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Abstract

Introduction: Sealants prevent the development of dental caries by forming a protective barrier that reduces bacterial growth and food retention. The morphology of the pits and fissures and the material of the sealant can affect the depth to which it penetrates into the fissures and the longevity and durability of the sealant.

Aim: To compare the depth of penetration into fissures and pits of different types of sealants in primary molars using micro-CT assessment.

Material and methods: Forty intact primary molars were extracted just prior to their physiologic exfoliation. They were sealed with glass ionomer cement (GIC) and resin sealant. The samples were scanned with a desktop X-ray microtomograph. The fissure profile, sealant penetration depth, and depth of the unfilled part of the fissure were measured. Descriptive and inferential statistics were used to analyze the data.

Results: The median penetration depth of GIC was 89% (IQR 81.31%–100.00%) in U-type fissures and 66% (IQR 55.64%–76.77%) in V-type fissures. The deepest median penetration with resin sealant was found in U-type fissures 89% (IQR 73.16%–100.00%) and the shallowest median depth was found in IK-type fissures 34% (IQR 25.39%–41.73%). Penetration depths ranged from 34% to 43% in the I and IK fissure types. No statistically significant difference was found in the penetration of the two types of sealants in the different types of fissures ($p>0.05$), except for those classified as other types. There, a significantly greater depth of penetration was found in the group of teeth sealed with GIC - median 56%, compared to the resin sealant, which reached only 40% of the fissure depth ($p=0.003$).

Conclusion: The morphology of the fissure plays a more important role in determining the depth to which the sealant will penetrate the fissure than the type of sealant material used.

Keywords

biofilm formation, implants, microbial, peri-implantitis, periodontitis

Introduction

Dental caries is the most common chronic disease among children aged 5-17. [1] In the United States, the prevalence of untreated carious lesions in children remains high, ranging between 41.4% and 45.7%. [2] Notably, about 44% of these lesions are found in pits and fissures, with studies indicating that 56%-70% of cases occur in primary dentition, despite the less retentive nature of primary molars' occlusal morphology.[3,4]

The primary methods for preventing dental caries include the application of sealants on pits and fissures, local fluoride treatments, the use of fluoride-containing toothpaste, substituting sugar with xylitol, regular dental checkups, and other preventive measures.[5] However, despite the effectiveness of these prevention strategies, the high percentage of carious lesions affecting the occlusal surface of teeth remains a significant concern.[6] Molars, in particular, are at a higher risk of developing caries due to the complex morphology of their occlusal surface, which provides an ideal environment for bacteria and food debris retention while being inaccessible to mechanical cleaning.[7]

Sealants are materials that are applied to the occlusal surfaces of molars, which are highly susceptible to dental caries.[8] These sealants can be classified as glass-ionomer cement, resin-based, or hybrid sealants.[3] By applying sealants to all fissure branches on the occlusal surfaces, a physical barrier is created against plaque formation, reducing the growth of microorganisms by blocking their metabolism.[9] The durability and effectiveness of sealants in preventing occlusal carious lesions depend on various factors, including the type of material used, the morphology and type of the fissure, the depth of penetration of the material, the isolation of the operative field, and the cooperation of the patient.[9-11]

The first studies on pit and fissure morphology involved the use of serial sections of extracted human teeth. Based on these studies, fissures were classified into five main types based on their anatomical shape: V-shaped fissures, which are wide at the top and gradually narrowing towards the bottom; U-shaped fissures, which have almost the same width at the top and bottom; I-shaped fissures - an extremely narrow slit; IK - a narrow slit in contact with a large space at the bottom. There are also other types that do not fit into these descriptions.

The key properties of a fissure sealant material include its ability to effectively seal and penetrate deeply, while also providing strong retention and resistance to wear.[4] The morphology of pits and fissures, as well as the extent of penetration of the sealant, can be accurately visualized and analyzed through microtomographic (micro-CT) examination.[12] This method allows for the generation of continuous high-resolution images with exceptional detail, offering invaluable advantages in the evaluation of sealant performance.[13] Despite the benefits of microtomographic examination, there is a notable lack of studies that assess the penetration depth of sealants in the primary dentition using this technique.

