INTRODUCTION

Dental caries usually occurs at early ages, but its risk remains throughout the entire life of natural dentition among various populations. In simple terms, caries is the result of tooth demineralization by acids that are produced through bacterial metabolism of sugars, and diffuse into enamel and dentin. Caries is a multifactorial disease process, and the tooth surface is only one of the involving factors. Destruction of the tooth surface is initiated by loss of minerals due to a localized shift in the dynamic balance between demineralization and remineralization of the highly mineralized enamel tissue. If the process is not arrested or reversed in the early stage, substantial loss of minerals from enamel eventually leads to surface break down of the lesion (known as cavitation)\(^1\). Emerging concepts in caries management, which are aimed at promoting the health rather than repairing cavities, involve preventive strategies as well as new approaches to protect the teeth against caries\(^2\).

In addition to caries, mechanical and chemical loss of dental hard tissue has been considered as a matter of concern. The prevalence and severity of dental erosion have increased significantly in the recent years\(^3,4\). Tooth erosion is defined as the loss of mineral substrate by intrinsic acids from the backflow of the gastric contents through the mouth or extrinsic acids such as acidic drinks and foods where the damage is more frequently located on the cervical third of the buccal surface of anterior teeth\(^5\). Moreover erosive tooth wear will happen as the accelerated loss of dental hard tissue through the combined effect of erosion and mechanical wear (abrasion and attrition) on the tooth surface. Without intervention, such wear will progress as cuspal cupping with exposed dentin and eventually lead to loss of occlusal morphology\(^6\).

Physical coverage of the tooth surface has been considered as one of the ways to protect teeth against caries and erosion. Pit and fissure sealants have been well known to decrease the incidence of caries, with a substantive amount of evidence\(^6,7\). It has also been suggested that extended enamel surface sealing by appropriate coating materials can potentially provide the benefits of physical protection, especially for interproximal surfaces\(^8,9\) and smooth buccal coronal sites, and in high-risk patients such as orthodontic patients\(^10,11\), special-needs or handicapped patients and the elderly. A clinical study showed that up to 75 percent of patients undergoing fixed appliance therapy were affected by...
decalcification of tooth surface. It was shown that gingival areas were most affected by demineralization, particularly on anterior teeth and that these specific sites could benefit from sealing and protection by a viscous resin\textsuperscript{12}. Nevertheless, some reports showed that the application of conventional sealants failed to provide consistent protection against white spot formation on smooth surfaces\textsuperscript{13}. Such new lesions were usually located in areas where extensive plaque accumulations occurred.

Some of the resin-based coating materials can release fluoride and act as reservoirs to increase fluoride levels in tooth surface, as an additional protective measure against intraoral challenges\textsuperscript{14-16}. Many commercially available resin-based coating materials have similar compositions to those of dental adhesives. Previous literatures have shown that some self-etching adhesives have the ability to improve the resistance of enamel and dentin against the demineralization by forming a layer of acid-base resistant zone below the interface\textsuperscript{17,18}. It has been also verified that coating of root dentin surface with such materials showed a remarkable reduction in caries susceptibility of the root site\textsuperscript{19}. Nevertheless, the use of physical barrier to protect the susceptible smooth enamel surfaces against demineralization is still not fully probed; perhaps partly due to the lack of materials suitable for the purpose, and partly due to the unavailability of objective means to provide evidence on the clinical efficacy of such an approach.

Clinically, the conventional dental radiographs (X-rays) are the most widely available diagnostic method besides direct visual inspection; however, dental X-rays are not capable of detecting early changes and demineralization of the tooth surface, and superimposition of the surrounding structures is an obstacle. In addition, the coating materials are usually radiolucent and may be thinner than the resolution of the X-rays\textsuperscript{20}. More recently, fluorescence-based techniques have been employed for the detection of early enamel demineralization\textsuperscript{21,22}. It has been shown that those which provide high-resolution fluorescence pictures are likely to be more reliable than those devices that obtain a signal intensity value via a single spot\textsuperscript{23}. However, the current fluorescence-based methods do not provide cross-sectional or in-depth images of the structure, and may be affected by the presence of resin material on the surface. Therefore, a cross-sectional imaging modality that can be used to inspect and monitor both the coating and the enamel surface is in demand.

