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The Effect of Edge Enhancement, Embossing, Noise Reduction and Sharpening in Detecting Proximal Caries

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ABSTRACT

Different enhancement filters have been used to improve the diagnostic accuracy of radiographic images in digital systems. However, distinct effects of these filters did not determined on the diagnostic accuracy of dental caries. The present *in vitro* study evaluated the effects of software enhancement filters of edge enhancement, emboss, noise reduction and sharpening on the accuracy of proximal caries detections. In this diagnostic *in vitro* trial, 42 non-cavitated and restoration-free extracted permanent molars and premolars were selected and mounted into 20 blocks in contact with each other. Radiographic images were obtained from the teeth in similar standardized conditions by parallel technique. The images were shown without any enhancement filters or using the filters of edge enhancement, emboss, noise reduction and sharpening. Depth of proximal caries was determined by a radiologist using 4-scaled criteria. The diagnostic accuracy indices of digital images were calculated using different enhancement filters. Diagnostic accuracy of the original digital images was lower than the gold standard technique. Following enhancement filters of edge enhancement, emboss, noise reduction and sharpening; diagnostic odd's of the enamel proximal caries was less than 20 score; although it was reported to be higher than 20 in the proximal caries located in the outer and inner half of dentin. Under this study limitations, enhancement filters of edge enhancement, emboss, noise reduction and sharpening did not significantly influenced the diagnostic accuracy of the enamel proximal caries; however, the diagnostic accuracy of digital images increased together with the caries progression in the outer and inner half of dentin using enhancement filters.

Key words: Enhancement , Digital Images, Proximal Caries.

INTRODUCTION

Use of digital systems for detection of carieshasseveral advantages namely the elimination of standard radiographic films,no chemical processing and significantly decreased the time of exposure. Quick access to image, digital enhancements of images, easy transfer, quick saving, computerized processing of the image are other advantages of digital systems. These advantages adequately justify the use of digital radiographic systems in dentistry[1, 2].

In order to increase the diagnostic accuracy of digital images, these systems allow adjustment of brightness, embossing, sharpness and contrast and can improve distortion of image margins. These enhancement filters can improve the diagnostic accuracy of digital images in detection of proximal caries[3, 4,5]. In contrast,some did not find a significant difference in diagnostic accuracy between the original images and digitally enhanced versions[6, 7].

The present study sought to assess the effects of different digital enhancement filters namely edge enhancement, embossing, noise reduction and sharpening on the diagnostic accuracy of digital images for detection of proximal caries in-vitro.

MATERIALS AND METHODS

This diagnostic in-vitro study was conducted on 42 non-cavitated or unrestored extracted human molar and premolar teeth. The selected teeth were mounted in silicone blocks in proximal contact. The teeth were mounted in similar 4-teeth rows with normal occlusion. The 4thtooth in the blocks was an anterior tooth mounted only to close the contact area. Each block was radiographed by Soredex (Min Rey intraoral radiography device) using the parallel technique and PSP (Digora-fmx with blue plates, Soredex, Tuusula, Finland) receptors under similar exposure settings (70 kVp, 8 mA, 0.16 s). The distance of the tube head from the tooth was 32 cm and the distance of the tooth from the receptor was 2cm.

Images were shown first as original images without any digital enhancement and then shown again by using edge enhancement, embossing, noise reduction and sharpening onthe 16 inch monitor with 900 x 1600 resolution. The images were shown under similar conditions and the desired contrast using SCANORA 4.3.1 software.

An experienced radiologist observed all images and expressed his opinion regarding the presence of proximal dentinal caries using a0-3 pointscale (0: no caries, 1: enamel caries, 2: caries in the outer half of dentin, 3: caries in the inner half of dentin).

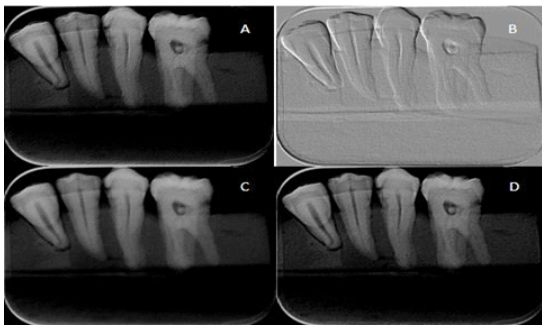

Fig. 1: a. Sharpening filter , b. Noise reduction filter, c. Embossing filter , d. Edge enhancement

All specimens underwent histological studies (as gold standard). The teeth were separately mounted in transparent acrylic blocks and sectionedmesiodistally byBUEHLER® IsoMet® Low Speed Saw (Lake Bluff, Illinois, USA). Thickness of each section was 0.1 mm. Slides were prepared from the specimens and observed under a light microscope (Olympus, Taiwan) by a maxillofacial pathologist. Presence or absence of caries was reported for each specimen based on the 0-3 point. (0: no caries, 1: enamel caries, 2: caries extends up to DEJ, 3: caries passes the DEJ)

Contingency table was used for comparison of the obtained results with the gold standard. Results were compared with the gold standard results usingthe chi-square test.

