# Caries-Preventive Effect of Fissure Sealant Containing Surface Reaction-Type Pre-reacted Glass Ionomer Filler and Bonded by Self-etching Primer

Shimazu K * / Ogata K ** / Karibe H ***

***Objective:*** *We aimed to evaluate the caries-preventive effect of a fissure sealant containing surface reaction-type pre-reacted glass ionomer (S-PRG) filler and bonded by self-etching primer versus those of 2 conventional resin-based sealants bonded by acid etching in terms of its impact on enamel demineralization and remineralization, enamel bond strength, and integrity of debonded enamel surfaces.* ***Materials and method:*** *Demineralization, remineralization, and bond strength on untreated enamel and enamel subsurface lesions of bovine incisors were assessed among the sealants by polarizing microscopy and microradiography; debonded enamel surfaces were examined by scanning electron microscopy.* ***Results:*** *The conventional resin-based sealants bonded by acid etching caused surface defects on the enamel subsurface lesions and significantly increased the lesion depth (p = 0.014), indicative of enamel demineralization. However, the S-PRG filler-containing sealant bonded by self-etching primer maintained the enamel surface integrity and inhibited enamel demineralization. No difference in bond strength on both untreated enamel and enamel subsurface lesions was noted among the sealants.* ***Conclusions:*** *An S-PRG filler-containing fissure sealant bonded by self-etching primer can prevent enamel demineralization, microleakage, and gaps without the tags created by acid etching regardless of the enamel condition. Such sealants are suitable for protecting the pits and fissures of immature permanent teeth.*

***Keywords:*** *fissure sealant, surface reaction-type pre-reacted glass ionomer filler, demineralization, remineralization*

J Clin Pediatr Dent 36(4): 343–348, 2012

## INTRODUCTION

The pits and fissures of immature permanent teeth are highly susceptible to tooth decay. Therefore, pit-and-fissure sealants are frequently used on such teeth to prevent occlusal caries.[1,2] A key factor for successful caries prevention by such materials is that the sealant should remain intact over time.

Resin composite is the most commonly used sealant material.[3-5] The caries-preventive effect of resin-based sealants depends on the sealing of pits and fissures through microretention in tags created by acid etching of enamel. Frequently, such sealants are used on teeth with early caries, appearing as a white spot. However, acid etching of these teeth easily destroys their enamel surface integrity, causing deep-seated caries and reducing the caries-preventive effect of the sealant.

Pre-reacted glass ionomer (PRG) technology has enabled the development of fissure sealants containing surface reaction-type PRG (S-PRG) fillers and bonded by self-etching primers. The glass ionomer phase comprises glass particles formed through the aqueous reaction of fluoroaluminosilicate glass with polycarboxylic acid. S-PRG fillers have recently been added to various dental materials,[6-10] and these materials are expected to effectively inhibit caries because of the fluoride-releasing and -recharging properties of the fillers.[6,11,12] However, studies establishing the caries-preventive effect of an S-PRG filler-containing fissure sealant have not yet been conducted.

The purpose of this *in vitro* study was to evaluate the caries-preventive effect of an S-PRG filler-containing fissure sealant bonded by self-etching primer versus those of 2 conventional resin-based sealants bonded by acid etching in terms of its impact on enamel demineralization and remineralization, enamel bond strength, and integrity of debonded enamel surfaces.

* Kisaki Shimazu, DDS, PhD, Department of Pediatric Dentistry, School of Life Dentistry at Tokyo, Nippon Dental University.

** Kiyokazu Ogata, DDS, PhD, Department of Pediatric Dentistry, School of Life Dentistry at Tokyo, Nippon Dental University; Division of Dentistry, Tokyo Metropolitan Children's Medical Center.

*** Hiroyuki Karibe, DDS, PhD, Department of Pediatric Dentistry, School of Life Dentistry at Tokyo, Nippon Dental University.

