Comparison of resin-based and glass ionomer sealants with regard to fluoride-release and anti-demineralization efficacy on adjacent unsealed enamel

Thwe Zin EI, Yasushi SHIMADA, Syozi NAKASHIMA, Maria Jacinta Rosario H. ROMERO, Yasunori SUMI and Junji TAGAMI

INTRODUCTION

Application of sealants is one of the most effective methods of preventing dental caries in high-risk children and young adults. The sealant forms a protective layer on the tooth structure that prevents metabolic exchange between the fissure micro-organisms and oral environment. The American Dental Association has recommended resin based sealants as the gold standard for sealing pits and fissures because of their superior retentive properties compared with glass ionomer sealants. However, the latter may be considered as a suitable alternative when adequate tooth isolation is difficult.

The current literature on the preventive effects of sealants varies considerably. Some studies have reported that the anti-cariogenic effects of glass ionomer sealants are equal to those of resin sealants that do not contain fluoride. Conversely, Mejare and Mjor reported that the preventive activity of glass ionomers surpassed that of the latter because of its greater capability to release fluoride. It is a well-known fact that fluoride prevents the initiation and progression of caries by forming fluoridated apatite. Although retention is a critical factor for sealants, in clinical practice, incomplete sealing often goes unnoticed despite good retention in the tooth. This favors biofilm accumulation that might lead to subsequent caries formation, particularly in high-risk patients. Therefore, incorporation of fluoride in sealants has been suggested as a viable option for caries prevention through the potential of fluoride released from materials that help to inhibit demineralization in the adjacent enamel. However, it is still unclear whether the fluorides released from resin-based sealants provide any additional clinical benefits.

Previous in vitro studies examining fluoride release have used water or purely inorganic artificial saliva and polarized light microscopy to qualitatively evaluate the adjacent enamel. They reported that materials releasing larger quantities of fluorides exhibited greater inhibition of demineralization. However, Carvalho et al. reported that increasing quantities of fluoride released by varnishes did not demonstrate any preventive effects on tooth demineralization. Therefore, the effectiveness of fluoridated materials against caries and what data that have been obtained are somewhat contradictory. Glass ionomer sealants have been well known as rechargeable reservoirs rather than resin sealants, delivering fluoride from exogenous sources. But it was reported that their recharging ability declines with maturation and still there is no information on efficacy of long term fluoride concentration released from glass ionomer excluding the influence of other F sources.

Optical coherence tomography (OCT) is a newly developed, non-invasive, cross-sectional, real-time
imaging tool that has been widely used for the non-destructive assessment of enamel and dentine demineralization, as well as the interfacial adaptation of sealant and restorative materials. Quantitative measurement of light propagation in tissues, measured as the attenuation coefficient ($\mu$) parameter in OCT, has shown promising results with regard to its ability to discriminate between sound and demineralized tooth structures. We believe that OCT may also be useful for clinically assessing the inhibitory effects of sealants on the demineralization of adjacent unsealed enamel surfaces.

Therefore, this study examined the degree of demineralization in the adjacent unsealed enamel surfaces using OCT, and the quantitative findings were associated with nano-mechanical hardness measurements. The nanoindentation technique has been reported to be superior to conventional hardness tests with regard to its ability to examine the local mechanical properties of materials because of its high resolution of force and accurate indent positioning. This technique has been employed in assessing the mechanical behavior of erosion, demineralization, and remineralization of tooth structures.

Therefore, the purposes of this study were to compare the behavior of fluoride release over time (incubation periods) and anti-demineralization effects of two resin-based sealants and a glass-ionomer sealant on adjacent unsealed enamel when fluoride releasing level of all the sealants become constant. The anti-demineralization effects were examined through optical assessment using SS-OCT and micromechanical assessment using nanohardness test.

