Diagnostic Accuracy of Digitized Images Using Different Resolution Settings of Digital Camera in Detection of Proximal Caries

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Abstract

Objective: When none of digital systems and scanners is accessible and it is essential to have digitized images of conventional radiographs, digital cameras can be used. The Aim of this study was to investigate whether digital images obtained by different resolutions of a digital camera are matched to the original radiographs in evaluation of caries.

Methods: In this diagnostic accuracy in vitro study the conventional radiographs of168 proximal surfaces of 84 teeth were produced, Then they were digitized with digital camera in three different resolutions; high (2048x1536), medium (1600x1200) and low resolution (480x460). Images were stored in Photoshop7.0 software, and were evaluated by5 observers to show the presence and depth of the caries. Cronbach's α calculated inter-observers agreement and in order to calculate the agreement with original conventional radiographs Kappa index was used.

***Results*:** In assessing the presence of caries, the agreement between low, medium and high resolutions with original radiographs were 0.286, 0.235 and 0 respectively. Also, assessing the depth of the caries agreement was reported0.21, 0.338 and 0.412 respectively. In most instances, there was a fair agreement between the different resolutions and original radiographs. The highest inter-observer's agreement was reported in diagnosis of the presence of the caries with using high resolution (α=0.837) and the lowest inter-observer's agreement was reported in diagnosis of the depth of the caries with medium resolution (α=0.762).There was no significant difference reported in observations of different resolutions and original images.

Conclusion: Using of high-resolution cameras did not show a significant difference with medium and low resolutions in caries evaluations. Therefore, considering the increase in the file size and difficulties in cameras selection, using of high-resolution digital cameras is not necessary in order to increase the diagnostic accuracy of digitized images.

Key words: Dental Caries, Dental Radiography, Diagnosis, Digital, Photography, ROC curve.

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Introduction:

Intraoral digital radiography has widely been used in dentistry because it improves the diagnosis of carious lesions (1). A digital image can be obtained in two ways –direct and indirect. In direct digital imaging the original image is captured in a digital format, but in indirect digital technique, the image is initially captured in an analog format and then converted into a digital format, by using a scanner or a camera (2). Direct digital radiographs are taken by using digital receptors, CCD or PSP. Often different types of scanners are used to digitize the conventional radiographs and produce indirect digital images in most medical centers (3).

When none of these systems are accessible and it is essential to have digitized images of conventional radiographs, digital cameras can be used. Digital cameras in compare with scanners are cheaper and more convenient. Also, these are a faster processes compared with scanners (4-6).
Recently, because of the speed, convenience, no darkroom procedures, ability to change the contrast, brightness and magnification of the images, the use of digital systems has increased. Using of digital radiographs facilitates storing the patient's documents and providing educational files from them in a space saving manner (5-9). Also, it makes the teleradiographic connections between dentists easier compared with duplicating the films, which is a time consuming procedure (10) .
One of the features influencing the price of the digital cameras is their resolution, which is measured by mega pixel. Nowadays, with advancement in technology, different cameras with different resolutions have been introduced. There is no doubt with increasing the resolution, more detail is apparent in the image but more space is needed to store the information and it is more time consuming to transfer them. If the cameras with lower resolution can produce images with acceptable details and adequate diagnostic accuracy, you can easily select the available digital camera and it is not necessary to use high-resolution cameras. The quality of the digital images from scanners and digital cameras has been compared before with conventional images (9, 11, 12).
Several researchers have claimed that density and contrast values of digitized radiographs would not be the identical as those of conventional radiographs, while they can be improved with image processing tools (13). In one report that compared four different film scanners and attended the potential loss of information through scanning, the authors established that the scanners could not create a reliable digital transformation of plain film because of their density range limitation (14). These outcomes match with another study that denoted a major loss of information in scanned original radiographs, particularly in the dark zones (15). But, others have found no differences in resolution between digitized images and the film-based radiographs (16), although the digitized radiographs revealed higher density. Although scanned digitization of conventional radiographs and their similarity with conventional original images has been reported, studies using digital cameras as the means of digitization are exact rare (17, 18).
The present study compared the diagnostic accuracy of digitized images of conventional radiographs by using digital cameras with different resolutions in diagnosis of proximal caries. In this section we emphasize that the presence or absence of caries is not what we are seeking for; what matters in this study is the ability of digitized pictures to reproduce the basic conventional images information or details. That means every other items could be replaced caries; but due to the importance of caries diagnosis in dentistry and minor density changes in primary lesions, we planned our study in this way.

