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Microleakage, adaptation ability and clinical efficacy of two fluoride releasing fissure sealants

Ispitivanje mikrocurenja, površinske adaptacije i kliničke efikasnosti dva zalivača fisura sa sposobnošću otpuštanja fluorida

Dejan Marković*, Bojan Petrović†, Tamara Perić*, Duška Blagojević†

***Department of Paediatric and Preventive Dentistry, Faculty of Dentistry, University of Belgrade, Belgrade, Serbia, Department of Paediatric and Preventive Dentistry, Dentistry Clinic of Vojvodina, Faculty of Medicine, University of Novi Sad, Novi Sad, Serbia**

Abstract

Background/Aim. Retention of fissure sealants and good adaptation to enamel are essential for their success. Fluoride releasing resin-based materials are widely accepted for pit and fissure sealing, but newly designed glass ionomers can serve as a good alternative. The aim of this study was to evaluate microleakage and sealing ability *in vitro,* and to clinically assess two fluoride releasing fissure sealants. **Methods.** The sample for experimental study consisted of 20 freshly extracted intact human third molars, divided in two experimental groups according to the sealing material: fluoride releasing resin-based (Heliosel F) and glass ionomer (Fuji Triage) material. Digital images and scanning electron microscope were used to assess microleakage and adaptation ability. Sample for clinical study consisted of 60 children, aged 6–8 years, with high caries risk, divided in two groups according to the sealant material. Fissure sealant was applied to all erupted, caries-free first permanent molars. Sealants were evaluated after 3, 6 and 12 months using modified Ryge criteria for retention, marginal adaptation, colour match, surface smoothness and caries. **Results.** Microleakage was detected in more than half of the specimen, without significant differences between the two groups ($p > 0.05$). Both materials exhibited acceptable sealing ability. Complete retention at the end of the observation period was 81.8% for resin-based, and 21.1% for glass-ionomer fissure sealant ($p < 0.001$). The presence of caries in sealed molars has been detected in one patient in both groups. During the 12-month observation period, Helioseal F demonstrated better retention, marginal adaptation and surface smoothness ($p < 0.001$). There were no differences between the two materials regarding caries and color match ($p > 0.05$). **Conclusion.** Both tested materials demonstrate satisfactory clinical and caries prophylactic characteristics that justify their use in contemporary preventive dentistry.

Key words:
pit and fissure sealants; fluorides; ion exchange resins; glass; sensitivity and specificity; child.

Apstrakt

Uvod/Cilj. Retencija zalivača fisura i dobro prilagođavanje površini gleđi prestavljaju suštinu njihove uspešnosti. Materijali na bazi smole koji emituju fluorid široko su prihvaćeni za zalivanje jamica i fisura, za koje su novi glasjonomeri dobra alternativa. Cilj ispitivanja bio je određivanje mikrocurenja, površinske adaptacije i kliničke efikasnosti dva zalivača fisura sa sposobnošću otpuštanja fluorida. **Metode.** U eksperimentu je korišćeno 20 sveže ekstrahovanih trećih molara podeljenih u dve grupe u zavisnosti od postavljenog materijala: kompozitni (Helioseal F) i glasjonomerni (Fuji Triage) zalivač jamica i fisura. Za procenu mikrocurenja i površinske adaptacije korišćene su digitalne fotografije i skening elektronski mikroskop. U kliničkoj studiji uzorak je činilo 60 dece visokog rizika od nastanka karijesa, uzrasta 6–8 godina, podeljenih u dve grupe u zavisnosti od materijala za zalivanje fisura. Za evaluaciju, nakon 3, 6 i 12 meseci, korišćeni su modifikovani Ryge-ovi kriterijumi za retenciju, marginalnu adaptaciju, ivičnu prebojenost, površinsku hrapavost i prisustvo karijesa. **Rezultati.** Fenomen mikrocurenja detektovan je na više od polovine eksperimentalnih zuba bez statistički značajne razlike između ispitivanih grupa ($p > 0,05$). Oba materijala pokazala su dobru adaptaciju uz zidove fisura. Potpuna retencija na kraju opservacionog perioda iznosila je 81,8% za kompozitni i 21,1% za glasjonomerni zalivač ($p < 0,001$). Karijes je detektovan kod jednog ispitanika u obema grupama. Heliosel F pokazao je bolje rezultate u pogledu retencije, marginalne adaptacije i površinske hrapavosti u odnosu na Fuji Triage ($p < 0,001$). Što se tiče karijesa i ivične prebojenosti, nije bilo razlike između ispitivanih materijala ($p > 0,05$). **Zaključak.** Ispitivani materijali pokazuju zadovoljavajuće profilaktičke karakteristike u nastanku karijesa.

