Proximal dental enamel caries diagnosis in digital radiography with and without sharpening enhancement filter (In vitro)

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ABSTRACT

Background and Aim: The purpose of this study is to evaluate the diagnostic accuracy of direct digital radiography with and without sharpening enhancement filter of digital radiography software in detection of proximal dental enamel caries in premolar teeth.

Materials and Methods: In this in-vitro study, 80 sound premolars extracted due to orthodontic treatments were fixed in two blocks with putty impression material in XCP film holder in a way that 2 teeth were in the upper jaw and two in the lower jaw. Bitewing digital radiographs were taken and sharpening tool of digital software was applied on them. Then, a cavity was shaped on the proximal surface of one randomly selected tooth from each block. At this stage, digital radiographs were again taken from the blocks as mentioned above. 80 obtained images were printed 1:1 on film and were evaluated by an oral and maxillofacial radiologist. Data were analyzed by proportion test and kappa weighted test.

Results: Positive predictive value and negative predictive value for direct digital radiography was 97% and 84.8% and after applying of sharpening filter was 91.2% and 80.4%. Kappa weighted rate for reader was 0.85. Proportion test showed that this difference is not statistically significant. (p<0.4)

Conclusion: sharpening filter of digital radiography software does not improve the detection of proximal enamel caries.

Inter-proximal enamel caries detection in sharpened digital radiographs

Introduction
Interpretation of intraoral radiographs for detection of shallow enamel caries is troublesome for dentists. Therefore, appropriate radiographic methods are necessary for caries detection. Most pathologic conditions and abnormalities are not readily detectable on digital intraoral images. Applying enhancement methods on intraoral digital images can improve the diagnostic process. Overall, digital images have high amount of noise with low contrast and blurred edges. With different tools of digital radiography software such as sharpening tool with the ability of making the edges more prominent, these limitations can be relatively minimized.

According to the previous studies in this regard, sharpening software can improve the interpretation of images and ease the detection of pathologic lesions in dental tissues including periradicular radiolucency, PDL widening and disruption or thickening of lamina dura. But in a study by Kositbowornchai, it was concluded that sharpening software has no effect on detection of demineralization on the occlusal surface of teeth. Absence of a real gold standard, dissimilarity in imaging methods, lack of differentiation between teeth samples of upper and lower jaw and deficiency in number of specimens are among some limitations of previous studies. Considering this lack of information, the present study was performed to evaluate digital radiography with and without using sharpening enhancement filter in detection of proximal dental enamel caries in permanent premolars in comparison with the standard method.

Materials and Methods
This diagnostic in vitro study was performed on 80 intact permanent premolars which were extracted due to orthodontic treatments less than 6 months ago. Teeth contained no restoration, cavity, crack, fracture or caries and were kept in formalin 10% solution. After inspecting teeth in adequate light with a sharp dental explorer probe, all 80 teeth were coded and mounted in two blocks with putty impression material and were fixed in XCP film holder in a way that two teeth were in the upper jaw and two in the lower jaw. In this way, 20 blocks of putty each containing 4 teeth were prepared. Initial digital bitewing images were taken with Trophy x-ray system (Finland) with exposure parameters of 0.2 seconds, 65 kVp and 10 mA and total filtration equal to 2.5 mm aluminum with preliminary settings of linear curve (contrast:1, Gamma: 100, brightness:Auto). These images were obtained with Digora Optime receptor with resolution of 12.5 lp/mm and pixel size of 40-64 micrometer and were saved.

On these 20 radiographic images, in addition to the above mentioned settings, option of sharpen=1 was applied and these 20 new images were saved. Then, from each block containing two teeth, one was randomly selected and on one proximal surface a cavity with depth of 1 millimeter was shaped with round bur (number 2) perpendicular to the tooth long axis. Again, from all blocks containing four teeth which two of them contained cavities in one proximal surface, digital bitewing images were obtained and saved and sharpening option was applied on these 20 new images which were saved. (5,6,8-11) 80 study samples included: 20 digital images from intact teeth, 20 digital images from teeth with cavity, 20 sharpened digital images from intact teeth and 20 sharpened digital images from teeth with cavity. Images were coded and printed with Fuji printer (China, 2010) on 20×25 inch radiographic films with blue base with no magnification. Radiographic images were inspected twice by an oral and maxillofacial radiologist blind to the presence or absence of caries, in a time interval separated by two weeks. (12-14)(Figure 1) Data were analyzed by proportion test and Kappa weighted test.

