Detection method of proximal caries using line profile in digital intra-oral radiography

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ABSTRACT

Purpose : The purpose of this study was to investigate how to detect proximal caries using line profile and validate linear measurements of proximal caries lesions by basic digital manipulation of radiographic images.
Materials and Methods : The X-ray images of control group (15) and caries teeth (15) from patients were used. For each image, the line profile at the proximal caries-susceptible zone was calculated. To evaluate the contrast as a function of line profile to detect proximal caries, a difference coefficient (D) that indicates the relative difference between caries and sound dentin or intact enamel was measured.
Results : Mean values of D were 0.0354 ± 0.0155 in non-caries and 0.2632 ± 0.0982 in caries ($p < 0.001$).
Conclusion : The mean values of caries group were higher than non-caries group and there was correlation between proximal dental caries and D. It is demonstrated that the mean value of D from caries group was higher than that of control group. From the result, values of D possess great potentiality as a new detection parameter for proximal dental caries. ***(Korean J Oral Maxillofac Radiol 2009; 39 : 185-9)***

KEY WORDS : Proximal caries; Line profile; Difference coefficient (D)

Introduction

Since the discovery of X-rays, radiography has been used to detect the activities of dental caries on dental hard tissues. Radiography has been primarily used for the detection of lesions on the proximal surfaces of teeth, which are not clinically visible for inspection. Commonly, radiographs are recommended as a supplement to the clinical examination of occlusal surfaces for the detection of pit and fissure caries. Over the years, it has been well established that radiography could detect more dental caries than clinical examination alone.[1-6] Various dental caries diagnostic methods were assessed including: visual and visual/tactile inspection, radiography, fiber-optic trans-illumination (FOTI), electrical conductance (EC), laser fluorescence (LF), and combinations of these methods. Dental radiography is the most common method for the dental caries detection. However, once carious lesion is detected on the radiograph, the demineralization is progressed enough to make the damage irreversible. Enamel which is mainly composed of calcium hydroxyapatite (95%) is the hardest tissue in the human body. The protective outer surface of anatomic crown is made up of enamel. Dental caries is the disease process of decay in which acid formed from carbohydrate and aided by streptococci mutans bacteria attacks tooth surface.[7] The disease can lead to pain, tooth loss, infection, and in severe cases, death. Use of filmless or digital X-ray systems has been increased in dental practice. They are generally presented as equivalent to film-based X-ray imaging systems for the diagnosis of dental caries.[8,9] The diagnostic image is available in digital form and thus also available for computer-based image analysis. However, it is difficult to monitor proximal lesions by serial radiographs because changes in irradiation geometry are likely to produce artificial changes in the radiographic image.[10-12]

For the dentist, a common, recurring diagnostic task is determining the presence or absence of proximal dental caries. Investigations have shown that dentists achieve only a modest level of accuracy and agreement in the diagnosis of caries on proximal surfaces from radiographs.[13-18] Using direct digital radiography, if two digital images are taken with the same X-ray projection geometry, it is possible to superimpose one image upon another, and subtract the grey scale values. And it, results

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in an image to represent the difference between them (subtraction image). If two images are identical, this would produce an image with no detail. However, if a carious lesion has progressed, the difference is seen as either an increase or decrease in pixel values on a more uniform background. By increasing the contrast in this image the caries signal is magnified so that changes can be detected more easily,[19,20] but digital subtraction radiography is some time later a second digital radiograph of exactly the same region is produced with identical exposure time, tube current and tube voltage. The purpose of this study is to investigate how to detect proximal caries using line profile and validate linear measurements of proximal caries lesions by digital manipulation of radiographic images. To evaluate the contrast as a function of line profile to detect proximal caries, a difference coefficient (D) that indicates the relative difference between caries and sound dentin or intact enamel was measured.

