Long-term evaluation of the remineralization of interproximal caries-like lesions adjacent to glass-ionomer restorations: A micro-CT study

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ABSTRACT: Purpose: To compare the remineralization of incipient artificial interproximal caries in the presence of three glass-ionomer cements (highly-filled glass-ionomer cement, compomer, resin-modified glass-ionomer cement) and a resin composite (control). Methods: Proximal restorations were simulated by placing tooth specimens and the various glass-ionomer cements in closed containers with artificial saliva at 37°C and pH 7.0 for 30 days with constant circulation. Tomographic images were obtained with a micro CT scanner at 90, 180, and 270 days, and density-measuring software was used to calculate the micro-density of artificial caries lesions in the specimens. The mean density changes were compared between groups in order to evaluate the effects of remineralization. All data were analyzed using one-way ANOVA and the post-hoc Tukey multiple comparison test at P< 0.05. Results: While the density of artificial caries lesions increased for all treatments, the increases for the three glass-ionomer groups were significantly higher than that for the resin group in each 3-month period. As time increased, the amount of density also increased for the glass-ionomer groups, and significant differences were found between the remineralization effects of the glass-ionomer groups. The micro CT proved to be an effective evaluation method. (Am J Dent 2008:21:129-132).

CLINICAL SIGNIFICANCE: This in vitro study showed that glass-ionomer restorations can affect remineralization of artificial adjacent interproximal caries to a much greater extent than do resin composite restorations. The micro CT proved to be an effective evaluation method.

Introduction

Early caries in proximal tooth surfaces are notoriously difficult to detect. Furthermore, these lesions remain difficult to treat even when they are detected.

Fluoride promotes remineralization and inhibits demineralization of dental hard tissue, and glass-ionomer cements are well-known fluoride-releasing restorative materials shown to have anti-carcinogenic properties specifically due to their significant release of fluoride. In addition to releasing fluoride, glass-ionomer cements bond directly to tooth structure, are easy to handle, and possess a coefficient of thermal expansion similar to that of the tooth.

Glass-ionomer cements have not been used in stress-bearing restorations because they exhibit lower tensile strength and greater wear than amalgam or composite materials. Highly-filled glass-ionomer materials with better mechanical properties than conventional glass-ionomer cements have been developed for long-term provisional restorations in the primary dentition.

Much is known about the fluoride-releasing properties of glass-ionomer cements, yet little information is available regarding the remineralization effects of these compounds on adjacent interproximal caries. Moreover, no objective and quantitative study had previously been performed to assess long-term changes in remineralization because conventional study methods depend upon human subjects and are destructive.

This long-term in vitro study compared the remineralization of incipient interproximal caries adjacent to three glass-ionomer cements (highly-filled glass-ionomer cement, resin-modified glass-ionomer cement), compomer, and a resin composite (control) for 9 months. The long-term changes in remineralization associated with each material were also assessed.

Materials and Methods

Twenty extracted permanent premolars stored in 0.1% thymol solution were used. The teeth were free of caries on the mesial and distal proximal surfaces. The teeth were completely covered with an acid-resistant varnish (nail varnish) except for areas of enamel approximately 1 mm x 6 mm at the proximal contact zone on the mesial and distal surfaces. The teeth were then suspended in an artificial caries solution (2.2 mM Ca\(^{2+}\), 2.2 mM PO\(_4^{3-}\), 50 mM acetic acid) at pH 4.4, 37°C, and constant circulation until lesions had been induced. Artificial lesions appeared after 3 days in the caries solution, at which time the varnish was removed. Two mesial and two distal specimens including the artificial caries lesions were obtained from each tooth by sectioning with an Isomet low speed saw. The sections were mounted in acrylic resin blocks and initial tomographic images were taken with a desktop x-ray micro CT scanner (SkyScan-1072).

To simulate adjacent restorations, 5-mm holes were drilled in new acrylic blocks and filled according to the manufacturers’ instructions with the following restorative materials: Group 1: Fuji IX GP, Group 2: Vitremer, Group 3: F2000, and Group 4: Z250.

Each group comprised 16 pairs of lesion specimens and “restored” blocks. The two-block pairs were affixed with utility wax and placed in closed containers with 250 mL of artificial saliva medium per 100 mL. The medium contained 1gm carboxymethyl cellulose sodium, 3 gm D-sorbitol, 84 mg NaCl, 120 mg KCl, 15 mg CaCl\(_2\), 5 mg MgCl\(_2\), and 34 mg dibasic phosphate. The acrylic blocks were maintained in artificial saliva at 37°C and pH 7.0 for 30 days with constant circulation. Tomographic images were then taken of the specimens with the micro CT scanner at 90, 180, and 270 days.
Three-dimensional images were constructed from the individual tomographs by Vworks 4.0. Figure 1 shows one such 3-D reconstructed image of a specimen. A density-measuring component of the Vworks software was used to calculate the surface density of the specimens. Data were recorded as the mean of 25 values from five randomly selected sites on each of five randomly selected slices. The procedure for micro-density measurement is illustrated in Fig. 2. The effect of remineralization was evaluated by comparing the mean density changes among the four treatment groups.