Results
This study was performed on 80 samples of digital bitewing radiography with and without use of sharpening enhancement filter of digital radiography software. The Detection of proximal dental enamel caries in plain digital radiographs compared to gold standard (enamel caries, shaped with round bur number 2) is presented in table 1. This table shows that if inspection of plain digital radiographs reveals that a tooth is carious, that tooth contains caries with 97% confidence level. (PPV=97) Total efficiency of digital radiography is 90%.

If inspection of plain digital radiographs reveals the presence of caries, then the diagnosis is correct with 98% confidence level. The accuracy of the standard method as a gold standard is 93%.

Table 1: Proportion test

<table>
<thead>
<tr>
<th>Condition</th>
<th>Caries Detection</th>
</tr>
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<tbody>
<tr>
<td>Caries</td>
<td>39 (97%)</td>
</tr>
<tr>
<td>No Caries</td>
<td>1 (3%)</td>
</tr>
</tbody>
</table>

PPV = 97%

PPV = Positive Predictive Value

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that a tooth has no caries, that tooth is free of caries with 84.8% confidence level. (NPV=84.8)

Distribution of samples based on detection of proximal enamel caries in sharpened digital radiographs compared to gold standard is presented in table 2 which shows that if inspection of sharpened digital radiographs reveals that a tooth is carious, that tooth contains caries with 91.2% confidence level. (PPV=91.2).

If inspection of sharpened digital radiographs reveals that a tooth has no caries, that tooth is free of caries with confidence level of 80.4%. (NPV=80.4) Total efficacy after using digital software is 85%.

Table 3- Distribution of samples based on correct diagnoses (correct detection of caries and correct detection of absence of caries) and incorrect diagnoses (false positive and false negative) divided by two radiography methods

<table>
<thead>
<tr>
<th>Detection of actual inter-proximal caries</th>
<th>Correct (True positive, true negative)</th>
<th>Incorrect (False positive, false negative)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plain</td>
<td>72 (90)</td>
<td>8 (10)</td>
<td>80 (100)</td>
</tr>
<tr>
<td>Sharpened</td>
<td>68 (85)</td>
<td>12 (15)</td>
<td>80 (100)</td>
</tr>
</tbody>
</table>

Distribution of samples based on correct diagnoses (correct diagnosis of caries and correct diagnosis of absence of caries) and incorrect diagnoses (false positive and false negative) based on two methods of imaging is presented in table 3 and shows that in sharpened images, 11 diagnoses (14.1%) were incorrect and in plain digital radiography 8 detections (10%) were incorrect. Proportion test showed that this difference is not statistically significant. (p<0.4)

Discussion

This study showed that sharpening enhancement filter had no effect on detection of caries or absence of caries.

Although recognition of digital imaging technology is more restricted in dentistry compared to medicine, difficulties caused by chemical film processing and their effect on the diagnostic
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quality of radiographs are among well-known problems in dental radiography. 15, 16 Digital imaging omits chemical film processing and eliminates the hazardous waste products in shape of chemical substances and aluminum foils. Also digital images can be transferred electronically to other health-care facilities without any degradation of original quality. In addition, digital intraoral image receptors require less radiation exposure. 2 Since the lesions extended into dentin are detected with more agreement among expert viewers, in the present study caries confined to enamel were considered. 14 This study showed that positive predictive value and negative predictive value for direct digital radiography was 97% and 84.8% and after applying sharpening enhancement filter was 91.2% and 80.4% respectively. Therefore, sharpening filter of digital radiography software does not aid in increasing PPV and NPV.