Send all correspondence to: K. Shimazu, Department of Pediatric Dentistry, School of Life Dentistry at Tokyo, Nippon Dental University, 1-9-20 Fujimi, Chiyoda-ku, Tokyo 102-8159, Japan

Phone : +81-3-3261-5823
Fax: +81-3-5216-3720

E-mail: kisaki-s@tky.ndu.ac.jp

## MATERIALS AND METHOD

Bovine incisors were used for the study. After confirming the absence of abnormalities on their labial enamel surface, such as discoloration or hypoplasia, the teeth were cut into blocks of 6 mm × 12 mm including the labial enamel. The enamel surface was smoothened by polishing, and whole blocks were covered with nail varnish at both ends, excluding the central area (3 mm × 12 mm; Figure 1). Each block was then placed in 40 ml of demineralizing solution containing 0.1 M lactic acid and 5% hydroxyethyl cellulose, prepared to pH 4.8 by using 10 M KOH, for 7 days at 37°C to create an enamel subsurface lesion in the central area.[13]

Thereafter, each block was cut into 4 specimens according to the type of sealant to be used (n = 4/group): BeautiSealant (BS) group (Shofu, Inc., Kyoto, Japan), Delton FS+ (DE) group (Dentsply Professional, York, PA, USA), Teethmate F-$1_{2.0}$ (TE) group (Kuraray Co., Ltd., Osaka, Japan), and uncoated (UN) group. Half of the enamel subsurface lesion area in each specimen was covered with nail varnish to serve as a control. Table 1 shows the main composition of these sealants and step-by-step instructions for their application.

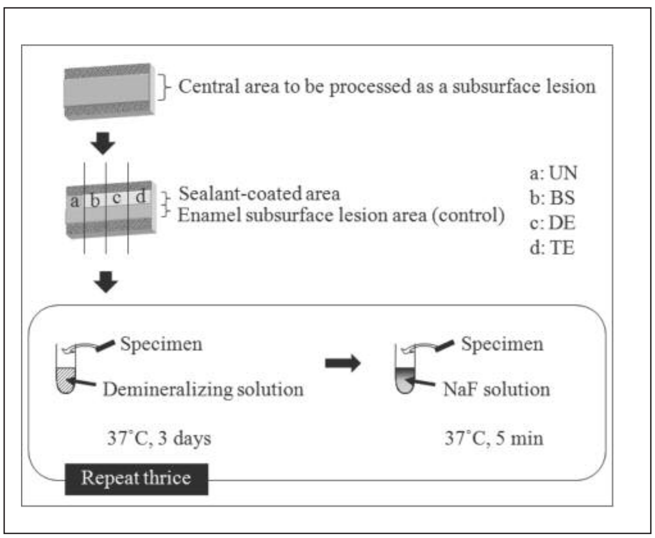


**Figure 1.** Flow diagram of the demineralization and remineralization experimental protocol
UN, uncoated; BS, BeautiSealant; DE, Delton FS+; TE, Teethmate F-$1_{2.0}$

**Table 1.** The pit-and-fissure sealants used in this study and systematic instructions for their application

| Sealant | Application steps |
|---|---|
| BS | Apply self-etching primer → leave for 5 s → air-blow → apply sealant → cure for 20 s |
| DE | Acid-etch → leave for 30–60 s → rinse → dry → apply sealant → cure for 20 s |
| TE | Acid-etch → leave for 40 s → rinse → dry → apply sealant → cure for 20 s |

Key: BS, BeautiSealant; DE, Delton FS+; TE, Teethmate F-$1_{2.0}$

### *Demineralization and remineralization experiment*

Each specimen was immersed in 5 ml of demineralizing solution (pH = 5.0) containing 0.1 M lactic acid, 0.1 M sodium lactate, 3 mM $CaCl_2$, 1.8 mM $KH_2PO_4$, and 5% hydroxyethyl cellulose for 3 days at 37°C. Thereafter, remineralization was initiated by using a cycle comprising 2 applications of NaF solution with 1000 ppm F and 1 application of NaF solution with 9000 ppm F for 5 min per solution (Figure 1). Before and after every application, each specimen was rinsed adequately with distilled water.[13]