Optical coherence tomography (OCT) is addressed as a non-invasive cross-sectional imaging of the internal biological system at the submicron scale\textsuperscript{24,25}. It is a promising imaging modality, which does not require cutting and processing of the specimens and allows the visualization of microstructures of tissues and biomaterials in real time\textsuperscript{26}. Recently, clinical OCT systems equipped with hand-held probes and suitable for intra-oral imaging have been launched by some manufacturers on a trial basis and showed a potential as a detecting tool for occlusal, interproximal and secondary caries, demineralization around orthodontic brackets as well as evaluation of dental materials defects\textsuperscript{27-29}. The introduction of faster spectral domain systems\textsuperscript{30} and incorporation of micro mechanical electrical systems into the probe designs\textsuperscript{29} have facilitated three-dimensional imaging and adoption of OCT in clinical dentistry\textsuperscript{29}. Previous studies showed that OCT imaging of sealants enabled clear detection of voids and failures in the adaptation of materials\textsuperscript{31,32}. It was also demonstrated that OCT could measure the inhibition of demineralization on smooth enamel surfaces peripheral to orthodontic brackets\textsuperscript{30}. Therefore, the aim of the current study is to evaluate the efficacy of different resin materials as enamel coating against demineralization using swept-source (SS)-OCT. The null hypotheses of this study were that covering enamel by resin material cannot resist demineralization, and that there was no difference in enamel protection among various coating materials.

MATERIALS AND METHODS

Materials used
The materials used in this study are listed in Table 1. The lot number and chemical compositions of each material are according to the information provided by the manufacturers. Three resin-based coating materials: Clinpro XT Varnish (CXT; 3M ESPE, St Paul, MN, USA), PRG Barrier Coat (PBC; Shofu, Kyoto, Japan), Tokuyama Shield Force Plus (SFP; Tokuyama Dental, Tokyo, Japan), and a two-step self-etch adhesive Clearfil SE Protect (SEP; Kuraray Noritake Dental, Tokyo, Japan) were used in this experiment.

Specimens preparation
The experimental procedure of the study is schematically presented in Fig. 1. Forty five fresh bovine incisors were obtained from a local slaughter house (Yokohama, Japan) and stored frozen prior to the experimental procedure. Enamel blocks 6×3×3 mm$^3$ (length×width×depth) were cut from the bovine incisors using a low speed diamond saw (Isomet; Buehler, Lake Bluff, IL, USA) under running water, and embedded in epoxy resin (Epoxy cure resin; Buehler). The outer enamel surface was slightly polished with a 800-grit silicon carbide (SiC) paper (Sankyo, Saitama, Japan) until a flat area was obtained on the surface. This was aimed to eliminate any possible superficial enamel cracks, and create a standard flat smooth surface. Two areas, namely coated (C), and un-coated (UC), were assigned on the polished enamel surface of each block as follows; The half surface of each treated block was covered carefully by placing a tape and stayed intact as UC area, while the other half surface of each block was carefully covered by one of the four materials (as described in Table 1) that served as the C area (n=10/group). The specimens were then stored in water for 24 h at 37°C. Five specimens were used as control, without any surface coating.

Following coating and water storage, the specimens were subjected to thermocycling challenge. They were
### Table 1  Materials used in this study