### MATERIALS AND METHODS

#### Preparation of specimens

The labial surfaces of 20 freshly extracted bovine incisors were cut into two enamel blocks (width x length x depth: 7 x 7 x 2 mm$^3$) using a low-speed diamond saw (Isomet, Buehler, Lake Bluff, IL, USA). Flat enamel surfaces were created by removing the rough enamel surface (approximately 200–300 µm) with silicon-carbide (SiC) paper (grit size ranging from #600 to #2000). Simplified sealant cavities (2 x 2 x 0.5 mm$^3$) were then prepared using a regular diamond bur (461R, Shofu, Kyoto, Japan) attached to a high-speed air turbine under water cooling. The preparation was monitored under OCT to ensure standardization of the cavity preparations, and to ensure similar volume and surface area for both sealing materials. The specimens were then randomly distributed into 4 groups (Table 1; 10 per group). The materials tested in this study included two resin sealants containing fluoride (Teethmate F-1 (TF), and Clinpro™ (CP)), and a glass ionomer sealant (Fuji VII (FVII)). The control group (C) used a one-step self-etch bonding agent.

### Table 1  Materials used in this study

<table>
<thead>
<tr>
<th>Material (Abbreviation)</th>
<th>Manufacturer</th>
<th>Composition</th>
<th>Procedure</th>
</tr>
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<tbody>
<tr>
<td>(C) G bond Plus, GC, Tokyo, Japan</td>
<td></td>
<td>Phosphoric acid ester monomer, 4-META, dimethacrylate, water, acetone, nano-silica filler, Photoinitiator</td>
<td>Apply one bottle of agent for 10 s, air-dry aggressively for 10 s, and light cure for 10 s.</td>
</tr>
<tr>
<td>Estelite flow Quick, Tokuyama Dental, Tokyo, Japan</td>
<td></td>
<td>Bis-MPEPP, UDMA, TEGDMA, Photoinitiator, SiO$_2$-ZrO$_2$</td>
<td>Apply composite resin and light cure for 20 s.</td>
</tr>
<tr>
<td>(TF) Teethmate F-1 Sealant, Kuraray Noritake, Osaka, Japan</td>
<td></td>
<td>MDP, MF-MMA, TEGDMA, HEMA, dimethacrylate</td>
<td>Etch the enamel for 15 s using 40% phosphoric acid gel (K etchant-kurary). Rinse thoroughly with water for 15 s and air dry. Apply sealant and light cure for 20 s.</td>
</tr>
<tr>
<td>(CP) Clinpro™ Sealant, 3M ESPE, St.Paul, MN, USA</td>
<td></td>
<td>Bis-GMA,TEGDMA, EDMAB, CPQ, TiO$_2$, amorphous silica, Tetrafluoroborate</td>
<td>Etch the enamel for 15 s using 40% phosphoric acid gel (K etchant-kurary). Rinse thoroughly with water for 15 s and air dry. Apply sealant and light cure for 20 s.</td>
</tr>
<tr>
<td>(FVII) GC Fuji VII, GC</td>
<td></td>
<td>Fluoroaluminosilicate glass, Polyacrylic acid</td>
<td>Apply GC cavity conditioner for 10 s. Rinse thoroughly with water spray for 10 s and air-dry. Apply FVII mixture, and then apply GC Fuji varnish.</td>
</tr>
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adhesive that did not contain fluoride (G bond plus) and a flowable composite resin (Estelite flow-quick). The composition and application procedures used in the different groups have been described in Table 1. Following polymerization, each specimen was again gently polished with #2000 grit SiC paper and sonicated for 1 min to remove any excess material on the enamel surface. The specimen surfaces were then coated with an acid resistant nail varnish (Revlon, New York City, NY, USA), leaving 2 mm of peripheral area around the margins of the cavity.

Measurement of released fluoride
Each specimen was immersed in a polyethylene tube containing 0.5 mL of AS solution (pH=6.3) containing 1 mM CaCl₂, 3 mM KH₂PO₄, 100 mM NaCl, 100 mM Na acetate, 0.02% NaN₃, and the salivary phosphoprotein homologue Casein 100 µg/mL. The specimens were stored in an incubator with a constant temperature of 37°C, and transferred to new tubes containing fresh solution every 2 days for 14 days. The released fluoride concentration was measured every 2 days using an ion meter (F-53, Horiba, Kyoto, Japan) attached to fluoride-specific electrodes and reference electrodes (2060A and 8010, respectively; Horiba) that had been calibrated using standard 0.05, 0.1, 0.5, 1, 5, and 50 ppm fluoride solutions. Prior to measurement, TISAB II (Orion Research, Cambridge, MS, USA) was added to each solution to a 10% concentration and the F electrode readings for each sample solution was recorded and converted to ppm concentration. The final results were reported as released fluoride amount (µg/cm²), taking into account the surface area and the solution volume for each specimen.

