Application of $1/e^2$ Theory to the Analysis of Enamel Demineralization Using Optical Coherence Tomography

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Abstract

Purpose: During the initial stages of carious lesions, decayed lesions are characterized by dissolution of the hydroxyapatite, and estimation of the amount of enamel subsurface porosity can be used to detect and quantify the early stages. Through being able to detect and diagnose carious lesions at an early stage, dentists can prevent progression of the decay, and avoid the need for invasive removal of sound tooth structures. Previous studies have demonstrated that Time-Domain Optical Coherence Tomography (TD-OCT) can be used to image the demineralization of early artificial carious lesions. However, an analytical method for quantifying coronary lesion severity has not been developed. The aim of this study was to evaluate a new method of analyzing OCT images for the evaluation of enamel demineralization.

Methods: After slicing bovine incisors, each slab was trimmed into a rectangular form ($4 \times 4 \times 2$ mm) using #2,000-grid silicon carbide paper. Specimens were treated with lactic acid buffer solution and then placed in artificial saliva (AS) or in distilled water (DW). The scanning probe connected to the TD-OCT was set at a fixed distance (2.0 mm) from the enamel surface. The scanning beam was set perpendicular to the surface of the tooth. From the OCT images, the peak intensity and width at $1/e^2$ were obtained. The data for each group were analyzed by a repeated measures analysis of variance (ANOVA) followed by a Tukey-Kramer post-hoc multiple comparison ($\alpha = 0.05$).

Results: The signal intensities for the DW group significantly increased from $-72.3$ dB to $-44.5$ dB, while there were no changes in the width of $1/e^2$. The signal intensities for the AW group significantly decreased from $-52.7$ dB to $-67.2$ dB, and the width of $1/e^2$ significantly increased. The changes in signal intensities and $1/e^2$ might be related to the reflection of light on the tooth surface.

Conclusions: The current study demonstrated that the TD-OCT successfully tracked the development of mineralization and that $1/e^2$ measurement may be a suitable indication of tooth demineralization.

Key words: Optical Coherence Tomography, $1/e^2$ theory, Enamel demineralization