Aim

This in vitro study aimed to compare the depth of penetration of two sealants into different fissure types in primary molars using micro-CT.

Materials and methods

Forty intact primary molars were extracted immediately before their physiological exfoliation from healthy children aged between 9 and 11 years after signing an informed consent by the parents. The Ethics Committee of the Medical University of Sofia KENIMUS approved the study procedures (Approval No 1598/20.05.2022).

After extraction, the crowns were cleaned with hydrogen peroxide and stored in a 1% thymol solution until the study began. Prior to silanization, the occlusal surface, fissures, and pit system were cleaned using a pressurized sodium bicarbonate suspension (PROPHYflex 3, Kavo, Biberach, Germany), and rinsed with an air/water syringe to ensure no debris or contaminants hindered the sealant penetration. The crowns were then examined under an operating microscope (Semorr 3000E, Semorr Medical Tech Co., Jiangsu, China) for any occlusal carious lesions, restorations, sealants, or defects. Only intact teeth were included in the study. The teeth were randomly divided into two subgroups:

1. Group 1 (20 primary molars) – silanization with glass-ionomer cement (GIC) GC Fuji Triage Capsule white (GC Corp, Tokyo, Japan) following the manufacturer's instructions. The enamel surface was conditioned with GC dentin conditioner for 10 seconds, rinsed for 10 seconds, and dried. The GC capsules were mixed using a GC Silvermix automatic mixer (GC Corp, Tokyo, Japan) as per the manufacturer's instructions. A new GIC capsule was used for each sample. The cement was applied to the occlusal surface fissures using the capsule's special cannula and spread with a brush. After allowing 10 seconds for penetration, it was light-cured for 20 seconds (Freelight 2 Elipar TM, 3MESPE, Ireland). The quality of the procedure was evaluated by a visual-tactile method and in the presence of areas with insufficient material, addition of cement was followed.
2. Group 2 (20 primary molars) – The teeth were sealed with resin sealant Grandio Seal (VOCO, Cuxhaven, Germany). The occlusal surface was etched for 20 s with 37% orthophosphoric acid 3M Scotchbond Universal Etchant (3M, Maplewood, Minnesota, USA), then carefully washed and dried with a water-air syringe. The acid treatment quality was assessed, and the occlusal surface should appear chalky white. If necessary, etching was repeated. The sealant was applied on pits and fissures using the cannula tip while avoiding incorporation of air bubbles. After waiting for 10 s to allow the material to penetrate deeper, the sealant was light cured for 20 seconds.

The examined samples were scanned with a desktop X-ray microtomograph SkyScan 1272 (Bruker, Billerica, Massachusetts, United States) in high resolution. Scanning properties were: 100 kV voltage, 100 μA beam current magnitude, 0.55 mm copper filter, conical radiation shape, and size of a single voxel 12 μm. At these parameters, the crowns were projected in their entire length into the detector field. The fissure profile, sealant penetration depth, and depth of the unfilled part of the fissure were measured using the two-dimensional images obtained. The degree of penetration was estimated with the formula:

$$\text{Penetration (\%)} = fa/(fa+ua)\times 100,$$

where fa is the filled portion of the fissure, ua is the unfilled depth, and fa+ua is the entire fissure depth. Data were analyzed according to the type of fissure morphology **(Fig. 1)**.