Methods:

This diagnostic accuracy in vitro study was conducted on 84 extracted posterior human teeth. Teeth were evaluated for the absence of gross caries, filling, attrition, fracture and dental anomalies. In total, 168 proximal surfaces were evaluated. The sampling procedure was not random. In order to disinfect the teeth, the sample was kept in Formalin 10% for 24 hours, then teeth were mounted in blocks of stone in a way that in each block, there were three teeth with proximal contact. The blocks thickness was 10 millimeter.
Each block was imaged with an intra oral radiography machine Gendex (Densply

International Inc. IL: USA, 765DC) in 65 kVP and 7 mA. The recommended time for film speed E was 0.30s and the filtration of 2mm Aluminum was used. A handmade device fixed the location of the tube head and teeth and film with 25 cm distance, so the procedure was reproducible. Films were processed with automatic processing device Gendex (Clarimax 300, London).

Then, the processed films were fixed on the negatoscope and a digital camera (Power shot Canon a570 IS, Japan) was used to take the pictures. The distance between the lens of the camera and the radiographs was fixed in 5 cm with a camera tripod. Pictures were taken in three different resolutions: high resolution (2048 x 1536), medium resolution (1600x1200) and low resolution (480x460). The images were then stored with Adobe Photoshop version 7. The images were evaluated on a 15 Inch monitor (LG Flatron W17525, Korea).

Five observers including three radiologists and two general dentists evaluated the three groups of images with different resolutions. A 5-point probability scale as follows: 1: definitely absent, 2: probably absent, 3: unsure, 4: probably present, 5: definitely present, was used for the presence or absence of caries. Also the following scales (6-point scale) were used for the location and depth of the proximal caries; 0: caries absent, 1: external half of the enamel, 2: internal half of the enamel, 3: DEJ, 4: external half of the dentin and 5: internal half of the dentin. There was no time limit for evaluation of the images by the observers. A two- week interval was between the first and the second observations. Also, the conventional radiographs taken at first were used as the Gold standard to compare the results. The reason for choosing the conventional radiographs as Gold standard is explained in conclusion.

SPSS (statistical package for social science) version 16 was used to evaluate the data. The inter-observer agreement in different resolutions was evaluated with Cronbach's Alpha (α) analysis and in order to evaluate the agreement between the diagnosis of different resolutions and the original conventional images as Gold standard the kappa index was used. Also, the Conchran Q test was used to compare the diagnostic accuracy of three resolutions. The possibility of type 1 error (α) was 0.05. In order to have a significant difference the P value should be equal or smaller than 0.05.

Results:

In the five-point probability scale, the average grade for high, medium and low resolutions were 1.47, 1.48 and 1.42 respectively. Also, in the six-point probability scale in diagnosis of depth of the caries with high, medium and low resolution, following average grades were respectively reported: 0.387, 0.357 and 0.35. Other central distribution factors of diagnosis of the caries with conventional original image as Gold standard are reported in table 1.

In order to evaluate the reliability of the observations, Cronbach's Alpha (α) index was used. The result for the diagnosis of the present and depth of proximal caries are as follows:

In analysis of inter-rater agreement of diagnosis of the caries presence with different resolutions of digital cameras, the highest consistency belonged to high resolution (2048x1536) (α=0.837). The Cronbach's Alpha (α) index reported for moderate and low resolutions were 0.817 and 0.777 respectively. Accordingly, the inter-rater agreement of the observers for high and low resolutions was similar. The reported value for moderate resolution was lower. However, the inter-rater values of all resolutions were close.

Moreover, in analysis of inter-rater agreement of diagnosis of the depth of proximal caries, the highest agreement belonged to high resolution (1536x2048) (α= 0.82) and in medium (1400 x 1200) and low (460x480), the agreement was

0.762 and 0.775.

In order to evaluate the agreement between different resolutions and results of original conventional radiographs in diagnosis of the presence of proximal caries Kappa index was used. Accordingly, the highest agreement reported belonged to original radiographs and low resolution (460x480) (k=0.286). The kappa index reported for medium resolution (1600x1200) and high resolution (2048x1536) was 0.235 and 0 respectively. Based on this, the agreement between the result of low and medium resolutions with original radiographs in diagnosis of the presence of proximal caries was fair. However, there was a poor agreement between the high resolution and original conventional radiographs (table 2).

Table 1- Central distribution parameters of diagnosis of proximal caries and the location (depth) of the caries with different resolution of digital camera.