### *Preparation and observation of sliced segments*

The treated specimens were dehydrated in ethanol and embedded in polyester resin (Rigolac; Nisshin EM, Ltd., Tokyo, Japan) after being soaked in and permeated by styrene monomer. They were each sliced into 3 polished sections (100 μm) by using a sectioning machine (IsoMet low speed saw; Buehler, Lake Bluff, IL, USA), including control, uncoated, and sealant-coated areas.

The demineralized and remineralized enamel surfaces were examined by polarizing microscopy (CX31-P; Olympus Corporation, Tokyo, Japan) and microradiography (soft X-ray generator M-100W; Softex Co., Ltd., Kanagawa, Japan) at 12 kV and 3 mA for 18 min. The lesion depth was measured with an image-analyzing software program (Scion Image; Scion Corporation, USA) by uploading images of the samples to a personal computer.[14]

### *Enamel bond strength measurement*

Bovine incisor blocks were embedded in polyester resin and their enamel surface was polished. The blocks were divided into 2 groups with different enamel conditions—the untreated enamel group and enamel subsurface lesion group—and the blocks in the latter group were exposed to demineralizing gel to create enamel subsurface lesions (following the preceding method). The blocks in each enamel condition group were then covered with tape excluding the experimental area (internal diameter = 4 mm) and divided into 3 sealant groups: BS group, DE group, and TE group. After adhesive application for each sealant on the experimental area, 10 specimens per sealant group were prepared by using a Teflon ring mold with an internal diameter of 4 mm and height of 2 mm. The sealant was placed in horizontal increments (2 layers) and each increment was separately light-cured by using a visible light-curing unit (Griplight II; Shofu, Inc.) After the tape and Teflon ring mold were removed, the specimens were stored in water at 37°C for 24 h.

The enamel bond strength of the sealants was tested in shear mode by using a knife-edge testing apparatus in a universal testing machine (Type 5543; Instron Corp., Canton, MA, USA) at a crosshead speed of 1.0 mm/min. The shear bond strength values (in MPa) were calculated from the peak load at failure divided by the specimen surface area.

### *Debonded enamel surface analysis*

The specimens were mounted and coated with osmium

(NEOC-AN osmium coater; Meiwafosis, Tokyo, Japan), and their debonded enamel surfaces were examined by scanning electron microscopy at 5.0 kV (S-4000; Hitachi, Tokyo, Japan).

***Statistical analysis***

The lesion depths among the 3 sealant groups were compared using the Kruskal–Wallis test. If a significant difference was found, a pair of lesion depths in the groups was tested with the Mann–Whitney *U*-test. As 3 pairwise planned comparisons were conducted, $p < 0.016$ was considered significant. One-way analysis of variance (ANOVA) was used to determine significant differences in enamel bond strength among the sealants (i.e., BS, DE, and TE groups) in the 2 enamel conditions (i.e., untreated enamel and enamel subsurface lesions). All analyses were performed with SPSS 15.0J for Windows (SPSS Japan, Inc., Tokyo, Japan).

## RESULTS

Figure 2 shows polarized light photomicrographs and microradiographs of each experimental group. In the UN group, the enamel surface was maintained and remineralization was observed in a number of layers according to the number of treatments; however, demineralization advanced significantly. In the BS group, the enamel surface was maintained and demineralization did not advance. On the other hand, in the DE and TE groups, enamel surface defects were noted. The mean (standard deviation [SD]) lesion depth was 0.0 (0.0), 0.0 (0.0), 19.8 (2.8), and 17.5 (1.6) µm in the UN, BS, DE, and TE groups, respectively. Significant differences in lesion depth were found in the BS group compared with the DE ($p = 0.014$) and TE ($p = 0.014$) groups.

