Comparative evaluation of performance of image processing using reverse contrast and sharpen filters in indirect digital radiography (PSP) for diagnosis of furcation involvement grade I & II (In vitro study)

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ABSTRACT

Background and Objectives: Most of the digital imaging systems have various image processing techniques. The purpose of this in vitro study was evaluation and comparison in the performance of reverse contrast and sharpens software in indirect digital radiography images (PSP) for detecting tooth furcation involvements (grade I and II). *Materials and Methods*: 41 extracted first and second mandibular molars were mounted and periapical indirect digital radiographies (PSP) were prepared, then they aggregate in three groups: 1. Control group 2. Simulation of furcation involvement grades I and 3. Simulation of furcation involvement grade II. Then digital software Inversion and sharpening filters was applied on the radiographs. Two observers evaluated the images and

rated them from 0 to 2 (0=no furcation involvement, 1=grade I, 2=grade II). Specificity and sensitivity for each image group were calculated. *Results*: The sensitivity of observers for recognizing furcation involvement in PSP radiographs without any image processing were 53/7%, 70/7% respectively whereas the values for reverse contrast filtered images were 46/3%, 73/2% respectively and also about applying Sharpen Filter on PSP radiographs were 39%, 82/9% respectively, which showed the sensitivity of detection in the three groups was distinct but there was no statistical difference. The specificity of unprocessed Radiographs (63/4%) was less than reverse contrast filtered (75/6%) and sharpening filtered images (82/9%) but the significant difference was seen just in sharpen filtered images group. *Conclusions*: Application of filters, reverse contrast and sharpen, in digital radiography does not make progress in detecting furcation involvement.
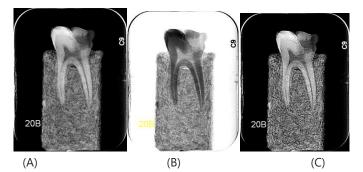
1. INTRODUCTION

Advanced periodontal disease and associated bone resorption may involve multiple root teeth furcation. The widening of the periodontal ligament space in the intraradicular bone is a strong evidence of this conflict in the furcation area. If the bone loss is sufficiently experienced in the buccal and lingual furcation of the mandibular molar, the lesion will have a clear radiolucent image (Sc & Pharoah, 2009). Furcation involvement may be due to a range of factors: (1) determinant factors: inflammation caused by microorganisms in the subgingival biofilm (the most common cause observed in teeth exposed to periodontal disorders). (2) Predisposing factors: enamel projection into the furcation, proximity of the furcation to the CEJ, accessory canals and the presence of interradicular canals on the floor of the pulp cavity, (3) modifying factors: trauma from occlusion possibly leading to greater bone loss and worsening the patient's condition (Gusmão et al., 2014). The furcation involvement usually occurs in the first molars in lower jaw and involves the mesial area of the first molars of upper jaw, unlike the maxillary premolar furcation area, which is very rarely affected. Periodontal disease prognosis is poor for teeth with three roots; so furcation involvement in the mandibular molar, will have a better prognosis (Svärdström & Wennström, 1996) and the conflict is directly proportional with age (Larato, 1970). Clinically, in periodontaly involved teeth, exposure through bifurcation or Trifurcation by X-rays is always a major problem to prepare radiographs (Hou & Tsai, 1987). The most commonly used parameter for diagnosis in the furcation area is the clinical examination of the interradicular space by the Nabers probe. Radiographs are also very helpful, but due to their two dimensional features, they have limitations in the detection of disorders, especially in the area of furcation. In addition, superimposition may also occur depending on the exposure angels and radiopacity of the adjacent structures make this condition worse, but advanced radiography techniques, especially in cases of severe periodontal involvement, can probably, demonstrate furcation involvement in the presence of bone loss, which is subsequently detected better by the probe. However, 30-60% of bone minerality should be eliminated to detect bone changes in radiographs (Reddy, 1992). Regarding to common radiography short comings, researchers have always tried to choose more advanced methods for imaging, Now a days digital radiography is considered as a choice versus conventional (Sakhdari et al., 2011). The benefits of digital radiography include better image quality, less likely to be repeated and therefore reduced patient dose, easy storage and easy retrieval of images, and the ability to exchange information to remote locations (Erdemir et al., 2005). Digital radiography systems have two types of direct and indirect receivers. The photostimulable phosphor plates (PSPs) are indirect types that absorb X-ray energy and then release this energy in the form of light (phosphorescence), when they are stimulated by another light with a proper wavelength (Sc & Pharoah, 2009). Some indirect digital systems have many software options ability, such as inverted contrast, pseudo-color, change in the contrast and brightness of images; many authors evaluate these options in detecting oral and dental lesions (Erdemir et al., 2005; Kositbornchai et al., 2001; Furkart et al., 1992; Wenzel & Gröndahl, 1995; Iannucci & Howerton, 2006; Shooshtari et al. 2020). One of the methods that improves the diagnostic power of the observer is the use of inversion contrast that changes the gray scale of the image by converting low pixel values (dark) to high (bright) values and vice versa. And another process is that changes the image and makes it more comfortable by changing Sharpness (Talaeipour et al., 2015). Sharpen filters eliminate noise, noise is an uneven density view that can be seen in unevenly exposed radiograph and is seen in a small area of the film in the form of localized variations in density sharpen filter Removes the low frequency noise and reinforces the boundaries between different intensities and result in Edge Enhancement (Sc & Pharoah, 2009). Compliance with the principles, evaluation of the quality and efficiency of software, and more precise methods for the preparation of radiographic images can help the early diagnosis of periodontal and bone lesions and thus have a significant effect on the outcome of treatment. Considering the increasing use of digital radiography in diagnosing dental problems, we decided to evaluate the effect of image processing methods on one of the common problems of patients (furcation involvement).
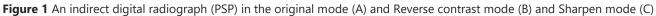
2. MATERIALS AND METHODS