Resolution/diagnosis parameter	Mean	Standard Error of Mean	Median	Standard Deviation
Diagnostic status of proximal caries in Camera resolution of 2048 x 1536 (scale 15)	1.47	0.88	1.0	1.15
Diagnostic status of depth of proximal caries in camera resolution of 2048 x 1536 (scale 05)	0.387	0.09	0	1.17
Diagnostic status of proximal caries in Camera resolution of 1200 x 1600 (scale 15)	1.48	0.089	1.0	1.15
Diagnostic status of depth of proximal caries in camera resolution of 1200 x 1600 (scale 05)	0.357	0.086	0	1/18
Diagnostic status of proximal caries in Camera resolution of 480 x 460 (scale 15)	1.42	0.089	1.0	1.15
Diagnostic status of depth of proximal caries in camera resolution of 480 x 460 (scale 05)	0.35	0.087	0	1.12
Diagnosis of proximal Caries in original conventional radiographs	1.67	0.11	1.0	1.47
Diagnosis of depth of proximal caries in original conventional radiographs	0.446	0.088	0	1.14

Table 2- Result of the agreement between the observations and the original conventional radiographs in different resolutions in diagnosis of the presence and location of the caries with cronbach's alpha test

Resolution/ Variable	Kappa index
2048x1536/ presence or absence of the caries	0.000
2048x1536/ location of the caries	0.210
1600x1200/ presence or absence of the Caries	0.235
1600x1200/ location of the caries	0.338
480x460/ presence or absence of the Caries	0.286
480x460/ location of caries	0.412

The highest agreement reported in diagnosis of the location of the caries belonged to high resolution (k=0.412). The kappa indices reported for medium resolution and low resolution were 0.338 and 0.210, respectively. Therefore, there was a moderate agreement with original radiographs and high resolution images in diagnosis of the location of the proximal caries and the agreement for low and medium resolutions was fair. Given the larger kappa index of the high resolution images in diagnosis of the proximal caries, the resulting images was

in more agreement with the original radiographs and showed higher diagnostic accuracy (table 2). Based on the results of the present study, the area under the ROC curve for medium resolution was 0.736. However, the area under ROC curve for high and low resolutions was close together: 0.602 for low resolution and 0.710 for high resolution (Diagram 1).

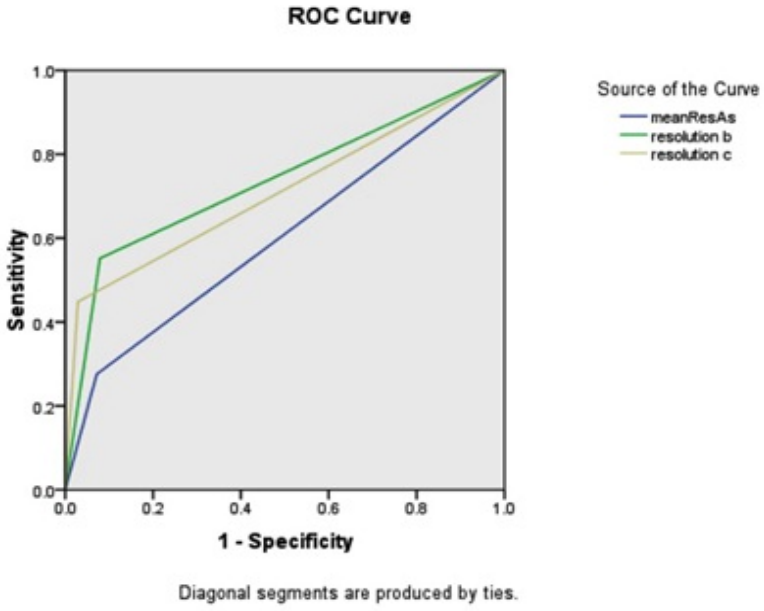

Diagram 1- The ROC (Receiver Operating Characteristic) of the low, medium and high resolutions of the camera

The specificity and sensitivity of the high and medium resolutions was close however, the specificity and sensitivity of the low resolution was in the acceptable range. In addition, the diagnostic accuracy of three resolutions using the Cochran Q test was evaluated and the result was significant ($p<0.05$). Accordingly, there was a significant difference among diagnosis performed by five different observers in three different resolutions.

Discussion:

In this study, to investigate how much original conventional radiographs details had been saved in digitized format in different resolutions of camera, the location and depth of caries in digitized images of camera were compared with conventional radiographs. As Peterz *et al.* research in 2009 (18) in our study the Gold standard was the conventional radiographs and the histopathology could not be considered as the Gold standard; since consider that there is an initial caries lesion in enamel and because of low mineralization it is not imaged on conventional radiographs, so the digitized images of camera will not be able to show these lesions and in this case if the histopathologic sections are considered as Gold standard, the absence of caries appearance on digitized images will be considered as an impotence or poor ability of this method; But this is not correct because practically digitized images, as mentioned before, are prepared based on conventional radiographs, which hadn't been able to show this details.