RESULTS

Observer (no digital enhancement)

Based on histopathological observations, 30 were carious and 54 were intact. The sensitivity, specificity and diagnostic accuracy of diagnosis based on observing original images was 66.7%, 74.1% and 74.1%, respectively. Positive predictive value, negative predictive value, diagnostic accuracy, positive likelihood ratio, negative likelihood ratio and diagnostic odds of this method were 58.82%, 80%, 71.43%, 2.5%, 0.45% and 5.7%, respectively. Since the diagnostic odds of this method was less than 20[5.7].

Chi-square test found significant differences in terms of location and extent of carious lesions between the observation of the original image without digital enhancement and the gold standard results ($P<0.001$).

For enamel caries, thediagnostic odds was7.62 (smaller than 20) and For outer and inner dentin caries,the diagnostic odds ratiowas16.67 and 13.33,respectively (less than 20), and digital images without enhancement filters did not have the required accuracy for detection of dentin

proximal caries in the outer or inner half dentin compared to the gold standard .

Sharpening

Sensitivity, specificity, positive and negative predictive values, diagnostic accuracy, positive and negative likelihood ratios and diagnostic odds of digital images following the use of thisfilter were 63.3%, 72.2%, 55.8%, 78%, 69.1%, 2.2, 0.5 and 4.4; respectively. The diagnostic odds ratiowas less than 20 (4.4). The results of the chi-square test for detection of proximal lesions revealed significant differences in terms of location and extent of carious lesions in observation of digital images with sharpening enhancement filter compared to the gold standard (P<0.001).

Noise reduction

By observation of digital images enhanced with noise reduction, of a total of 84 surfaces, 26 were diagnosed as carious and 58 as intact. Sensitivity, specificity, positive and negative predictive value, diagnostic accuracy, positive and negative likelihood ratiosand the diagnostic odds

Table 1: Indices of the diagnostic accuracy of observation of digital images for various methods

Method Indices	Positive predictive value	negative predictive value	positive likelihood ratio	negative likelihood ratio
Observer	58.82%,	80%	2.5%	0.45%
Sharpening	2.2	0.5	55.8%	78%
Noise Reduction	4.05%	0.46%	69.23%	79.31%
Embossing	66.6%	71.0%	3.6	0.7
Edge Enhancement	66.6%	76.6%	3.6	0.54

of digital images following the application of noise reduction filter were found to be 60%, 85.19%, 69.23%, 79.31%, 76.19%, 4.05%, 0.46% and 8.6%, respectively.

Chi square test found significant differences in location and extent of caries between observation of digital images enhanced by noise reduction and the gold standard (P<0.001).

The highest diagnostic odds value for evaluation of depth of caries following the application of noise reduction filter belonged to caries in the inner half of dentin. The diagnostic odds for these lesions was over 20

Embossing

Observation of digital images enhanced by embossingrevealed that of 84 surfaces, 15 had caries and 69 were caries-free. Sensitivity, specificity, positive and negative predictive values, diagnostic accuracy, positive and negative likelihood ratios and diagnostic odds of digital images following embossing enhancement were 33.3%, 90.7%, 66.6%, 71.0%, 70.2%, 3.6, 0.7 and 4.9, respectively. Considering the diagnostic odds<20.

Chi square test revealed significant differences in terms of location and extent of caries between observation of images enhanced with embossing and the gold standard observation (P<0.001).

The diagnostic odds ratio obtained for evaluation of depth of caries following embossing enhancement was 17.25 and 46 for outer dentin and inner dentin caries, respectively. As observed, the diagnostic odds ratio for the inner dentin caries was over 20.

Edge enhancement

Observation of images following application of the edge enhancement filter revealed that of a total of 84 surfaces, 22 had cares and 60 were caries-free. Sensitivity, specificity, positive and negative predictive values, diagnostic accuracy,

positive and negative likelihood ratios and diagnostic odds ratio of digital images following edge enhancement were 53.3%, 85.2%, 66.6%, 76.6%, 73.8%, 3.6, 0.54 and 6.5, respectively. Chi-square test demonstrated significant differences in location and extent of lesions between observation of digital images following application of edge enhancement and the gold standard (P<0.001).

DISCUSSION

Based on the obtained results, it seems that as the caries progress and extends into outer and inner dentin layers; the mentioned enhancement filters become more applicable and increase the diagnostic accuracy of digital images. However, it should be noted that by the progression of caries into dentin, the results of observation of original images would be more reliable as well. The important point is to be able to detect enamel proximal caries when the carious lesion has minimal extension.