Materials and Methods

1. Materials

The study population comprised 30 dental image for control group (15) and caries teeth (15) from patients. Proximal caries and non-caries were selected from the decided by a dentist. For the images, the observer was asked to register proximal caries on the confidence scales of 1-5: (1) definitely no caries; (2) prbably no caries; (3) equivocal; (4) probably caries; (5) definitely caries. Since a preliminary analysis of the results showed that a 5-point scale was not warranted, the readings 4 and 5 (probable or definitely caries) were grouped in a "caries" category, and the rest (readings 1-3) in a "non-caries" category. We decided on group the equivocal readings (3) as non-caries since most probably these surfaces would not be treated in a clinical setting. The digital radiographs were acquired using an intra-oral X-ray system by Heliodent DS (Sirona Dental System Gmbh, Bensheim, Germany) and storage phosphor plates by Kodak RVG 6100 system. The digital images receptor were 1140 × 1920 pixels (dimensions of active area: 27 × 36 mm^2) with true image resolution and had 256 gray levels and capable of providing more than 20 lp/mm of spatial resolution. The image was extracted in uncompressed format (Windows jpeg). Each of images was taken using the system setup with a 12-inch cone operating at 60 kVp, 7 mA, and 0.4 sec.

2. Image histogram and line profile

The histogram of an image indicates the quantitative distribution of pixels per gray-level value.[21] It provides a general description of the appearance of an image and helps identify various components such as the background, objects, and noise. The histogram is the function H defined on the gray-scale range [0, ⋯, k, ⋯, 255] such that the number of pixels equivalent to the gray-level value k is