<table>
<thead>
<tr>
<th>Material</th>
<th>Brand</th>
<th>Code</th>
<th>Composition</th>
<th>Application instruction</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resin-based coating material</td>
<td>Clinpro XT</td>
<td>CXT N352376</td>
<td>Liquid: HEMA, water, camphorquinone, calcium glycerophosphate and polyalkenoic acid. Paste: HEMA, Bis-GMA, water, initiators and fluoroaluminosilicate glass.</td>
<td>Apply acid etchant for 15 s with 35% phosphoric acid. Rinse with water. Apply air for 5 s. Mix paste/liquid components together rapidly for 15 s (2.5 min working time). Apply thin layer to tooth surface. Light cure for 20 s. Wipe the coating by a moist cotton applicator.</td>
<td>3M ESPE, St. Paul, MN, USA</td>
</tr>
<tr>
<td></td>
<td>PRG Barrier Coat</td>
<td>PBC 051101</td>
<td>Base: glass powder, purified water, Methacrylate monomer, S-PRG filler, phosphonic acid monomer. Activator: methacrylate acid monomer, Bis-MPEPP, carboxylic acid, TEGDMA, catalyst.</td>
<td>Put one drop of Activator into Base and mix together. Apply thin layer of the mixture, Light-cure for 10 s.</td>
<td>Shofu, Kyoto, Japan</td>
</tr>
<tr>
<td>Two-step, self-etch adhesive</td>
<td>Clearfil SE Protect</td>
<td>00103A 00165B</td>
<td>Primer: MDP, MDPB, HEMA, hydrophilic dimethacrylate, water HEMA, dimethacrylate hydrophobic, di-camphorquinone, N,N-diethanol-p-toluidine, silanated colloidal silica, surface treated sodium fluoride. Bond: MDP, Bis-GMA, HEMA, dimethacrylate hydrophilic, water.</td>
<td>Apply primer and leave for 20 s. Dry with gentle air flow. Apply bond. Air flow gently. Light-cure for 10 s.</td>
<td>Kuraray Noritake Dental, Tokyo, Japan</td>
</tr>
<tr>
<td>Resin-based dentin coating and desensitizer</td>
<td>Shield Force Plus SFP 009</td>
<td>3D-SR monomer, HEMA, Bis-GMA, TEGDMA, alcohol, Water, camphorquinone, fillers.</td>
<td>Apply SFP then leave for 10 s. Apply weak air for 5 s. Strong air for 5 s. Light cure for 10 s.</td>
<td>Tokuyama Dental, Tokyo, Japan</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: HEMA, 2-hydroxyethyl methacrylate; Bis-GMA, bisphenol-A-diglycidyl methacrylate; S-PRG, surface pre-reacted glass inomer fillers; Bis-MPEPP, 2,2-Bis[4-(2-methacryloyloxyethoxy)phenyl] propane; TEGDMA, triethylene glycol dimethacrylate; MDP, 10-methacryloyloxydecyl dihydrogen phosphate; MDPB, 12-Methacryloyloxydodecyl pyridinium bromide; 3D-SR monomer, 3 dimensional self-reinforcing monomer, methacryloyloxyalkyl acid phosphate.

Placed in wire-mesh basket, aged for 5,000 thermocycles alternating between 5°C and 55°C water bath (Cool line CL200 and Cool Mate TE200, Yamato Scientific, Tokyo, Japan). The dwell time was 30 s in each bath with a transfer time of 5 s between baths.

**Demineralization procedure**

After thermal challenge, samples were subjected to a demineralization solution (CaCl$_2$ 1.5 mM, KH$_2$PO$_4$ 0.9 mM, CH$_3$COOH 50.0 mM, NaN$_3$ 3.08 mM) at pH 4.5 at 37°C for one week$^{33}$. The volume of demineralization solution was 140 mL per each five samples in the following order of one sample in the center and four samples in the each corner of the container. On the other hand in order to clarify the ion releasing and buffering effect of each material, the solution was not refreshed till the end of treatment.

**OCT system**

The OCT system (Dental OCT Prototype 2, Panasonic Healthcare, Ehime, Japan) operates at 1,330-nm center wavelength. Laser light is projected onto the object surface and scans across the section of interest in two dimensions using hand-held probe. The focused light-source beam is projected onto the sample and scan across the area of interest in two dimensions (x, z) using a hand-held probe. Backscattered light from the sample is returned to the system, digitized in time scale...
Fig. 1 Schematic drawing for the sample preparation and visualization under the OCT. Bovine enamel blocks were embedded in epoxy resin; one of the coating materials (CXT, PBC, SFP or SEP) was applied on half of the enamel surface; SS-OCT scans were obtained at the baseline, after 5,000 thermal cycles, and after 1, 4 and 7 days of demineralization; specimens were secondly embedded, cross-sectioned and polished for laser microscopy (CLSM) observation.

OCT imaging and analysis
In-depth 2D OCT images were carried out at five stages (after 1 day of storage, after thermocycling and after 1, 4 and 7 days of demineralization) using OCT. During the scan, the OCT probe was set at 5-cm distance from the specimen surface, with the scanning beam oriented about 90 degree to the surface. In order to ensure the repeatability of the OCT scan after each treatment, the cross-sectional B-scan was performed along the same line between the two points marked by a marker pen on the specimen surface. All OCT B-scan images were taken in wet condition for the specimens to decrease the strong reflection from the surface of the specimen.