Optical assessment of demineralization by OCT imaging and quantitative analysis
Swept-Source OCT (SS-OCT) (IVS-2000, Santec, Komaki, Japan) was used to capture baseline images of the specimens after 14 days of incubation in AS and completion of fluoride-release measurements. All the specimens were then individually immersed in 1.5 mL of demineralizing solution (0.05 mol/L acetic acid, 0.1 mol/L KCl, pH 4.8, 37°C) for 5 days, after which the solution was replaced and the process was repeated. SS-OCT imaging was performed after each demineralization interval. This OCT system utilizes a high-speed frequency-swept external cavity laser with a center wavelength of 1,310 nm and a rate of 20-kHz. The axial and lateral optical resolutions in air were 12 and 20 µm, respectively. The details of this system have been described elsewhere[16,17].

The specimens were washed with deionized water under controlled hydrated conditions at each scanning time-point. Thereafter, the surfaces were blot dried using a cotton pellet so as to leave the surface moist but with no visible water droplets. They were then fixed on a micrometer metal stage and cross-sectional images were recorded at the center of the sealant in each specimen. Raw OCT data, 2,000×1,000 pixels corresponding to 7×7.48 mm for each cross-section, were imported to ImageJ software (National Institutes of Health, Bethesda, MD, USA), and a noise reducing median filter (size 2) was applied to the data. The region of interest (ROI; width×optical depth: 500×400 µm), extending from the surface of the enamel to deeper levels adjacent to the sealant, was selected, converted to a signal-intensity depth profile, and µt values were recorded for each average signal-intensity profile, as described in previous studies[18-20]. The ∆µt value of the specimen for each demineralization interval was calculated as follows:

$$\Delta \mu_t = [\mu_t \text{of each demineralization interval}] - [\text{baseline } \mu_t \text{after 14-day incubation}]$$

where a lower ∆µt value indicates a lower degree of demineralization.

Mechanical assessment of demineralization by nanohardness test
The five specimens were embedded in epoxy resin (EpoxiCure, Buehler) after OCT imaging, and each specimen was cut cross-sectionally using Isomet in the same area where the OCT imaging was carried out. The surface of interest was polished using SiC papers (ascending grit size ranging from #1000 to #2000 grits), followed by diamond slurries with particle sizes ranging from 6 to 0.25 µm in an automatic lapping machine (Maruto, Tokyo, Japan) so as to make them smooth and parallel for the nanoindentation test. Sound untreated enamel surfaces were also prepared and measured as a reference for normal bovine enamel hardness.

The nanohardness profile of the 200 µm (lateral and axial dimension) demineralized area adjacent to the sealant cavity was recorded with a nanoindentation device (ENT-1100a, Elionix, Tokyo, Japan). The maximum load was 3 mN at a loading rate of 0.2 mN/s and 1 s holding segment with a Berkovich diamond
tip. The first line of indentation was created below the visible enamel border. Each row included 20 points, with lateral and axial spacing of 10 µm between two neighboring points for the first 110 µm depth, 40 µm spacing for the next row, and 50 µm spacing for the subsequent rows up to 200 µm in depth (Fig. 1).

The data was analyzed using a nanoindentation software, and the hardness was calculated by dividing the maximum load (F) by the area projected under the load (Ap), according to the equation: H = F/Ap (h), where (h) is a function of indent penetration depth into the substrate. Integrated nanohardness (INH) was calculated for the whole lesion up to a depth of 200 µm (Fig. 1).

Statistical analysis
Two-way Repeated Measures ANOVA were performed to compare the interaction between the type of materials for each time point in fluoride release. In order to assess significant differences within these factors and the cumulative fluoride release after 14-day incubation between groups, one-way ANOVA with Tukey’s test was applied. Two-way ANOVA for ∆µt between groups at different demineralizing intervals and one-way ANOVA for comparison of INH values between groups were used with Tukey’s post-hoc test respectively. The relationship between µt and INH for each specimen was examined using Pearson’s correlation test. All statistical analyses were performed using a statistical software (SPSS Ver.11 for Windows, SPSS, Chicago, IL, USA) (α=0.05).