All data from this study were processed with the Statistical Package for Social Science (SPSS), Version 11.0. Analysis included calculations of mean density change and standard deviation for each group. A one-way ANOVA quantified the remineralization effects of the restorative materials, and the post-hoc Tukey multiple comparison test identified significant differences between the mean density changes.

## Results

Table 1 displays the mean (±S.D.) density values of the specimens during this 9-month trial. △D signifies the change in density for a single specimen. △Dn refers to the density change between the nth-3 and nth-9 months after treatment. For example, △D3 is the difference between pre-treatment density and 3-month post-treatment density.

Without exception, lesion density increased in all groups at 90, 180, and 270 days.

Table 2, the post-hoc Tukey multiple comparison test demonstrated that every 3 months △D was significantly greater (P< 0.05) for all glass-ionomer cement groups (Groups 1, 2, and 3) than for the control group (Group 4). There were no statistically significant differences among the glass-ionomer cement groups.

Figure 3 shows △D for each restorative material included in our study, and the amount of density change decreased in all glass-ionomer groups.
Discussion

In this study, all groups demonstrated an increase over time in the density of artificial caries lesions on interproximal surfaces adjacent to restorations. The glass-ionomer treatment groups (Groups 1, 2, and 3) showed significantly more density change than did the resin composite group (Group 4) at 3, 6, and 9 months after treatment. These findings confirmed that the remineralization effect of glass-ionomer restorations was superior to that of the resin composite in a short and a long-term period.7 The density of artificial caries lesions would be expected to increase with fluoride release, as occurs with glass-ionomer cements. Nevertheless, some increase in density was also observed in the control group with resin composite that did not release any fluoride. This apparent contradiction likely resulted from calcium ion deposition from the artificial saliva into the artificial caries lesion.

The present study demonstrated that remineralization of adjacent proximal caries lesions was greater with highly-filled glass-ionomer, resin-modified glass-ionomer, and compomers than from a resin composite. It is already accepted that fluoride released from Class II glass-ionomer cements in direct interproximal contact with adjacent teeth reduced enamel demineralization and promoted remineralization.8 12 The findings from this in vitro study thus agree with a previous report.8 A review of the literature suggests that resin-modified glass-ionomer materials released at least as much fluoride as conventional glass-ionomer cements.13 14 The caries inhibition effect of resin-modified glass-ionomer cements was equivalent to that of conventional glass-ionomer cements when tested in vitro.13 14

Asmussen & Peutzfeldt15 compared fluoride release from glass-ionomer cements and composites. The rate of fluoride release decreased over time from the former materials. The present study suggests that the remineralization effect of the composite also decreases with time.

Most frequently, polarized light microscopy, microradiography, and light microscopy are used to examine the remineralization of tooth enamel.16 While these methods are effective, they have limitations. The use of microtomography in this study represents a novel quantitative assay for remineralization.17 19

Any conventional optical or electron microscope allows visualization of a specimen’s surface or of thin slices in two dimensions. However, in the majority of cases meaningful conclusions about the original 3-D structure cannot be made from such 2-D information. One method for obtaining 3-D representations of specimens is to cut them into very thin slices, visualize these by light microscopy, and interpolate a 3-D model from the 2-D images. Another approach is to use an x-ray (radiography) system that produces 2-D shadow images of complete internal 3-D structures. Again, this method is limited because a single 2-D shadow projection loses all information of depth. Only an x-ray tomography system allows us to visualize and measure complete 3-D structures without destructive sample preparation or chemical fixation.

Conventional medical CT-scanners typically achieve a spatial resolution in the range of 1-2.5 mm, corresponding to 1-10 cubic mm voxel (volume element) size. Computerized x-ray microscopy now allows this spatial resolution to be refined by seven to eight orders of magnitude in the volume term. The SkyScan-1072 system, for example, gives a spatial resolution of 5 μm, or 1 x 107 cubic mm voxel size, and as in “macro” CT-scanners, the internal structure can be reconstructed and analyzed with no specimen destruction.

Vworks 4.0 is a PC-based application for reconstructing DICOM (Digital Image Communication in Medicine) 3.0 files or images from CT, MR, 3-D ultrasound, and other medical equipment into various formats (slice image, MPR image, oblique image). The software allows users to create, save, and manage 3-D medical models and images conveniently on their desktop computers. The operator can then measure distance, density, volume, and other variables of the 3-D models or images they have created.

This imaging method offers several advantages: First, microtomographic study is nondestructive. As opposed to the microhardness test or traditional microscopic study, microtomography permits the investigator to perform before- and after-treatment comparisons on the same specimen. Microtomography is also more objective and accurate than conventional methods because the data processed by Vworks are quantitative.17-20 Finally, microtomography makes it to visualize the effect of remineralization.

The present study did not take into account some characteristics of glass-ionomer cements, such as fluoride uptake by fluoride dentifrices and mouthrinses, so the results do not represent the true oral environment.5 6 12 21-24 Exact results could be obtained by considering such factors in future investigations.

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References

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