Ključne reči:
zub, zalivači jamica i fisura; fluoridi; smole, jonoizmenjivačke; staklo; osetljivost i specifičnost; deca.

Correspondence to: Bojan Petrović, Dentistry Clinic of Vojvodina, Faculty of Medicine, University of Novi Sad, Hajduk Veljkova 12, Phone.: +381 21 661 2222. E.mail.: bpetrovicns@yahoo.com

Introduction

The prevalence of dental caries has been decreased during the last decades, but it is still a widespread disease [1]. Effects of caries preventive measures are greater on smooth surfaces, while occlusal caries remains a problem. It has been shown that a carious lesion most frequently occurs in pits and fissures of occlusal surfaces [2], primarily due to their specific anatomy [3], which is considered to be an ideal site for the retention of bacteria and food remnants rendering mechanical means of debridement inaccessible [4].

Sealing pits and fissures is considered to be an effective way of preventing caries development [5]. A fissure sealant is a material that is placed in pits and fissures of teeth in order to prevent or arrest the development of dental caries. Any primary or permanent tooth judged at risk would benefit from sealant application [6].

Today, there is a wide spectrum of available sealing materials. These materials differ according to the base material, the method of polymerisation and weather or not they contain fluoride. Resin sealants are bonded to the underlying enamel by the use of the acid etch technique. Their caries preventive effect is based on the establishment of a tight seal which prevents leakage of nutrients to the microflora in the deeper parts of the fissure. Glass ionomer cements are mainly recommended for pits and fissures sealing for two reasons. First, they are less susceptible to moisture which allows their use in noncooperable children or in partially erupted teeth where isolation could be a problem [7] and secondly, due to their potential to act as a fluoride reservoir making enamel more resistant to demineralisation [8].

Microleakage is defined as the passage of bacteria, fluids, molecules, and ions between the teeth and the sealing material. Microleakage is considered as the main problem with direct restorative procedures and one of the main reasons for restoration failure [9]. A dental sealant is successful only if it firmly adheres to the enamel surface, and protects pits and fissures from the oral environment.

The aim of this study was to evaluate microleakage and sealing ability *in vitro*, and to clinically assess two fluoride-releasing fissure sealants.

Methods

Experimental study

Twenty intact third molars extracted form orthodontic or surgical reasons were used in this study. Teeth were stored in the same bottle in distilled water at +4°C for a period not longer than 1 month. Specimen was randomly divided into two groups (n = 10): resin-based fluoride-releasing fissure sealant, Helioseal F (Ivoclar Vivadent AG, Schaan, Liechtenstein), and glass ionomer sealant, Fuji Triage (GC Int., Tokyo, Japan). The materials used in this study were prepared according to the manufacturers' instructions. For resin-based sealant, enamel was etched with 37% phosphoric acid gel (Total Etch, Ivoclar Vivadent AG) for 20 s. Sealant was applied and polymerized utilizing a visible light for 40 s after a 20 s interval. For glass ionomer cement, enamel was conditioned with 10% polyacrilic acid for 20 s (GC Dentin Conditioner, GC Int.), the material was applied and coated with varnish (GC Fuji Coat LC, GC Int.) which was light cured for 10 s to protect material from moisture and desiccation. After application of the sealant, teeth were stored in distilled water at +4°C for one week. During this period, teeth were thermocycled at 5°–7°C, 35°–37°C, and 55°–57°C for 300 cycles, with a dwell time of 30 s. Teeth were coated with nail varnish, except 1 mm around the sealant, and subsequently immersed in 5% methylene blue for 24 hours. Each tooth was then sectioned at 3 sites in the buccolingual plane using a water-cooled diamond-impregnated law speed saw (Isomet Low Speed Saw, Buehler; Lake Bluff, IL, USA), yielding 6 sectioned surfaces per sample for analysis.