For image analysis, a custom code in the image analysis software (ImageJ version 1.45S; National Institutes of Health, MD, USA) was used to import the raw data of the OCT. A noise reducing median filter (size 2) was applied to the data. In order to measure the initial coating thickness, ImageJ was used to calculate the thickness value in the thickest area. Then, a region of interest (ROI) width 1 mm×optical depth 500 μm from the surface of enamel in UC area to deeper levels was selected and lesion depth was measured using an experimental plugin which was developed for ImageJ (Fig. 2). Threshold function of the software allows the user to find appropriate intensity values that correspond to the visual boundary, suggesting the demineralization front or optical lesion depth. For the purpose of comparing OCT and CLSM measurement, all optical depth values obtained under the hydrated conditions for coating thickness and lesion depth were converted to real depth values by dividing them to the estimated refractive index of 1.5 for resin and demineralized enamel.
Fig. 2 (a) Lesion depth (OLD) and coating thickness (OT) of SEP coat determination on OCT images. (b) Demineralization depth was determined through the binarization process over ROI; a visible sharp border was taken as the depth of lesion. The OLD reading from OCT image (b) was 206 µm (optical) or approximately 140 μm in real (RLD) considering \( n \) of 1.5 for demineralized enamel. This depth corresponds to the lesion front depth marked by dashed arrow on the CLSM image of the same cross-section after cutting (b'). The OT was measured directly on the OCT image as presented in (c). The actual coating thickness (RT) was later confirmed under CLSM imaging. Note that matching the two thicknesses (OT vs. RT) suggests \( n \) value of \( \frac{52}{35}=1.48 \) (c'). A: air, E: enamel, D: dentin, RR: polyester second embedding resin, ROI: Region of interest, OLD: Optical lesion depth, RLD: Real lesion depth, OT: Optical thickness and RT: Real thickness. The CLSM scale bar shows 84.4 µm distance.

Table 2 Optical thickness and frequency of detachment and demineralization for each coating material obtained from OCT images (n=10/group)

<table>
<thead>
<tr>
<th>Material</th>
<th>Initial optical thickness ±SD (µm)</th>
<th>Detachment (&gt;0.5 mm) After thermal cycling</th>
<th>Detachment (&gt;0.5 mm)</th>
<th>Demineralization under the coating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1-day DEM</td>
<td>4-day DEM</td>
<td>7-day DEM</td>
</tr>
<tr>
<td>CXT</td>
<td>253.7±55.26</td>
<td>0/10</td>
<td>2/10</td>
<td>3/10</td>
</tr>
<tr>
<td>PBC</td>
<td>123.1±49.43</td>
<td>1/10</td>
<td>2/10</td>
<td>2/10</td>
</tr>
<tr>
<td>SEP</td>
<td>67.4±29.75</td>
<td>0/10</td>
<td>0/10</td>
<td>0/10</td>
</tr>
<tr>
<td>SFP</td>
<td>*61±7.48</td>
<td>3/10</td>
<td>6/10</td>
<td>7/10</td>
</tr>
</tbody>
</table>

(*) Data excludes two samples that were not measurable (thickness<10 µm).

by diamond slurries with particle sizes of 6 µm, 3 µm, 1 µm, 0.5 µm, and 0.25 µm in a lapping machine (ML-160A; Maruto, Tokyo, Japan).

Statistical analyses
Repeated measures analysis of variance (ANOVA) was used to compare the progress of lesion depth with demineralization time among different coating materials and their interaction. This was followed by comparisons between each two material groups with Bonferroni correction. All the statistical procedures were performed at a significance level of \( \alpha=0.05 \) with the statistical package for social science (SPSS for windows, Version 16.0, SPSS, IL, USA).

RESULTS

Optical thickness of the coating with their integrity and protection against enamel demineralization are summarized in Table 2. The highest mean optical thickness values measured by OCT were found in CXT, followed by PBC and SEP. Representative OCT images are presented in Figs. 3–5 and confirmatory CLSM images are presented in Figs. 4 and 5.

