

The Pilot Study of Proximal Initial Dental Caries Measurement Correlates with Grayscale Values of Digital Bitewing Radiography

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Abstract

None of the previous studies reported an effective method to compare radiographic carious lesions with histological gold standard. This study aims to find an effective method to measure initial proximal carious lesion in histology which is the most associated with radiographic carious lesion. Sixty extracted premolar teeth (30 initial proximal carious lesions and 30 adjacent teeth without carious lesions) were randomly paired up and embedded in plaster of Paris blocks. Bitewing technique was performed to image digital radiograph, the mean grayscale values were calculated. Ground sections, 1 mm thick, were cut and observed with a stereomicroscope. All carious lesions were measured by three different methods: Method1, measuring by depth of carious lesions (μm); Method2, measuring by area of carious lesions which all borders were straight lines (μm^2); Method3, measuring by area of carious lesions which all borders were actual outlines of carious lesions (μm^2). Among three methods, Pearson correlation coefficient of the mean grayscale values and Method3 were highly significant in this study (0.793) following by Method2 (0.691) and Method1 (0.517) ($P < 0.001$), respectively.

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Introduction

Radiography is implemented in the diagnosis of caries on the proximal surfaces of teeth and intraoral radiographic examination is still commonly used in routine dental practice.¹ Among the various types of techniques used, the bitewing projection technique is suggested.² Since the digital radiographic receptors are delivered into use in routine clinical practice, radiation exposure, projection errors and retakes are significantly reduced. The digital radiograph, especially photostimulable phosphor (PSP) plates, has a higher degree of accuracy in diagnose proximal caries over traditional radiograph.³ Because the digital images are very clear and simple to manipulate for preferable viewing even by a non-computer expert, digital radiographs make the diagnosis and treatment

process reliable with more accuracy.⁴ Besides, digital radiographs also have the potential to improve diagnostic accuracy and make quantitative diagnoses.

The effective radiographic depth assessment on proximal surfaces in radiography which can also vary as radiographic density is strongly related to actual lesion depth. For small carious lesions, validity is poor.⁵⁻⁸ Variations in perceived lesion depth in radiography can lead dentists to erroneousness and result in unnecessary restorative intervention or delay in treatment.⁹ Radiographic diagnosis is based upon the amount of demineralization needed to create a change in radiographic density, with a minimum of 40% mineral loss needed for radiographic visibility.¹⁰ The mineral content of enamel and dentin loss are recorded on the image receptor as an increase in radiographic density. In the previous studies, there were none of the modalities which can offer both of high sensitivity and high specificity, and none of the modalities obviously exceed the others in the detection of initial proximal carious lesion.¹¹ Combination different types of caries detection modalities can probably achieve the optimal

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diagnostic result.¹²

A histological investigation was achieved as a reference test or a gold standard to regulate an accurate assessment of the extent of any carious lesions present.¹³ Thus, histological observation served as the validating criteria for the presence carious lesions. Several studies show measuring depth of carious lesions in radiography comparing with level of progression into enamel and dentin, for example dental caries deep into half of enamel.^{14,15} But none of the studies shows measuring depth of carious lesions in radiography comparing with measuring carious lesion by actual lesion depth or actual lesion area. Accordingly, this study aims to find an effective method to measure initial proximal carious lesion in histology which is the most associated with radiographic carious lesion.

Materials and methods

The samples were recruited from sixty human premolars without restorative material and extracted for an orthodontic purpose. Thirty teeth with initial proximal carious lesions (non-cavitated carious lesions) and thirty adjacent teeth without carious lesion were randomly paired up and embedded in plaster of Paris blocks. Photostimulable phosphor (PSP) plates sized 2 film exposing at 70 kV, 15 mA and 0.5 seconds were performed to image each set of teeth and held in place with an X-ray device (XCP-DS, DentSply Sirona, York, PA, USA) holder during exposure. Using the bitewing technique, an XCP-DS was horizontally positioned with a 35-cm focus-receptor distance. Photostimulable phosphor (PSP) plates were processed immediately after exposure follow by the manufacturer's instructions. The radiographs were exported in an 8-bit grayscale image with a *.tiff file format. Images of each tooth were isolated and analyzed by an investigator on an LCD medical monitor (MDNG2121; Barco, Kortrijk, Belgium) set at a screen resolution of 2*106 pixels. Mean grayscale of pixels was measured from the carious sides using standard software (ImageJ; National Institute of Health, Bethesda, MD, USA). All images were examined for presence of proximal caries without overlapping between the adjacent teeth. A region of interest (ROI) was selected to cover an extension of the lesion. A mean grayscale was computed from the grayscale values containing

in each ROI area with ImageJ software.