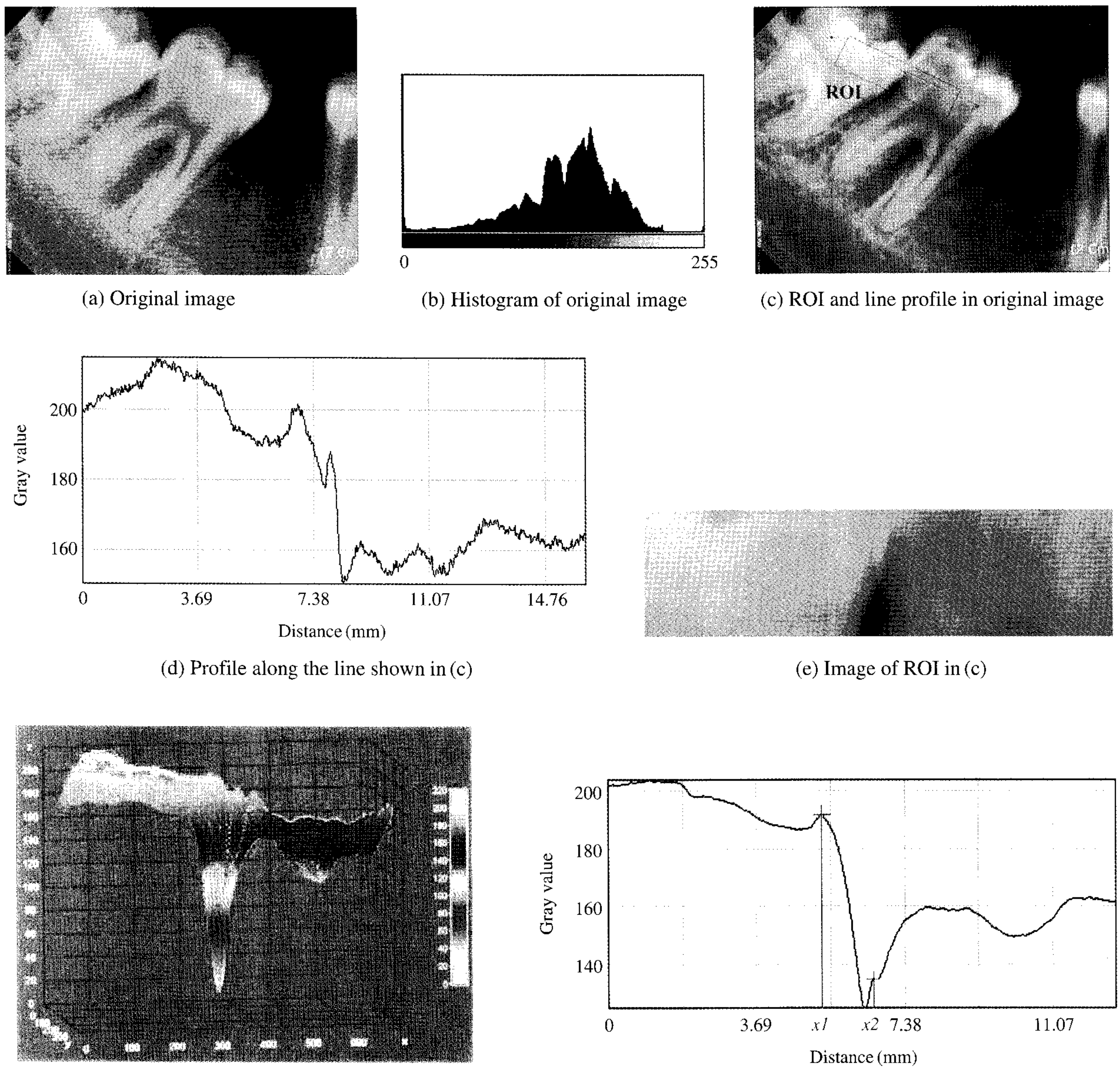
$$H(k)=n_k \qquad (1)$$

where k is the gray-level value, n_k is the number of pixels in an image with a gray-level value equal to k, and $\sum n_k=n$ is the total number of pixels in an image. The following histogram plot reveals which gray levels occur frequently and which occur rarely. Two types of histograms can be plotted per image: the linear and cumulative histograms. In both cases, the horizontal axis represents the gray-level ranges from 0 to 255. For a gray-level value k, the vertical axis of the linear histogram indicates the number of pixels n_k set to the value k, and the vertical axis of the cumulative histogram indicates the percentage of pixels set to a value less than or equal to k.

The image line profile operation provides sampling of a source image along an arbitrary path which consists of line segments between every two consecutive user-specified vertices. In each segment the profile is calculated at a number of points (profile points) equivalent to the sampling density of the original image. At each profile point the profile value is calculated by averaging samples along the normal to the profile line segment.

Results and Discussion

A histogram counts and graphs the total number of pixels at each grayscale level. Use the histogram to determine if the overall intensity in the image is suitable. From the histogram, whether the image contains distinct regions of a certain gray-level value. Based on the histogram data, it can adjust image acquisition conditions to acquire higher quality images. A line profile plots the variations of intensity along a line. It returns the grayscale values of the pixels along a line and graphs it. Line profiles are helpful for examining boundaries between components, quantifying the magnitude of intensity variations, and detecting the presence of repetitive patterns. The peaks and valleys of a line profile represent increases and decreases of the light intensity along the line selected in the digital radiographic image. Their widths and magnitudes are proportional to the size and intensity of their related regions. In this study, a new radiographic diagnosis method of dental proximal caries using histogram and line profile plots was suggested. Typical



(a) Original image

(b) Histogram of original image

(c) ROI and line profile in original image

(d) Profile along the line shown in (c)

(e) Image of ROI in (c)

(f) Interactive 3-dimension surface plot in (e)

(g) Mean value for profile plots of ROI caries scan: on x-axis: $x1$=5.31 mm, $x2$=6.57 mm

Fig. 1. Profile distribution of digital radiographic image with caries.

excitation plot profile obtained from surface of the same tooth is shown in Fig. 1.

As shown in the Fig. 1 in each image, the line profile at the proximal caries-susceptible zone was calculated. Image with region of interest (ROI) and line profile interactive 3-dimensional surface plot for ROI is shown in Fig. 1(e). Profile plot displays a 2-dimensional graph of the intensities of pixels along a line (x-axis) with the caries ROI X-ray image (Fig. 1(d), 1(g)). In Fig. 1(g), $x1$ and $x2$ are boundary valleys with change gray values showing the lack of tissue in profile plots on x-axis the caries location in the range 6.57 mm to end value. The plateau at higher level defines the sound enamel, sound dentin and grooves within this plateau to show the extent and severity of mineral loss within that area.