When sharpening filter is applied, the probability of incorrect diagnosis is 11% but in viewing of plain digital images, the probability of error is 7%. Although this difference is not statistically significant, it is important from the clinical point of view.

Kositbowornchai et al. evaluated the accuracy of detection of occlusal caries on plain digital images and enhanced images with software tools of sharpness, pseudo color and zoom and reported no significant statistical difference between enhanced and plain images. 7 Their result is in line with the results of the present study. Note that the mentioned study was performed with adequate sample size based on definite detection of caries after histologic examination, while the present study was based on artificial caries shaped by bur. Kamburoglu et al. evaluated the enhanced digital images on in detection of vertical root fractures with the aim of comparing plain digital images with images produced by sharpening, zoom in and reverse contrast tools of digital software. 17 They concluded that these enhancement tools could not ease the detection of vertical root fracture. Dissimilar Lesions were considered in the above study and the present study but the results were in agreement regarding the diagnostic accuracy of enhanced digital images.

Azevedo Vaz et al. performed a study on the role of enhanced CBCT images in detection of external root resorption after using sharpening and smooth filters of digital software. 18 The results showed that these enhancements were of slight significance in detection of external root resorption compared to plain images which is in agreement with our results.

Another study was performed on the influence of enhancement compound algorithm of intraoral radiographic images in detection of pathologic lesions including periradicular radiolucency, PDL widening and disruption of lamina dura. Sharpening and histogram equalization enhancements were applied on 10 images. Images obtained after simultaneous use of sharpening and histogram equalization enhancements were superior in detection of all three lesions compared to plain digital images. 3 Since dissimilar lesions were considered in the mentioned study and the present study, the results are not in line with each other. This inconsistency can be due to inadequate sample size and possibility of changes made by magnification or printing of images when viewed by observers. These factors can influence the results of the mentioned study.

Ahmad et al. performed a study on performance of contrast enhancement based on sharpening on detection of pathologic lesions including periradicular radiolucency, PDL widening and disruption of lamina dura. Their result is in line with the results of the present study. 5 In detection of disruption of lamina dura, best results were obtained on simultaneous use of sharpening and contrast enhancements, while in detection of PDL widening and periradicular radiolucency no significant difference was detected compared to plain images. This result is not in agreement with the results of the present study. Dissimilarity in viewing conditions (possibility of applying alterations when viewing images) and different entity of samples are among factors influencing the accuracy of results.

In another study, plain intraoral radiographic images were compared with images obtained after applying sharpening and histogram equalization enhancements in detection of pathologic lesions.
including periradicular radiolucency, PDL widening and disruption of lamina dura. In detection of disruption of lamina dura best results were obtained after simultaneous use of sharpening and contrast enhancement, while in detection of PDL widening and periradicular radiolucency, no significant difference was detected compared to plain digital images. This result is not in line with the results of the present study. Based on the claims made by manufacturers of digital systems, these systems with diverse software tools are made to improve and aid in detection of lesions. Nevertheless, there is not enough clinical evidence on their diagnostic capability. Therefore, investigation in this area can lead to discovery of a new and reliable method for detection of dental and oral lesions which was also the aim of the present study. It should be considered that this study was done in vitro and caries produced by bur cannot simulate what really occurs in oral environment.

**Conclusion**
The results showed that the sharpening enhancement filter of digital radiography could not improve the detection of proximal dental enamel caries compared to plain digital radiography.

**Acknowledgments**
The authors extend their gratitude to N. Vallai for help with the statistical setups.

**Authors’s contributions**
The subject of research has been proposed by L.Hafezi. Data acquisition was performed by S. h. Mirarjomandi. The data were analysed and interpreted by L.Hafezi, S. h. Mirarjomandi, A.Niktash. The manuscript was prepared by A.Niktash and edited by L.Hafezi and A.Niktash. Also A.R.Talaipour has been the advisor of this research work.

**Conflict of interests**
Authors report no conflict of interest related to this study.

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