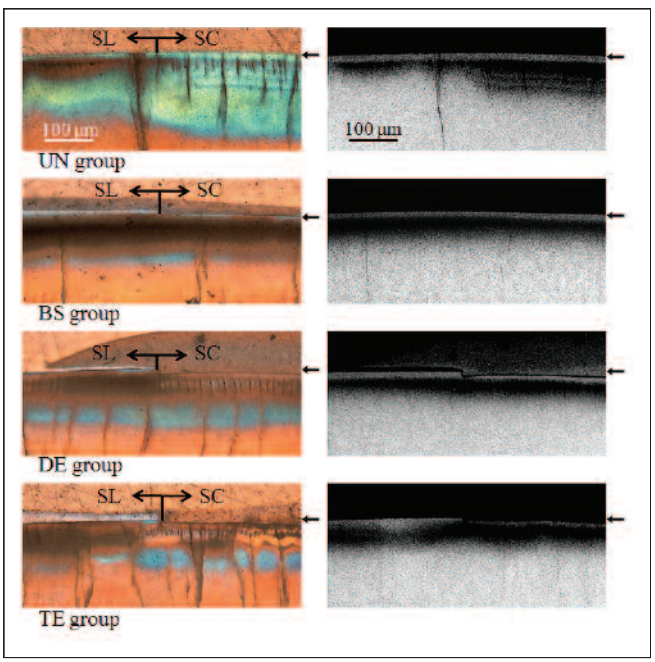


**Figure 2.** Post-treatment polarized light photomicrographs and microradiographs of the sealant groups

The enamel surface (arrow) is shown as an extension of the enamel subsurface lesion. SL, Enamel subsurface lesion area (control); SC, Sealant-coated area; UN, uncoated; BS, BeautiSealant; DE, Delton FS+; TE, Teethmate F-$1_{2.0}$

Table 2 lists the enamel bond strength values of each sealant group in the 2 enamel conditions. One-way ANOVA revealed no significant differences in enamel bond strength among the sealants in both the enamel conditions (untreated enamel: $p = 0.898$; enamel subsurface lesion: $p = 0.721$).

**Table 2.** Mean (SD) values of the enamel bond strength of each sealant in the 2 enamel conditions

| Sealant | Bond strength (MPa) | |
|---|---|---|
| | Untreated enamel | Enamel subsurface lesion |
| BS | 14.6 (5.6) | 12.0 (4.1) |
| DE | 14.5 (5.5) | 10.9 (2.8) |
| TE | 13.6 (5.1) | 10.9 (3.7) |

Key: BS, BeautiSealant; DE, Delton FS+; TE, Teethmate F-$1_{2.0}$

Figure 3 shows SEM images of the debonded enamel surfaces in the sealant groups according to the 2 enamel conditions. Rough surfaces of untreated enamel were observed in the DE and TE groups, but smooth surfaces of untreated enamel were observed in the BS group. Further, the debonded surfaces of the enamel subsurface lesions appeared similar to the debonded surfaces of untreated enamel in the BS group. However, the debonded surfaces of the enamel subsurface lesions were remarkably fractured in the DE and TE groups.

## DISCUSSION

Sealants protect pits and fissures from caries by preventing food and bacterial impaction.[15] Glass ionomer sealants can bond chemically to enamel without acid etching, but clinical studies have found the retention of such sealants to be significantly poorer than that of resin-based sealants. Moreover, the mechanical properties of glass ionomer sealants are reportedly inferior to those of resin-based sealants.[16-20] However, the procedure for resin-based sealant application involves placement of the etching material, waiting time, rinsing, and drying followed by sealant application and exposure to the curing light. These time-consuming steps increase the risk of saliva contamination during the procedure, which may have a deleterious effect on bonding if it occurs after etching.[21,22] Consequent microleakage and gaps may result in the formation of secondary caries around the sealed fissure.