Figure 3 a–f represented 2D OCT B-scans of sound and 4 days demineralization challenge. UC enamel area showed high reflectivity from the lesion and decreased reflectivity just beneath the lesion, revealing a lesion boundary. For CXT, a decrease in reflectivity from UC superficial areas adjacent to protected zone was noted. In most specimens, the C area appeared to be intact after 4 days of demineralization; however, localized increase in reflectivity appeared in some areas coated by SFP. While it was difficult to distinct the coating layer of SFP, its enamel protection effects could be observed.

Figures 4 and 5 represented typical B-scan images obtained by the OCT and cross-sections as confirmed by the CLSM for each material after 7 days of demineralization. The B-scan images of the CXT sample showed bright clusters at several areas beneath the resin coating indicating interfacial gaps, which were later confirmed by CLSM imaging. A distinct
area appearing similar to sound enamel was observed adjacent to the C area of CXT, which was confirmed to be a demineralization inhibition zone in corresponding CLSM image. In another hand, PBC maintained its integrity and protected enamel beneath the coating, but no defined inhibition zone was seen adjacent to the coating. DEJ was not clearly observed beneath the demineralized enamel in OCT images. All groups showed complete protection against demineralization of enamel in C areas after 7 days, except for SFP which showed patches of partial demineralization.

The values in the bar graph represent optical lesion depth (µm), which were obtained using OCT images of different groups through demineralization days (Fig. 6). Repeated measures ANOVA revealed that demineralization time (within subject effects; $F=175.8$, $p<0.001$) and its interaction with coating type ($F=5.2$, $p<0.001$) significantly affected the depth of lesion formed in UC area. Coating type, the between subject factor, was also significant ($F=11.3$, $p<0.001$). Pair comparisons revealed that lesion progress in UC area of CXT was significantly different from all other groups ($p<0.05$) but there was no significant difference among other groups including the control.

**DISCUSSION**

In the present study, bovine teeth were used, which are widely used in de/remineralization studies and resin infiltration tests. Comparing to human enamel, it is easier to obtain bovine teeth in large numbers and good conditions with less variable composition. Bovine teeth have large flat surfaces and have not experienced prior caries challenges that might affect the test results\(^{35}\). A routine thermal cycling challenge was used to evaluate the durability of resin coats on the surface. Although thermal expansion of such thin layers on flat enamel surface may not be considered as a serious concern, previous studies have suggested that the increased number of thermal cycles accelerated degradation of resin through such mechanisms as increased water sorption and elution of ingredients\(^{36}\). Tooth brush abrasion and mechanical wear of resin coatings are also important challenges facing the application of these materials clinically\(^{37}\).

The demineralization solution in this study was based on previous works, which resulted in formation of a subsurface enamel lesion\(^{38}\). It should be noted...
that the solution was not changed during the period of demineralization; this was done to boost the effects of any ions releasing from the materials in the in vitro study. Demineralization and remineralization processes on enamel and dentin are difficult to detect at early stages by visual inspection alone. The application of OCT for detection of enamel caries beneath composite filling and sealants has been reported\(^\text{[31,32]}\). The current results demonstrated the excellent potential of OCT imaging for observing coating thicknesses and changes which occurred under the coating after demineralization. Despite attenuation of OCT signal through the resin-based coats, surface of the enamel under the coats could be clearly monitored. In this regard, it was shown that the composition of resin materials affected the OCT signal pattern\(^\text{[30]}\). In addition it is difficult to detect the DEJ beneath the demineralization in some images of UC area, due to a very low signal intensity from the structure. It was shown that enamel demineralization results in increased attenuation coefficient of near-infrared light and rapid loss of signal intensity\(^\text{[29]}\).