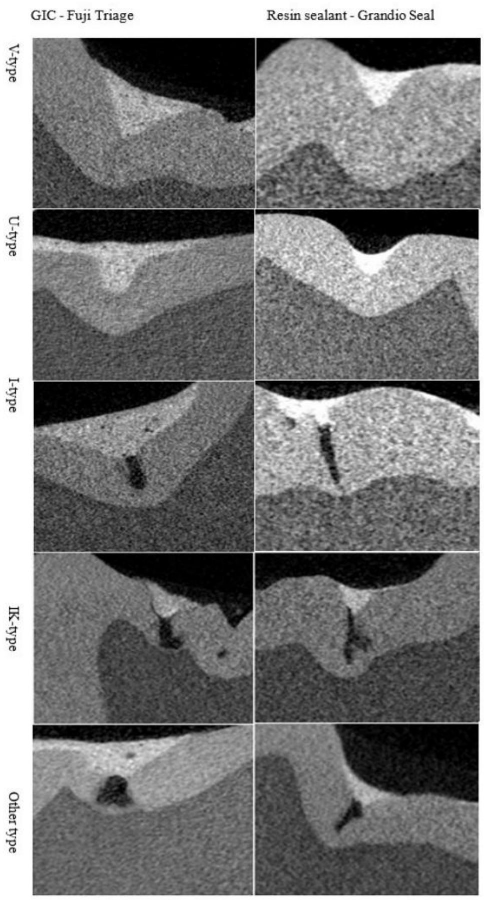

Figure 1. Penetration of both types of sealant in primary molars.

Statistical analysis

The results were reported as median and interquartile range for numerical variables due to their non-Gaussian distribution. The distribution was assessed by using the Shapiro-Wilk test. Each two groups were compared by using Mann-Whitney U test.

Results

Figs 2, 3 show the penetration depth of the two sealants used in the study and their statistical analysis by fissure type.

There was no fissure type in which the resin sealant penetrated to full depth or close to 100%. About 84% of the fissure was filled if its profile was U-shaped and about 62% for the V-type fissures. In the remaining fissure morphologies, filling in the fissure depth was between 34 and 40%, significantly less than U- and V-type fissures ($p<0.001$).

Fig. 3 shows the rate of penetration when using GIC as a sealant. The deepest penetration was found in fissures with a U-type profile, close to 88%, and the shallowest depth of penetration was found in the IK-type fissures - below 38%. Close to 60% of the depth was filled if the fissure profile was classified as some other type. More than 30% of the entire fissure depth remained unfilled in the V-type profiles.

presents a comparative analysis of the penetration depth of the resin sealants Grandio Seal and GC Fuji Triage GIC capsule depending on the fissure morphology.

No statistically significant difference as found in the penetration of the two types of sealant in the different types of fissures, except for those classified as other types. In them, a significantly greater depth of penetration was found in