Digital images were used to assess microleakage. Photographs were made using a camera (Olympus SP565, Tokyo, Japan) at 10 × magnification (Figure 1). One blinded examiner evaluated depth of dye penetration in each section. The scoring system [10] is described in Table 1.

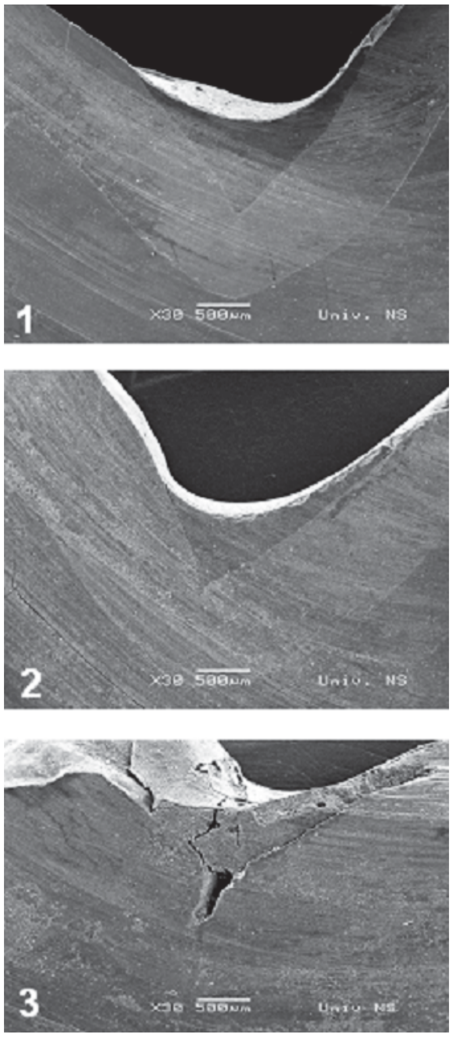

Fig. 1 – Scoring for adaptation ability

Adaptation ability was evaluated using scanning electron microscopy (SEM). The specimens were mounted on aluminium stubs, sputter-coated with gold (Bal-Tec SCD 005

Table 1

Criteria for evaluation in the experimental study

Microleakage		Adaptation ability	
Score	Description	Score	Definition
0	No dye penetration		
1	Dye penetration restricted to the outer half of the sealant	1 – good	Complete adaptation to all fissure walls
2	Dye penetration to the inner half of the sealant	2 – fair	One minor failure of adaptation
3	Dye penetration into the underlying fissure	3 – poor	Major failure of adaptation

Sputter Coater; Balzers, Liechtenstein) and than examined with SEM (JEOL JSM-6460LV, JEOL Industries; Tokyo, Japan). To standardise the microscopic observation, micrographs of the fissures were taken at magnification of 30 × (Figure 2). Scoring for adaptation ability [11] is described in Table 1.