RESULTS

Released fluoride
Figure 2 plots the fluoride concentration pattern of sealants between each tested period. Repeated measures ANOVA revealed the significant differences in fluoride concentration among the sealants with different time points (p<0.05). For all the sealant, the greatest amount of fluoride released was at the first measurement after
day 2 and the highest from FVII followed by TF and CP. FVII showed significant difference in fluoride released among the groups on all incubation days \((p<0.05)\). Though fluoride released from FVII declined rapidly after day 2, it continued until the entire test whereas that from TF and CP became no significant in fluoride release from day 4 until the tested periods \((p>0.05)\).

The amount of fluoride release varied depending on the material and there was a significant difference in the cumulative amount of fluoride released after 14 days in all sealant groups, with the highest amount observed in the FVII group \((69.5\pm12\ \mu g/cm^2)\), followed by the TF \((7.26\pm2.13\ \mu g/cm^2)\) and CP \((3.94\pm0.9\ \mu g/cm^2)\) groups. No fluoride was released in the control group.

**Anti-demineralization assessment by SS-OCT**
Representative OCT images of demineralized enamel lesions from each group are shown in Fig. 3. The reflectivity of each sealant in the OCT images varied with the composition of the tested materials. In 70% of TF specimens, demineralization was accompanied by a decrease in reflectivity in the area adjacent to the sealant up to a level approximately equal to the reflectivity of sound enamel, and this area can be referred to as the protected zone (Figs. 3c, 3c', 3c''). Conversely, all other sealant materials exhibited higher reflectivity in the adjacent enamel surface, suggesting demineralization of the enamel substrate (Fig. 3).

The average \(\Delta \mu_t\) of all groups are presented in Fig. 4. The two-way ANOVA revealed a significant interaction between sealant and demineralization days, and both factors significantly influenced the \(\Delta \mu_t\) \((p<0.05)\). Upon comparison with Tukey’s post-hoc analysis, we observed a significant difference in \(\Delta \mu_t\) in the TF group compared with the other groups at the 5-day demineralization period, while no significant differences were observed between the other groups (FVII and CP, CP and Control). No significant differences in \(\Delta \mu\) were observed between the FVII, CP, and control groups after 10 days of demineralization. TF showed the lowest \(\Delta \mu\) amongst all the groups on both demineralization days \((p<0.05)\).

**Nanoindentation**
The overall mean hardness profiles of all tested groups have been shown in Fig. 5a. Apparently the highest hardness value immediately beneath the enamel surface was seen in the FVII group, while the hardness value of TF was lower than that of FVII at a depth of around 5 \(\mu m\), although this rapidly increased to the level of sound enamel and then remained constant. Among the tested sealants, CP showed the lowest hardness value in the superficial enamel, but this too increased after a
fluoride level in the methodologies used, specimen sizes, frequency of variations in the results can be attributed to differences in the fluoride released by different dental materials. Although several studies have measured the amount of fluoride released12,26,31), the variations in the results can be attributed to differences in the methodologies used, specimen sizes, frequency of renewal, and quality of storage media used to measure fluoride level20).

In the present study, bovine teeth were employed instead of human teeth. Bovine teeth have more uniform composition and high level of porosity even though quite similar in mineral content and constituents of human teeth27). These properties can provide less variable response to demineralization and remineralization experiments with relevant information similar to human teeth. The specimens were incubated in a newly developed AS that contained casein to better simulate the human salivary composition. The role of salivary proteins in controlling fluoride availability has been investigated in vivo28,29) and overlooking the effects of these proteins may yield results that are not congruent with the remineralization phenomenon observed in subsurface enamel lesions in vivo28). It was also recently reported that casein can mimic the mineral regulatory functions of salivary phosphoproteins, such as stabilization of supersaturation of AS regardless of presence and absence of F− in AS, and inhibition of unwanted apatite crystals growth as well as superficial fluoridated apatite precipitation on sound enamel; which will never happen in vivo situation24). If the superficial fluoridated apatite precipitation on sound enamel take place, it may inhibit further incorporation of fluoride into enamel during 14-days incubation in this study. Therefore, the AS containing salivary phosphoprotein homologue, casein, which may provide the result of fluoride release behavior, fluoride incorporation into enamel and anti-demineralization efficacy similar to those achieved by in vivo situation in this study design.

Although the results of this study showed a quantitative difference in the amount of fluoride released among the tested materials, the pattern of release was similar to other studies where an initial rapid release was followed by a slow and long lasting pattern of release9,10,31). FVII exhibited the highest amount of fluoride release, and this was in agreement with other studies9,10,31).