To evaluate the contrast as a function of change profile plot in the detection of proximal caries we defined a coefficient (D) that means the relative difference between carious and sound dentin or intact enamel.

$$D=\frac{\text{sound dentin or enamel}-\text{caries dentin}}{\text{caries dentin} / 2} \tag{2}$$

The values for D calculated for carious dentin in relation to sound dentin and sound enamel are shown in formula (2). To evaluate the contrast as a function of line profile to detect

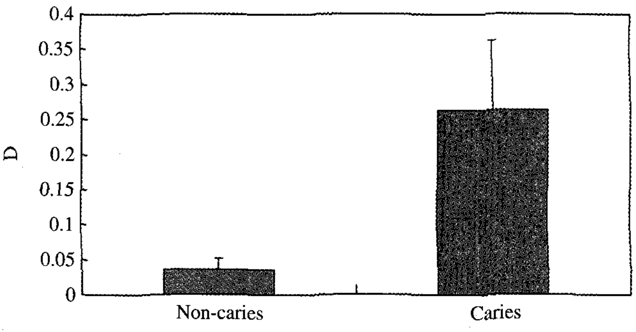


Fig. 2. Result for change plot profile in the detection of non-caries and caries: mean values (±SD) for D in formula (2).

proximal caries, a difference coefficient (D) that defines the relative difference between caries and sound dentin or intact enamel was measured Fig. 2 shows the results of changes in plot profile of the detection of non-caries and caries.

Mean values of D were 0.0354±0.0155 in non-caries and 0.2632±0.0982 in caries ($p<0.001$). It is demonstrated that the mean value of D from caries group was higher than that of control group. Results suggested that D possess great potentiality as a new detection parameter for proximal dental caries.

Conclusion

Radiography is useful for detecting carious lesions because the caries process causes demineralization of enamel and dentin. The lesion is seen in the radiograph as a radiolucent (darker) zone because the demineralized area of the tooth does not absorb as many X-ray photons as the unaffected portion. A recent development in the fields of electronic imaging have provided a new set of imaging tools for intra-oral imaging and clinical diagnosis. 15 dental images with proximal caries and 15 dental images with non-caries were selected from the decided by a dentist.

In this study, we investigated proximal caries detection using line profile. We also described several approaches for quantitative assessment of radiographic images for proximal caries detection, including digital subtraction radiography, and 2-dimensional and 3-dimensional density profiling. To increase the accuracy and reduce observer variability the use of 3-dimensional imaging and computer-aided diagnosis is presented as future direction for clinical caries diagnosis. Radiographic diagnosis of dental caries is fundamentally based on the fact that as the caries process proceeds, the mineral content of enamel and dentin decreases with a resultant decrease in the attenuation of the X-ray beam as it passes through the teeth. This is recorded on the image receptor as an increase in radiographic density. This increase in radiographic density must be detected by the clinician as a sign of a carious lesion. X-ray scans furnish detailed images of an object such as dimensions, shape, internal defects and density for diagnostic and research purposes.

The line profile was then used to calculate averaging samples along the normal to the profile line segment. Once the teeth locations and shapes are known each caries lesions within each tooth can then be located and classified by gray scale analysis.

This study suggested that a new detection method of dental proximal caries using histogram and line profile. The profile plot displayed a 2-dimensional graph of the intensities of pixels along a line (x-axis) in the caries ROI X-ray image (Fig. 1(d), 1(g)). So that boundary valleys with change in gray values to show the lack of tissue in profile plots on x-axis the caries location, and evaluate the contrast as a function of changes in profile plot for the detection of proximal caries we defined a coefficient (D) that indicates the relative difference between carious and sound dentin or intact enamel. Mean values of D were 0.0354±0.0155 in non-caries and 0.2632±0.0982 in caries.

The X-ray images of sound and caries teeth of individuals were analyzed. It could be seen that the mean values of caries group were higher than non-caries group and there was correlation between proximal dental caries and D. It is demonstrated that the mean value of D from caries group was higher than that of control group.

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