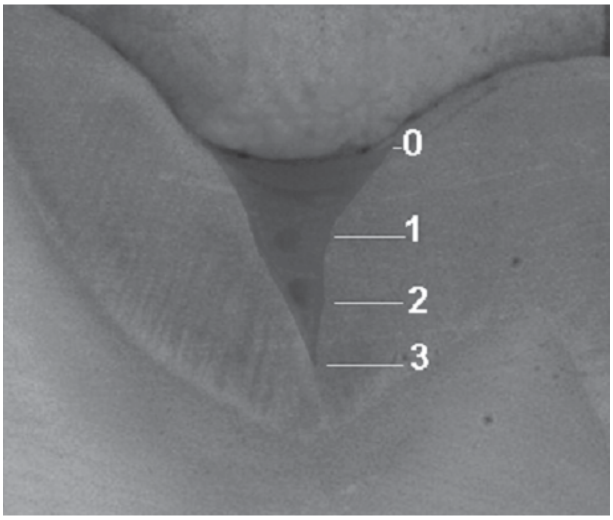

Fig. 2 – Scoring for microleakage

Clinical study

This was a prospective clinical trial with a 12-month observation period. Patients were treated at the Dentistry Clinic of Vojvodina, the University of Novi Sad, and at the Clinic for Paediatric and Preventive Dentistry, the University of Belgrade. The study was conducted in accordance with the guidelines of the Declaration of Helsinki and approved by the local ethics committee.

The sample was composed of 60 children, aged 6–7 years, with at least one active caries lesion, restored tooth or primary tooth extracted due to the caries complications. All patients appeared for a regular dental examination when it was determined whether they met the inclusion criteria. The included patients had at least two recently erupted permanent molars with sound pits and fissures. Teeth with an obvious cavity, with a restoration or a sealant completely or partially presented in the fissure system were excluded from the study. The children and the parents were precisely informed on the purpose of the investigation, clinical procedures to be performed, and the possible benefits and potential risks involved. Informed parent consents were obtained in writing prior to the childrens participation in the study. Informed assents were obtained from the children.

The children were randomly divided into two groups (n = 30) according to the sealing material. The sealing materials, Helioseal F and Fuji Triage were placed according to manufacturers' instructions.

Two clinicians that were standardized for fissure sealing performed the sealing procedure. Two examiners evaluated all sealants. Ten percent of each investigator's sample was randomly assessed by another investigator to check inter-examiner reliability. Kappa inter-examiner reliability score was 0.93. Sealants were evaluated using a dental mirror and an explorer after 3, 6 and 12 months following the modified Ryge's criteria [12] for sealant retention, marginal adaptation, color match, surface smoothness and the presence of caries (Table 2).

Table 2

Modified Ryge criteria for clinical sealant evaluation

Criterion	Score	Definition
Retention	A	Sealant completely present
	B	Partial loss of sealing material
	C	Complete loss of sealing material
Marginal adaptation	A	Sealant is continuous with adjacent tooth structure
	B	Visible evidence of crevice formation that an explorer will penetrate
Colour match	A	Visually undetectable
	B	Mismatch in colour outside acceptable range
Surface smoothness	A	As smooth as natural adjacent tooth structure
	B	Not as smooth as natural tooth structure but not pitted
	C	Not as smooth as natural tooth structure and pitted
Caries	A	Caries free tooth
	B	Caries present

The χ^2 test was used to asses differences between the tested materials and the level of significance was set at $p < 0.001$.

Results

Experimental study

Regarding the adaptation ability, there were no statistically significant differences between glass ionomer and resin-based fissure sealants ($p > 0.05$; Table 3).

Some extent of microleakage was detected in more than 70% of the complete specimen, but without statistically significant differences between the tested materials ($p > 0.05$; Table 3).