The high fluoride release from FVII may be due to the fact that ionomer is more porous than resinous sealants, and this may have a great influence on the amount of fluoride released10,26). Moreover, the observation that the highest levels of fluoride release on the first day of measuring may be caused by a superficial rinsing effect resulting from an initial burst of fluoride released from the glass particles as they dissolved in the polyacrylic acid during the setting reaction. This pattern then becomes constant over the following days, possibly because of the slower dissolution of glass particles into the acidified water of the hydrogel matrix20).

Conversely, TF contains an organic fluoride compound chemically bound to resin (MF-MMA), wherein the covalently bound fluoride is hydrolyzed and its release is facilitated by anion diffusion/exchange mechanisms11,20). We assumed that CP releases fluoride ions in two steps, where the first occurs because of ionic separation into tetrabutylammonium cation and tetrafluoroborate anion and the second is a result of slower hydrolysis of tetrafluoroborate that causes release of ionized fluoride (F−) from the tetrafluoroborate.

The anti-demineralization potential of each material on the adjacent unsealed enamel was also evaluated by OCT and nanoindentation measurements, and compared with their fluoride release. In the OCT images, the demineralized areas appeared as intense scattering zones with high reflectivity from the lesion surface, and the reflectivity decreased just beneath the lesion. This can be interpreted as the lesion boundary (Fig. 3). Stronger demineralization revealed higher μ values18,20).

\[ y = -0.0015x + 2.0359 \]
\[ R^2 = 0.7719 \]

Fig. 6 Pearson's correlation between µ and INH (p<0.001, r=−0.879, 95% CI: −0.951~−0.715) with linear regression (R2=0.77).
To substantiate the optical findings, nanohardness measurements were employed to evaluate demineralization hardness at a large depth. Good correlation was found between the OCT findings and hardness parameters (Fig. 6). This finding suggests that OCT may be useful in assessing the anti-demineralization efficacy of sealants in the clinical setting.

The TF group exhibited the lowest ∆µ, in both demineralization intervals, suggesting the least demineralization. This was consistent with the presence of a demineralization resistant zone on the adjacent enamel in the OCT images. The hardness values for TF reached the value for sound enamel after a few micrometers, and presented the highest INH among the groups. In this study design, fluoride-release was monitored in the presence of an enamel substrate that underwent pre-treatment with acid etching prior to sealant application. Etching sound enamel with 37% phosphoric acid for 15 s removes approximately 3 µm of enamel tissue, exposes the enamel prisms, and affects demineralization up to a depth of 50 µm[32,33]. In TF, 40% phosphoric acid was used and, therefore, the enamel surface was probably demineralized more or less to a similar extent. It has been reported that fluoride uptake in acid etched enamel is approximately five times greater than in sound enamel[34]. Therefore, although measurable fluoride from TF during incubation periods is low (the mean concentration: 0.37 ppm on day 2, 0.019 ppm on day 14), it can be speculated that most of the released fluoride have been incorporated into adjacent demineralized enamel and enhanced acid resistance. Margolis et al. also reported that even low concentrations of fluoride (0.004–1 ppm) incorporated in AS was able to inhibit demineralization, depending on the concentration[35]. Moreover, TF contains an organic fluoride compound chemically bound to resin (MF-MMA) and hydrolyzed MF-MMA might release only ionized F⁻ and it was assumed that there would be no influence of other ions in their release[36]. Only ionized F⁻ released from TF would facilitate easily uptake of the F⁻ by unsealed enamel during incubation period. Tanaka et al. also reported that the fluoride released from MF-MMA copolymer sealants is tightly bound in enamel, thereby protecting the enamel from caries attack in vivo[37].

In addition to fluoride release and uptake by adjacent enamel, TF contains 10-methacryloyloxydecyl dihydrogen phosphate (MDP) monomer which forms acid-resistant calcium-MDP complexes on the enamel surface[38]. These complexes may also have contributed to the superior anti-demineralization efficacy of TF. In addition, low viscosity resin sealant, TF, had been reported in resin infiltration to acid etched enamel approximately 15 µm in width[39]. This thin layer of infiltrated resin could synergistically increase the demineralization resistance of adjacent enamel with fluoride.