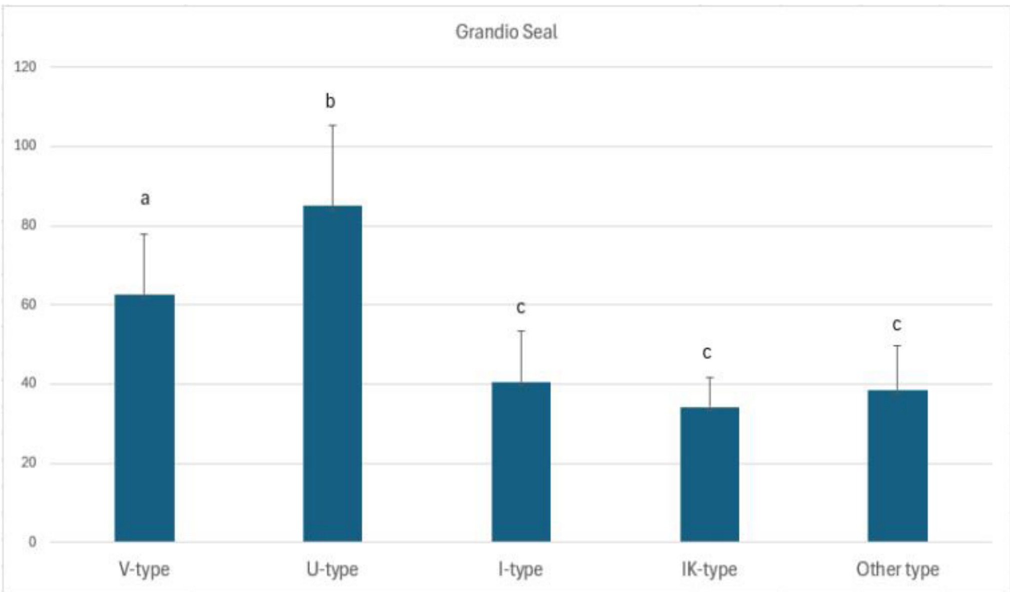

Figure 2. Comparison of the degree of penetration by fissure profile: Grandio Seal. Different letters correspond to a statistically significant difference in the degree of penetration between the different profiles ($p<0.05$, Mann-Whitney U test)

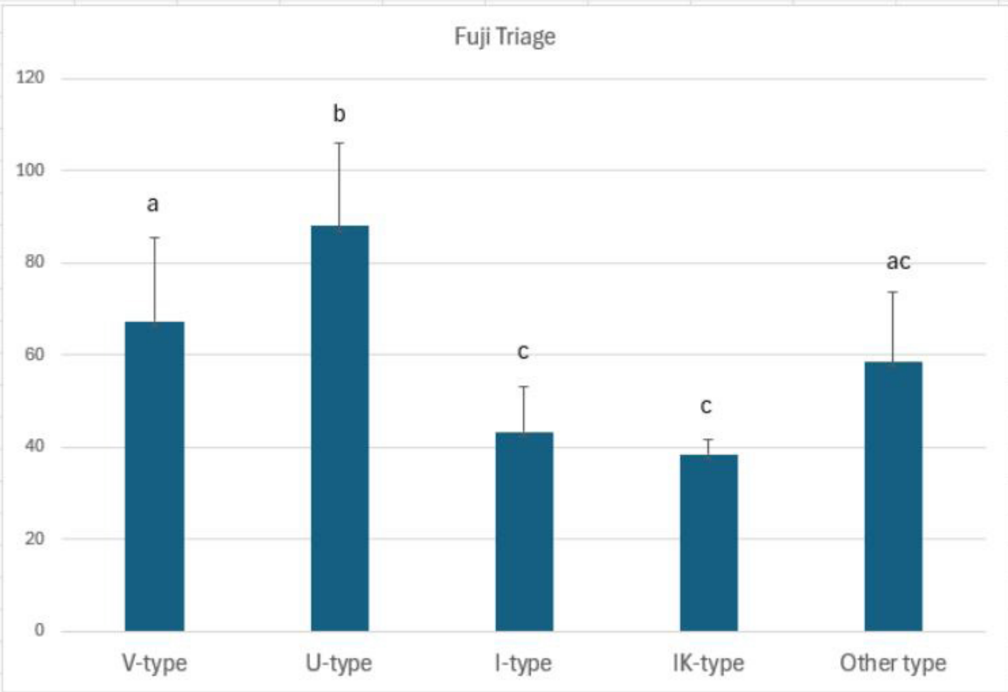

Figure 3. Comparison of penetration rate by fissure profile: GC Fuji Triage. Different letters correspond to a statistically significant difference in penetration between the different profiles (p<0.05, Mann-Whitney U test).

Table 1. Comparative analysis of penetration depth of Grandio Seal and GC Fuji Triage capsule against fissure morphology

Fissure type Material	V-type (Median/IQR)	U-type (Median/IQR)	I-type (Median/IQR)	IK-type (Median/IQR)	Others (Median/IQR)
Group 1 - GC Fuji Triage	66.59% (54.64-76.77)	89.62% (81.31-100.00)	45.74% (36.53-50.91)	39.31% (35.16-41.07)	56.58% (45.27-74.67)
Group 2 - Grandio Seal	59.75% (53.27-70.32)	89.96% (73.16-100.00)	39.38% (33.31-46.24)	34.46% (25.39-41.73)	40.18% (30.22-47.55)
p (Mann-Whitney U test)	0.197	0.641	0.203	0.217	0.003

IQR: interquartile range, 25th-75th percentile

the group of teeth sealed with GIC - 58% compared to the composite sealant, which reaches only 38% of the depth of the fissure.