Table 3

Adaptation ability and microleakage of fissure sealants

Score	Sealants Fuji triage n (%)	Helioseal F n (%)	Statistical analysis
Adaptation ability			
good	7 (11.6)	8 (13.3)	
fair	40 (66.7)	38 (63.3)	$\chi^2 = 0.76$
poor	13 (21.7)	14 (23.4)	$p > 0.05$
Microleakage			
0	26 (43.3)	23 (38.3)	
1	15 (25.0)	17 (28.4)	$\chi^2 = 4.63$
2	13 (21.7)	11 (18.3)	$p > 0.05$
3	6 (10.0)	9 (15.0)	

Clinical study

The results of the clinical examination of resin-based and glass ionomer fissure sealants are shown in Table 4. Regarding retention, resin-based fissure sealant exhibited higher retention rate at control examinations after 3, 6 and 12 months in comparison with glass ionomer ($p < 0.001$). In addition, better scores were recorded for Helioseal F when surface smoothness was analysed ($p < 0.001$). Regarding color match, marginal adaptation and caries, there were no statistically significant differences between the tested materials during the observation period ($p > 0.05$).

Materials in this study are representative for their groups. Resin-based sealant with fluoride (Helioseal F) is an improved descendant of previous resin-based sealants. Glass ionomer sealant used in this study (Fuji Triage) is the only glass ionomer material for fissure protection available in the market. It is claimed to have greater fluoride release compared with other glass ionomer materials, as well as the highest recharge capacity [13].

The efficacy of pit and fissure sealants depends on their ability to achieve adequate bonding with conditioned enamel. Both glass ionomer and resin based fissure sealants interact with enamel surface during bonding procedure and adaptation to fissure walls can affect clinical performances of a placed material. In the present study adaptation ability was evaluated with SEM. Because of its magnification and depth of focus, SEM provides visual observation of the adaptation of sealing material to enamel walls through the whole fissure system.

SEM analysis showed that both tested materials demonstrated satisfactory adaptation ability. In the glass ionomer specimen group, the presence of cohesive failures was recorded. Even though cohesive failures were seen in all glass ionomer specimens and detachment of sealants occurred, there was still a continuous layer of a sealant covering the enamel. Fracture of the sealant above this layer probably occurred as a result of a low cohesive strength of glass ionomers, and invasive experimental preparation procedures. Similar findings were described by Birkenfeld et al. [14]. In the Helioseal F group no cohesive failures were observed, as the material is resin-based, and unlike glass ionomer, less desiccation sensitive with higher cohesive strength.

Many studies demonstrate that there is no material that could hermetically seal pits and fissures and prevent gap formation and subsequent microleakage. The most likely explanation for the gap formation is difference in thermal expansion between sealing material and the tooth structure [15]. Coefficients of thermal expansion for sealing materials are 2–4 times greater when compared with enamel [16]. Daily temperature fluctuation in the oral environment can result in gap formation and bacterial penetration through sealant/enamel interface. Based upon this explanation, techniques of thermal cycling and cycling under loading are frequently used to determine the extent of microleakage. In the present study specimens were thermocycled between 4°C and 55°C.

The use of organic dyes as tracers is the most common method for microleakage assessment *in vitro*. In the present

Table 4

Clinical evaluation of fissure sealants according to the modified Ryge criteria*

Sealants	Evaluation period months	Retention A n (%)	Retention B n (%)	Retention C n (%)	Marginal adaptation A n (%)	Marginal adaptation B n (%)	Color match A n (%)	Color match B n (%)	Surface smoothness A n (%)	Surface smoothness B n (%)	Surface smoothness C n (%)	Caries A n (%)	Caries B n (%)
Fuji Triage	3	48 (64)	26 (35)	1 (1)	61 (81)	14 (19)	75 (100)	–	30 (40)	45 (60)	–	75 (100)	–
	6	31 (46)	31 (46)	5 (8)	40 (60)	27 (40(	67 (100)	–	17 (25)	50 (75)	–	67 (100)	–
	12	12 (21)	39 (69)	6 (10)	23 (40)	34 (60)	54 (95)	3 (5)	2 (3)	55 (96)	–	55 (97)	2 (3)
Helioseal F	3	73 (95)	4 (5)	–	73 (95)	4 (5)	77 (100)	–	75 (97)	2 (3)	–	77 (100)	–
	6	63 (88)	7 (10)	1 (2)	63 (89)	8 (11)	71 (100)	–	69 (97)	2 (3)	–	71 (100)	–
	12	45 (82)	7 (13)	3 (5)	46 (84)	9 (16)	53 (96)	2 (4)	48 (87)	7 (13)	–	54 (98)	