CP group was similarly treated by TF group by 40% H₃PO₄, thus the released fluoride was expected to be incorporated into the acid treated enamel and considerable anti-demineralization efficacy. However, the CP group in terms of ∆µ, showed no significant difference compared to the control group. This is probably due to very low concentration of released fluoride (the mean: 0.12 ppm on day 2, 0.017 ppm on day 14), resulting in less amount of the fluoride incorporation into the acid treated enamel. In other word, the anti-demineralization efficacy by the incorporated fluoride may be less effective than increased solubility by acid pretreatment with 40% H₃PO₄. Nevertheless, the nanohardness profile of CP revealed better acid resistance in the deeper enamel, and its INH was significantly higher than that of the control group. This contradictory finding of OCT infers there may be some limitation to evaluate degree of demineralization by attenuation coefficient parameter which is based in nonlinear curve fits, with higher mathematical complexity[40].

Despite having the highest amount of fluoride (1.98 ppm on day 2, 0.38 ppm on day 14) among the tested groups, FVII did not exhibit a higher anti-demineralization effect than TF and CP. Fluoride release in FVII is accompanied by other ions, namely aluminum, calcium and strontium[41]. Among them, aluminum is known to have strong affinity to F⁻ with forming Al-F complex and reduces the levels of free fluoride ions (F⁻)[42]. Fluoride action on the efficacy of anti-demineralization and promotion of remineralization is based on availability of F⁻ in de- and remineralization fluids (plaque and saliva)[41,42]. Although total high fluoride concentration of FVII was measureable with dilution of de-complexing agent TISAB, it can be speculated that the efficacy of F⁻ might be low during 14-day incubation and also 10-day acid attack period in FVII group due to influence of the released aluminum ions.

A previous in vivo study reported that, along with superficial fluoride uptake in the outer 2 µm enamel layer from a glass ionomer adhesive, traces of aluminum were also detected in the superficial enamel area when examined by energy-dispersive X-ray microanalysis. They also revealed the lack of any fluoride uptake in the deeper enamel after 6 months in the oral cavity[43]. This finding corroborates the results of the current study wherein FVII exhibited the highest average nanohardness in the superficial layer of the enamel, but this decreased in the deeper layers compared with the resin sealants. The hardness, however, was comparable to that of sound enamel at a depth of 200 µm, as shown in Fig. 5a.

Knight et al. reported strontium incorporation into dentine by applying FVII[44]. Interest in the release of strontium from modern glass ionomer materials have been increased[45]. But this study did not perform the analyses of aluminum and strontium in AS and demineralization solution. Strontium and fluoride has been suggested to improve the crystallinity of carbonated hydroxyapatite which is very similar to enamel, but their cariostatic properties, predominantly in the presence of fluoride has still not clear[46].

Although this study did not measure the fluoride
concentration in the demineralization solution, one must take into consideration the possibility of enhancing fluoride release from the materials tested when the materials are exposed to acid which may enhance hydrolysis of fluoride component in the materials. This may partly explain the difference in the anti-demineralization efficacy among the materials. Currently, there are no standardized protocols for monitoring fluoride-release by dental sealants. Unlike others studies, the demineralization resistance potential was tested when fluoride releasing level of all the sealants become constant without external fluoride recharging. As was demonstrated in this study, the amount of fluoride released from a material should not be the only factor considered when determining the potential protective benefits of different sealant materials to tooth structure. In case of glass ionomer cement, the role fluoride recharging properties may play an important role in caries prevention rather than released fluoride itself present in the material. Long term slow release of fluoride from resin sealants may additionally protect the adjacent enamel in combined with high retentive and adhesive potential of resinous materials3,4. Within the limitations of this study, anti-demineralization effect of resin sealants on adjacent unsealed enamel was comparable with a glass ionomer sealant but it is too hasty to conclude with the released amount of fluoride alone. Further clinical study still need to evaluate the clinical longevity of fluoride sealants, and their cariogenic potential.

CONCLUSION

Within the present study’s limitations, our results demonstrated that the glass ionomer sealant released the highest fluoride concentration during tested periods. Resin based sealant (TF) exhibited the effective protection in adjacent unseal enamel from acid demineralization over the glass ionomer sealant. Low concentrations of fluoride released from resin sealants may provide comparable anti-demineralization effect on adjacent unsealed surfaces with the glass ionomer sealant.

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