Due to the diagnostic odds<20 for detection of caries depth of enamel, outer dentin or inner dentin caries by observation of original images without digital enhancement, this method is not sufficiently reliable compared to the gold standard method.

It appears that no significant differences exist in the diagnostic accuracy of enhanced and unenhanced images[8, 9].

Some studies have shown that application of enhancement filters can increase the diagnostic accuracy of digital images for detection of proximal caries[4, 5] and decrease the high rate of inter-observer disagreements[7]. Observers usually have significant differences with one another for detection of dental caries attributed to their clinical experience. Any enhancement filter that can decrease this controversy is of great value. At the same time, some researchers have shown that enhancement filters did not significantly enhance the diagnostic accuracy of digital images for detection of caries compared to the original digital image or conventional radiographic images[15]. In a study by Belem *et al*, in 2013 no significant difference was observed between different imaging modalities for detection of subsurface proximal demineralization[16]. In general, digital radiography enhancement filters should not be applied for detection of small proximal caries. In another study, no significant difference was found between primary images obtained from photostimulable storage phosphor plates and those manipulated by task-specific filters[6]. However, application of fine enhancement filter has been suggested for dentists looking for detection of small caries even if this process does not have a significant effect on improving the diagnostic accuracy of imaging modalities compared to primary radiographs[6].

Kositbowornchia *et al*, in 2004 compared the diagnostic accuracy of original images and those with increased sharpness, zoom and pseudocolor for detection of occlusal caries and showed that images with increased sharpness, zoom and pseudocolor did not have higher diagnostic accuracy for detection of occlusal caries under in-vitro conditions. This finding is somehow in concord with our obtained results. However, we only evaluated proximal caries in our study [17]. Ohki *et al*, in 1994 showed that manipulation of digital images significantly decreased their diagnostic accuracy. It seems that the eyes get acquainted with the observation of frequently viewed images and previous visual experiences prevent the observer from correct diagnosis of enhanced images. Considering the complexity of human visual perception and related effective factors (namely various visual errors), this subject requiresmore extensive investigations[18].

Moreover, Belem *et al*, in 2013 evaluated the diagnostic performance of digital radiography with the use of enhancement filters for diagnosis of proximal caries and reported that the diagnostic sensitivity and accuracy of images with sharpen filter were higher[16]. However, application of negative filter decreased the sensitivity and overall accuracy of images. Use of sharpen filter increased the diagnostic accuracy of images for detection of proximal caries.. Higher diagnostic accuracy of the observer when using sharpen filter may be due to the 2-D nature of radiographic images because this way radiolucencies progressing into dentin are more clearly displayed. Sharpen filter makes the contrast areas more prominent; thus, proximal

enamel subsurface demineralization that has been overlooked in the primary image may be diagnosed following the application ofthe sharpen filter[20, 21]. Despite all the above, use of sharpen enhancement filter had adequate diagnostic accuracy only for proximal carious lesions that progressed into dentin and did not have acceptable diagnostic accuracy for enamel or outer dentin caries. Wenzel and Fejerskov (1992) also showed that application of sharpen filter had no effect on improving the diagnostic accuracy of images for detection of occlusal caries [22].

The main goal of application of enhancement filters is to change physical characteristics of the image to prepare it for the observer's specific target[15]. An enhancement filter can change the original input image and compensate the defects in image quality due to under-exposure or noise development[6].

Observation of digital radiographic images is different from conventional radiography and their diagnostic accuracy is influenced by the resolution of monitor display, type of image. By using digital enhancement filters we can change the digital radiographs and may be able to increase their diagnostic accuracy. However, these filters were not significantly helpful in our study. Enhancement software programs should be easy to use and be able to aid the clinician in detection of caries. It seems that the default or original image in a digital radiography system should be the best achievable image of the system. Also, these systems should not need the manual application of filters or specific tools to change the diagnostic properties for detection of caries. By doing so, use of digital radiographic systems is enhanced and there will be no need for further manipulations that in some cases may even interfere with theinterpretive results. However, the user can manually select the desired graphic software and save the settings. Primary carious lesions are usually not detectable radiographically until penetrating into more than half the enamel thickness. Enamel-confined lesions may not be radiographically observable until causing 30 to 40% demineralization. Therefore, radiographic images underestimate the actual depth of caries. Detection of caries that have penetrated into dentin is easier. This issue, in our study, was observed as increased diagnostic odds for caries extending into outer and inner dentin halves following digital enhancement of images.

CONCLUSION

Within the limitations of this study, enhancement filters did not have a significant effect on improving the diagnostic accuracy of digital images for detection of enamel caries. However, it seems that by progression of proximal caries and their penetration into inner and outer dentin, enhancement filters may become more applicable and may increase the diagnostic accuracy of digital images.

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