In this study, the caries-preventive effects of an S-PRG filler-containing sealant bonded by self-etching primer and those of 2 conventional resin-based sealants bonded by acid etching on enamel subsurface lesions were compared. Acid etching of the enamel subsurface lesions created a defect on the enamel surface and significantly increased the lesion depth; moreover, the debonded enamel surface was remarkably fractured. On the other hand, application of the self-etching primer on the enamel subsurface lesions maintained

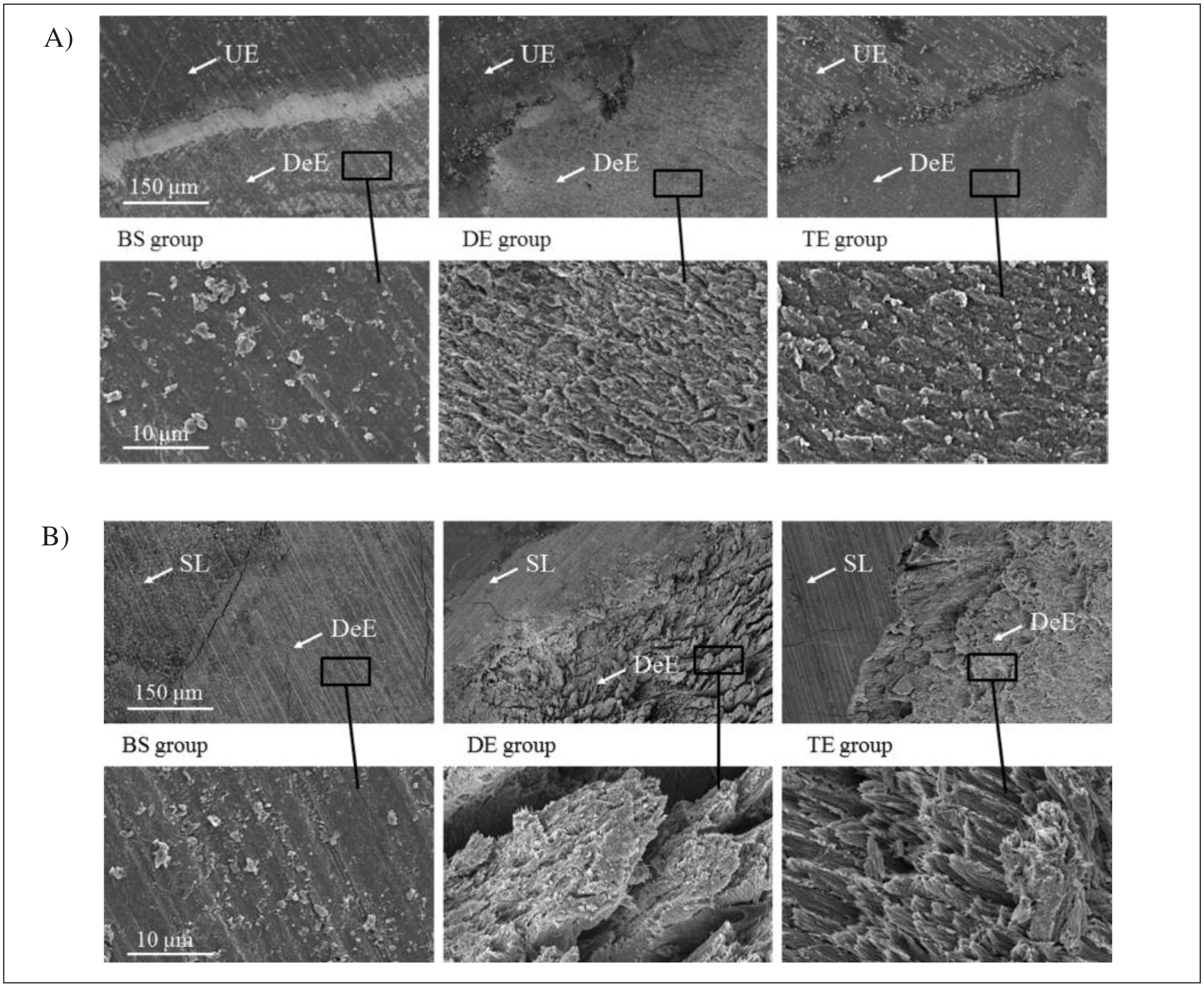


**Figure 3.** SEM images of debonded enamel surfaces in the sealant groups The effects on (a) untreated enamel and (b) enamel subsurface lesions are shown. Upper panels, low-magnification (×200) views of the specimens; lower panels, high-magnification (×3000) views of the debonded enamel surfaces. UE, untreated enamel area (control); DeE, debonded enamel area; SL, enamel subsurface lesion area (control); BS, BeautiSealant; DE, Delton FS$^{+}$; TE, Teethmate F-1$_{2.0}$



the integrity of both the treated enamel surface and the debonded enamel surface.

With regard to the bonding of resin-based sealants, self-etching adhesive application is reported to be equally effective as acid etching in preventing secondary caries formation when applied on saliva-contaminated enamel and less effective when applied on uncontaminated enamel.[23] However, in the present study, the sealant bonded by self-etching primer showed an excellent preventive effect on demineralization compared with the conventional resin-based sealants. Furthermore, the enamel bond strength values of the sealants were not significantly different on both untreated enamel and enamel subsurface lesions. These findings suggest that an S-PRG filler-containing sealant bonded by self-etching primer can prevent microleakage and gaps without the tags created by acid etching.

On the basis of the present results, a fissure sealant containing S-PRG filler and bonded by self-etching primer can inhibit enamel demineralization regardless of the enamel condition. S-PRG fillers release several types of ions into distilled water or lactic acid solution, such as Sr, B, Na, Al, and Si ions,[24,25] implying that a sealant containing S-PRG filler can release and recharge fluoride.[26] A long-term follow-up study is necessary to confirm the remineralization-promoting effect of fissure sealants containing S-PRG fillers.

## CONCLUSIONS

A fissure sealant containing S-PRG filler and bonded by self-etching primer can prevent enamel demineralization regardless of the enamel condition and maintain the integrity of debonded enamel surfaces. Furthermore, such a sealant has enamel bond strength similar to that of the conventional resin-based fissure sealants. Therefore, it is suitable for protecting the pits and fissures of immature permanent teeth.