Discussion

The aim of this study was to compare the penetration depth of two different types of sealants used to seal primary molar fissures. Occlusal surfaces represent 6-12% of the total tooth surface but are eight times more susceptible to caries than smooth surfaces.[14,15] Sealants reduce the risk of fissure caries development, with resin-based materials or glass ionomer cement being the most commonly used.[16,17] Resin-based sealants are composed of urethane dimethacrylate (UDMA), bisphenol A glycidyl methacrylate (bis-GMA) or triethylene glycol dimethacrylate (TEGDMA) monomers, and glass-ionomer sealants are composed of fluoroaluminosilicate glass powder and a water-based solution of polyacrylic acid.[18] The main advantage of resin-based sealants is their good mechanical strength and wear resistance, while glass ionomers also have the advantage of releasing fluoride ions.[18]

The varying degree of penetration of sealants appears to be directly related to the type of fissure morphology.[10] According to Montean et al., the penetration rate of resin sealant in the different types of fissures is as follows: U-type – 91.69%, V-type – 75.42%, IK-type – 71.24%, I-type – 63.98% [10], but their study included permanent teeth. No material can penetrate the entire depth of the fissure, especially in deep and narrow areas.[10] The present study also did not find complete penetration in any of the materials tested **(Figs 1, 2)**. The best penetration depth of the sealant was observed in U- and V-type fissures and the lowest in I- and IK-type fissures, regardless of the type of material used **(Table 1)**. Complete penetration of the sealant into the complex fissure system of the molars, especially in deep and narrow fissures compared to wide and shallow fissures, is challenging but simultaneously necessary for better material retention.

One of the materials examined in the study was Fuji Triage. It is a fluoride glass ionomer cement with a flowable consistency that provides adequate wetting and tight adhesion to tooth surfaces.[19] Glass-ionomer cement can chemically bond to the tooth structure and is widely used due to its fluoride ion-releasing properties. It is less sensitive to moisture, making it an excellent alternative to resin-based sealants in primary dentition.[20] The results from the present study showed no difference in the degree of penetration between GIC and resin composite sealants. This makes GIC suitable materials when moisture control cannot be achieved. The success of the sealant depends not only on its retention but also on its preventive effect, with several studies confirming the anti-caries effect of GIC used as a sealant.[3,19,21-23]

The penetration of the Grandio Seal resin sealant is most likely due to the higher molecular weight of the resin and the high content of inorganic fillers (70%). The viscosity of the sealant increases with the addition of fillers to its composition, which results in improved abrasion resistance and a lower ability to penetrate the depth of fissures and pits[4,18], as seen in more retentive fissure types such as I-type, IK-type, and some other types **(Fig. 2, Table 1)**. The results of the present study show that GIC and composite sealants have almost the same penetration depth in different fissure profiles. A statistically significant difference was observed only when comparing fissures with a different profile, possibly due to the greater variability in this type of fissure. Penetration depth is an important parameter that can increase the longevity, retention, and adaptation of the sealant. Therefore, if the fissure is not completely filled with sealant, the potential risks are less durability, easier wear, and weaker sealant retention. Some limitations should be mentioned. The use of a highly filled composite sealant improves visualization on micro-CT examination but would affect the penetration rate compared to a less filled resin sealant. The study of naturally exfoliated primary molars may also be biased because the teeth with the most at-risk occlusal anatomy are likely to develop carious lesions soon after eruption or be filled before their natural exfoliation occurs.

Conclusion

The highest penetration depth was seen in U- and V-type fissures, while the lowest was in I- and IK-type. Both GIC and resin sealant showed similar results. Fissure morphology impacts penetration depth more than the type of sealing material.

Funding

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Competing Interests

The authors have declared that no competing interests exist.

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