***For explanation see Table 2**

Discussion

Resin-based fluoride-releasing sealants have been developed in effort to add therapeutical and preventive effect of fluoride to a material with excellent mechanical and retentive characteristics. Application of glass ionomers as fissure sealants is based upon their ability to form chemical bond with tooth tissues and continuing fluoride release.

study specimens were stored in methylene blue for 24 h, according to the methodology used in the studies by Hatibovic et al. [17] and Birkenfeld at al. [14], and microleakage was scored according to the level of leakage at the sealant/enamel interface. All specimens in the present investigation showed some amount of microleakage. This finding support reports by Theodoridou-Pahini et al. [15] and Borem and Fiegel [18] who stated that microleakage can be expected in all restorative materials.

Although it is clear that there is no sealing material, application technique or sealing procedure that can prevent microleakage [17, 19, 20], results of the studies in which glass ionomer and resin-based fissure sealants are compared are not uniform. According to some reports [14, 21], higher extent of microleakge was observed under glass ionomer sealant, which is attributed to the solubility of the material. Pardi et al. [22] showed no differences between conventional glass ionomer, resin-modified glass ionomer and resin-based fissure sealants.

With the improvement of contemporary materials for pit and fissure sealing, clinical evaluation that comprises only data regarding retention and caries are considered insufficient. That is the reason why in this study modified Ryge [12] criteria were used.

The results of the present clinical evaluation clearly confirm that resin-based sealant possess superior retention in comparison with glass ionomer material. In a study with two-cohort design, Simonsen [23] found complete retention in 27.6% of sealed first permanent molars with caries reduction rate of 52% 15 years after a single application. Raadal et al. [24] and Gandini et al. [25] reported complete retention rate after two years of 97% and 66%, respectively. In a study by Vrbic [26], 95.8% of permanent molars and 91.5% of premolars treated with Helioseal F were completely sealed after 3 years. However, older participants were included in that study, and this is probably the explanation for such a high retention rate.

The longevity of glass ionomer cements as sealants is significantly lower when compared with resin-based sealants [27]. Findings on use of conventional glass-ionomer fissure sealants [24, 28], as well as resin-modified glass ionomers [29] uniformly demonstrate their lower retention rates in comparison with resin-based fissure sealants. The results from the present investigation completely correspond to these findings.

Despite higher clinical loss, glass ionomer sealant showed equal caries preventive effect as resin-based sealant. Some studies verified no differences in caries incidence or even better preventive effects for glass ionomer sealing materials, even though their retention rate was lower than for resin-based sealants [30–32]. Nevertheless, other studies found better retention and caries preventive effect of resin-based fissure sealants [33, 34].

A relevant factor that should be considered when glass ionomer material is studied as a fissure sealant is that even after it has been clinically lost, small amounts of sealant are left at the bottom of the fissure and continue to release fluoride [8], providing another kind of occlusal protection.

For both tested material, the absence of marginal discoloration was observed during the entire observation period. Regarding marginal adaptation and surface smoothness, resin-based material showed superior results when compared to glass ionomer. These results completely correspond with the literature [35].

Conclusion

Resin-based and glass ionomer fissure sealant demonstrate satisfactory sealing ability. None of the tested materials could prevent dye penetration, suggesting that microleakage still can occur in real clinical situations. Although resin-based fissure sealant demonstrates better retention, both materials are equally effective in caries prevention, and could be recommended as materials of choice for pits and fissure sealing procedure.

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