According to histological investigation, thirty teeth with carious lesions were serially and mesio-distally cut through their anatomical crown's long axis using a hard tissue macrotome (Isomet 5000; Buehler, Lake Bluff, IL, USA) under water irrigation for the histological validations of the caries states, ground sections, and a final thickness of 1 mm. A high-resolution stereomicroscope (Olympus SZX16, Tokyo, Japan) at a 1.25 magnification with reflected light was used to analyze ground sections. A carious lesion was defined as a demineralized, opaque white or yellowish-brown discoloration at enamel or dentin in the caries' susceptible area. Images were taken in JPEG format from the microscopic views and transferred to the Olympus cellSens Standard software for determining the exact size of lesions.

The histological observation served as the validating criteria for the presence of carious lesions. To measure and define carious lesions, all carious lesions were measured by three different methods as follows in Figure 1: Method1, measuring by depth of carious lesions (μm); Method2, measuring by area of carious lesions which all borders were straight lines (μm^2); Method3, measuring by area of carious lesions which all borders were actual outlines of carious lesions (μm^2). All measurements of the histological examination were recorded.



Figure 1. Measuring the size of carious lesions in the histological specimens by three different methods using the Olympus cellSens Standard software.

The mean grayscale values of the digital images and the size of carious lesion in the histological specimens of three different methods were calculated for every image and specimens.

Correspondences between the mean grayscale values of the digital images and the size of carious lesions in the histological specimens of three different methods were calculated using Pearson correlation test with a 0.001 significant level. All computations were performed with the statistical software (SPSS 20.0, SPSS Inc., Chicago, IL, USA). Intra-and inter-observer agreements of grayscale measurement and histological investigation were assessed with a weighted kappa coefficient.

Results

The mean grayscale values of thirty digital images in 8-bit digital radiograph were computed from the grayscale values containing in each ROI area with the ImageJ software and recorded. From histological analyses of thirty teeth with proximal carious lesions, the sizes of carious lesions were measured and recorded by three different methods. All data were put in the statistical software and analyzed. Intra- and inter-observer kappa coefficients of mean grayscale values were assessed with a weighted kappa coefficient 0.96 and 0.87, respectively. Intra- and inter-observer kappa coefficients of histological examinations were assessed with a weighted kappa coefficient 0.98 and 0.88, respectively.

		Method1	Method2	Method3
Mean grayscale value	Pearson Correlation	.571**	.691**	.793**
	Sig. (2-tailed)	.001	.001	.001
	N	30	30	30

Table 2. Pearson correlation coefficient of the mean grayscale values of digital radiograph images and three different methods.

Table 2 shows the correlation of the mean grayscale values with three different methods. Pearson correlation coefficient among three methods and the mean grayscale values was carried out. A significant and positive correlation were observed between the mean grayscale values and Method1 (0.517) ($P < 0.001$), the mean grayscale values and Method2 (0.691) ($P < 0.001$) and the mean grayscale values and Method3 (0.793) ($P < 0.001$).

Among three methods, Pearson correlation coefficient of the mean grayscale values and Method3 were highly significant in this study (0.793) ($P < 0.001$) following by Method2 (0.691) ($P < 0.001$) and Method1

(0.517) ($P < 0.001$), respectively. The positive correlation stated that there were corresponding relations between three different methods and the mean grayscale values, while Method3 had the most corresponding relation with the mean grayscale values.

Discussion

Dental carious lesions have traditionally been diagnosed by visual inspection in combination with radiography. It was agreed in the literature that radiography is a more sensitive diagnostic method than clinical inspection for detecting approximal and occlusal lesions in dentin, for estimating depth of the lesion, and for monitoring lesion behavior.¹⁶ Radiographic examination displays both of difference in absorption and scattering properties of healthy and diseased tissues. This difference in mineral content is recorded by radiographic image receptors and depicted as optical density in film-based imaging or grayscale level in the digital radiographic approach. In the present study, the mean grayscale values of digital images were determined using an ImageJ® software to enhance and investigated grayscale level. Moreover, this study was interested in how to measure the sizes of carious lesions in a histological examination that was observed by three different methods using the Olympus cellSens Standard software. Since, a histological investigation was achieved as a reference test or a gold standard to regulate an accurate assessment of the extent of any carious lesions present. Consequently, this study evaluated correlation between the mean grayscale values and various measuring methods to figure out the optimal measuring method. There had an important finding that was the significant Pearson correlation coefficient value of Method3 (0.793) confirmed what was apparent from Table 2. There appeared to be a strong positive correlation between the mean grayscale values and Method3 following by Method2 and Method1. Thus, from this finding could be assumed that Method3 measuring by areas of carious lesions which all borders were actual outlines of carious lesions was the most associated to a radiographic carious lesion among three different methods. This may be explained by grayscale values of digital radiographic images are commonly observed by

a region of interest (ROI) which is selected to cover an extension of the lesion and measured by area. Corresponding with Method3 that was measured an actual size of carious lesion by area in the same manner. However, this present study shows all methods had a positive correlation with the mean grayscale values, there were slightly different in results.

Conclusions

In summary, this study reveals the most correlation with the mean grayscale values and method3 significantly ($P < 0.001$) which can imply that the measured method by connecting actual outlines of carious lesions in histology is the most associated to a radiographic carious lesion.

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Declaration of interest

The authors report no conflict of interest.

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