## REFERENCES


1. Takeuchi M , Kizu T. Sealing of the pit and fissure with resin adhesive. I. Results of sealing on extracted teeth. Bull Tokyo Dent Coll, 7: 50–59, 1966.
2. Handelman SL, Leverett DH, Espeland M, Curzon J. Retention of sealants over carious and sound tooth surfaces. Community Dent Oral Epidemiol, 15: 1–5, 1987.
3. Adair SM. The role of sealants in caries prevention programs. J Calif Dent Assoc, 31: 221–227, 2003.
4. Feigal RJ. The use of pit and fissure sealants. Pediatr Dent, 24: 415–422, 2002.
5. Simonsen RJ. Pit and fissure sealant: review of the literature. Pediatr Dent, 24: 393–414, 2002.
6. Han L, CV E, Li M, Niwano K, Ab N, Okamoto A, Honda N, Iwaku M. Effect of fluoride mouth rinse on fluoride releasing and recharging from aesthetic dental materials. Dent Mater J, 21: 285–295, 2002.
7. Han L, Okamoto A, Fukushima M, Okiji T. Evaluation of a new fluoride-releasing one-step adhesive. Dent Mater J, 25: 509–515, 2006.
8. Itota T, Carrick TE, Rusby S, Al-Naimi OT, Yoshiyama M , Mccabe JF. Determination of fluoride ions released from resin-based dental materials using ion-selective electrode and ion chromatograph. J Dent, 32: 117–122, 2004.
9. Mukai Y, Tomiyama K, Shiiya T, Kamijo K, Fujino F, Teranaka T. Formation of inhibition layers with a newly developed fluoride-releasing all-in-one adhesive. Dent Mater J, 24: 172–177, 2005.
10. Mukai Y, Kamijo K, Fujino F, Hirata Y, Teranaka T, Ten Cate Jm. Effect of denture base-resin with pre-reacted glass-ionomer filler on dentin demineralization. Eur J Oral Sci, 117: 750–754, 2009.
11. Itota T, Carrick TE, Yoshiyama M, Mccabe JF. Fluoride release and recharge in giomer, compomer and resin composite. Dent Mater, 20: 789–795, 2004.
12. Kamijo K, Mukai Y, Tominaga T, Iwaya I, Fujino F, Hirata Y , Teranaka T. Fluoride release and recharge characteristics of denture base resins containing surface pre-reacted glass-ionomer filler. Dent Mater J, 28: 227–233, 2009.
13. Ogata K, Warita S, Shimazu K, Kawakami T, Aoyagi K , Karibe H. Combined effect of paste containing casein phosphopeptide-amorphous calcium phosphate and fluoride on enamel lesions: an in vitro pH-cycling study. Pediatr Dent, 32: 433–438, 2010.
14. Inaba D, Takagi O , Arends J. A computer-assisted videodensitometric method to visualize mineral distributions in in vitro and in vivo formed root caries lesions. Eur J Oral Sci, 105: 74–80, 1997.
15. Wendt LK, Koch G , Birkhed D. On the retention and effectiveness of fissure sealant in permanent molars after 15-20 years: a cohort study. Community Dent Oral Epidemiol, 29: 302–307, 2001.
16. Nunn JH, Murray JJ, Smallridge J. British Society of Paediatric Dentistry: a policy document on fissure sealants in paediatric dentistry. Int J Paediatr Dent, 10: 174–177, 2000.
17. Welbury R, Raadal M , Lygidakis NA. EAPD guidelines for the use of pit and fissure sealants. Eur J Paediatr Dent, 5: 179–184, 2004.
18. Mejare I , Mjor IA. Glass ionomer and resin-based fissure sealants: a clinical study. Scand J Dent Res, 98: 345–350, 1990.
19. Forss H, Saarni UM, Seppa L. Comparison of glass-ionomer and resin-based fissure sealants: a 2-year clinical trial. Community Dent Oral Epidemiol, 22: 21–24, 1994.
20. Boksman L, Gratton DR, Mccutcheon E, Plotzke Ob. Clinical evaluation of a glass ionomer cement as a fissure sealant. Quintessence Int, 18: 707–709, 1987.
21. Johnson WW, Armanazi Y, Sharp H. Sealant leakage with and without isolation. J Tenn Dent Assoc, 77: 32–34, 1997.
22. Xie J, Powers JM, Mcguckin RS. *In vitro* bond strength of two adhesives to enamel and dentin under normal and contaminated conditions. Dent Mater, 9: 295-299, 1993.
23. Seemann R, Kluck I, Bizhang M, Roulet JF. Secondary caries-like lesions at fissure sealings with Xeno III and Delton—an in vitro study. J Dent, 33: 443–449, 2005.
24. Fujimoto Y, Iwasa M, Murayama R, Miyazaki M, Nagafuji A , Nakatsuka T. Detection of ions released from S-PRG fillers and their modulation effect. Dent Mater J, 29: 392–397, 2010.
25. Ito S, Iijima M, Hashimoto M, Tsukamoto N, Mizoguchi I, Saito T. Effects of surface pre-reacted glass-ionomer fillers on mineral induction by phosphoprotein. J Dent 2011; 39: 72–9.
26. Shimazu K, Ogata K, Karibe H. Evaluation of the ion-releasing and recharging abilities of a resin-based fissure sealant containing S-PRG filler. Dent Mater J, 30(6): 923–927, 2011.