Based on the present study, observers showed high level of agreement in diagnosis of proximal

caries and the depth of these lesions with three different resolutions in digitalized radiographs. The highest agreement with conventional radiographs belonged to the high-resolution images in diagnosis of the presence of the lesions and the lowest agreement belonged to the medium resolution in diagnosis of the depth of the caries. Moreover, the results show fair to poor agreement with original radiographs in diagnosis of the presence of proximal caries. The results for the depth of the caries show fair to moderate agreement with the Gold standard.

As well, the area under the ROC curve shows the highest sensitivity and specificity belonged to the digitalized images with medium resolution (1600x1200), however, the area under curve reported for two other resolutions were also high and close to the medium resolution.

The result of these study parallels Peterz B. *et al*. research in 2009 that investigate whether digital images obtained by a digital camera are deficient compared to the original radiographs. They reported that storing existing radiographs in a digital medium for space saving purposes using a digital camera does not loose critical information and Clinicians can use digital cameras to digitize and store radiographic images without losing important diagnostic information (18).

Valizadeh *et al.* (2008) reported comparable accuracy of diagnosis of the presence and depth of caries of digitized images with camera and scanner. So that, there is a moderate agreement between these two techniques (19). Although, in this study, the different digital imaging modalities were compared, the results are comparable with different resolutions of the present study.

Berkhout *et al*. (2007) compared the accuracy of diagnosis of proximal caries with standard and high-resolution digital radiographs (20). In this study, no significant difference between different resolutions was reported, which is similar to our results. However, the absence of significant difference between different resolutions does not prove that there is no advantage in applying different or higher resolutions. There is no doubt; the endodontic files in higher resolution digital cameras are easier to be localized, while there are some limitations in application of lower resolutions. In the present study, with consideration of the diagnostic grades of the digitalized images, all three resolutions represent almost same level of accuracy in diagnosis of proximal caries. So, diagnostic accuracy of low and moderate resolutions is efficient in diagnosis of the presence and depth of the proximal caries. The main advantage of low and moderate resolution (18) is the smaller size of the saved files and consequently making the procedure of transfer them through Internet easier.

With respect that in the present study the depth of the proximal caries was based on a five-level (grade) criteria, and it differs for one level in different regions, the difference between the diagnosis and original radiographies limited. If the average of the difference between the diagnosis and original radiograph in the external half of the enamel was 0.1, there was false positive result and the patient treatment will not be adequate. An average difference of 0.1 in the internal half of the enamel requires the minimal invasive treatment. Considering the minimal differences between the observed caries depth and the original image, this difference does not influence the clinical decision. In general, the diagnostic accuracy of the high resolution digital cameras and the highest diagnostic accuracy of low and medium resolutions is almost in the same range.

The result of the present study matches other studies in some extent (21). In the present study, observers were asked to determine the quality of the images subjectively. However, in the Prapayasatok *et al*. (2006) study with using consumer- graded digital camera, reported these cameras can be used to digitalize the images(9).

Also, Brault *et al*.(2004) compared seven digital cameras and reported that cheap digital cameras are not a good choice for teleradiography. Digital cameras used in this study were in the average price range and the digitized conventional images with these cameras represent an adequate diagnostic accuracy in diagnosis of the presence and depth of the proximal caries (22). Considering the time interval between two studies, the advancement of digital technology and introduction of new cameras with reinforced technology, the comparison between two studies is not reliable. Since digital imaging is a new method, the level of familiarity and knowledge of the dentists influences the accuracy of this technique. Therefore, the knowledge of the dentist acts as an interventional factor in the results (23, 24).

Paurazas *et al*. in 2000 compared the accuracy of different image receptors in diagnosis of proximal caries. In their study the diagnosis of the caries was influenced by the depth of the lesion, however, the depth of the lesions was underestimated. Their study showed that radiologists performed better than general dentists (25). These results were also observed in the present study and different observers show different diagnostic accuracy with digital systems. This can be the result of the different level of experience, different level of education and different visual perception of the observers (8, 25) . On the other hand, general dentists may have less diagnostic efficiency in compared with radiologist, however, regardless of the type of the imaging modality, radiologist showed significantly higher accuracy in diagnosis of caries and the actual depth of them.

Conclusion:

The present study revealed that using of high-resolution cameras did not show a significant difference with medium and low resolutions in caries evaluations. Therefore, considering the increase in the file size and difficulties in cameras selection, using of high-resolution digital cameras is not necessary in order to increase the diagnostic accuracy of digitized images

Conflict of Interest: "None Declared"

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