There are two potential mechanisms that underlie the protective effect of the coats in this study. First and foremost, the hermetic sealing of the coating surface act as a physical barrier to impede the ingress of acid. Second, they supposedly release fluoride and other ions that reinforce the tooth structure against acid or have buffering effects. The detected loss of interfacial integrity in this material may be related to the incomplete infiltration of CXT, which has a relatively viscous paste, into the phosphoric acid-etched enamel\(^\text{[7]}\). CXT is somewhat similar to the generic resin modified glass ionomers (RMGIs), and contains bisphenol-A-diglycidyl methacrylate (Bis-GMA) that has a high molecular weight. Moreover, in cross-sectional microscopy images (Fig. 4), the coating layer appeared to be fractured. Such voids and cracks have been attributed to the continuous internal acid-base reactions known for glass ionomers\(^\text{[38]}\); and could also be due to the effect of the acidic environment on the integrity of material\(^\text{[39]}\). On the other hand, anti-caries effects of RMGIs were attributed to the presence of the loosely-bound fluoride ions from the glass fillers, which are free to move and protect enamel surface\(^\text{[15]}\). Fluoride may reduce the rate of dissolution of enamel in the demineralization phase in acidic conditions and enhance the remineralization at the crystal surface\(^\text{[16,40]}\). Moreover, CXT contains a compound that releases calcium into the solution\(^\text{[41]}\). The development of calcium-releasing dental restoratives is becoming a new trend\(^\text{[10,42]}\). Calcium ions can enhance the remineralization effects of fluoride and increase the local buffering effect at the demineralization site, which may explain significantly lower lesion progress in CXT compared to all other groups (Fig. 6) and the presence of the demineralization inhibition zone adjacent to the CXT coating, which is clearly observed in both OCT and confirmatory CLSM (Fig. 4).

OCT scan in PBC group showed complete protection
against demineralization despite partial detachment of the coating from enamel surface in two samples. In addition to the physical barrier effect of coating, the acid resistance of the enamel surface underlying the PBC can be explained by the release of multiple ions from the surface pre-reacted glass (S-PRG) fillers included in the composition of PBC as a giomer-based product. The release of fluoride, silicon, boron, strontium and other ions is believed to be due to the presence of a glass ionomer phase around the glass core of the filler\(^\text{45}\).

SEP coat remained intact after 7 days and no gap neither detachment occur in this group. SEP is considered as a mild self-etch system which usually has a pH of about 2 which produce a shallower enamel etching than phosphoric acid etchants. Moreover, SEP is a fluoride-releasing bonding agent; previous works have shown effective release of fluoride from this bonding agent\(^\text{18}\), due to the presence of NaF crystals in the bonding agent. It was suggested that the total amount of fluoride released into solution from the bonding agent over 7-day period was comparable to those of RMGI and conventional glass ionomer when applied as enamel coating\(^\text{45}\); however, the surface treated NaF crystals in the bonding agent may not offer the fluoride recharging ability that has been shown for glass particles in glass ionomers and S-PRG fillers in giomers\(^\text{46,47}\).

In SFP group, the resin showed detachment or damage and occasional demineralization patches in C area (Figs. 3f and 5b), it is formulated to have a very thin film thickness; however, it should be noted that this resin-based dentin desensitizer has similar composition to those of all-in-one adhesive systems. Several studies have reported on the permeability of the layer formed by this type of adhesives when applied as a single coat\(^\text{20}\); the simultaneous presence of hydrophilic and hydrophobic domains, together with solvent within the bonding agent might affect the curing process and the integrity of the polymer formed thereby. It has been reported that the polymerized adhesive layer was porous due to the presence of residual solvents\(^\text{34}\).

From a conservative point of view, an ideal coating material would form very thin, durable coat that can resist chemical, mechanical and thermal challenge, with no or limited need for etching and demineralization of enamel prior to its application. The thickness and wear resistance are especially important in proximal and occlusal areas. Such a material would seal the surface completely, while actively and sustainably releasing ions that reinforce the teeth and buffer the local environment such as, but not limited to, fluoride. Finally, the desired coat would be antibacterial, resistant against biofilm formation and have ion recharging ability. In view of these properties, none of the coating materials alone fulfilled all the requirements in the current study; nevertheless, many of these properties were cumulatively observed, confirming the possibility of developing such a protective factor for the dental practice.

OCT can be an ideal adjunct clinical tool for regular monitoring of these coatings. In this view, the coating can be repeated or repaired in required areas that can be detected by OCT. Further probing of these coating, including the mechanical evaluation of both the resin coating with the underlying and surrounding enamel is underway since one of the main concern with applying a dental resin coating is wear and tooth brush abrasion. Within the limitations of the research, which included a narrow study design, the proposed null hypotheses were rejected as covering enamel by resin material could prevent demineralization, and there was a difference between materials in this regard.

**CONCLUSION**

A sealed enamel surface by thin resin coatings can contribute to the protection of smooth enamel surface from acid challenge depending on the properties of the material. Coating materials that actively release ions such as fluoride would not only protect the covered areas, but also benefit the adjacent hard tissue.

**ACKNOWLEDGMENTS**

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