In this invtro study, 41 extracted mandibular first and second molars were collected in 2019. Then bone powder mixed up (at a ratio of 50%) and teeth were mounted individually in the combination as furcation area was invisible. As the control group, all the mounted teeth were evaluated before any furcation simulation involvement. Then, Grade I and II were simulated artificially and radiographs were prepared. In order to create the involvement in furcation area, acryl was removed by a turbine round diamond bur (015), in the Grade I group, acryl removal has been done to entry of the furcation, in Grade II group slightly more to reconstruct 3 millimeter of probing depth in the furcation area while the probe does not come out from the other side of the area (Based on the Glickman's classification of furcation defects).

In this study an indirect digital periapical radiography (PSP) was used (which exposure conditions include: kvp = 70, mA = 8, and s = 0.32). The receptor (PSP) was maintained by a holder at a constant distance of 10 cm to the X-ray tube, waxed block mounted equally between the radiation source and the sensor to stimulate soft tissue. Indirect digital periapical radiographs (PSP) were prepared using parallel technique with the de Gotzen Italian design device then processed by the sordex-finland Digora optime device. The images were stored in a special file and then transmitted to the scanora system by using the processor software, each image was once improved with sharpen and once the inversion filter and then saved. Finally each image had three versions; original, sharpened and inverted. Images of each version were randomly sorted into three separate files and were available for two oral, maxillofacial radiologists those who have at least two years of observing digital images experience for evaluation these files. The presence or absence of furcation involvement and the type of that (grade I or II) were reported by the two observers and then interred in some predefined lists. Observation was performed in the same conditions for each observer. The digital PSP images has been seen in a dark room on a Flat LG 22-inch monitor with a resolution of 1440 x 990 pixels, and the results were coded from 0 to 2 (0 = no furcation involvement, 1 = grade I of involvement, 2.grade II) (Figure 1). Only the executor was aware of the actual answers while observers were unaware. All data is provided to the statistic consultant for statistical analysis.

Figure 1 An indirect digital radiograph (PSP) in the original mode (A) and Reverse contrast mode (B) and Sharpen mode (C)

3. RESULTS

After analyzing the statistical data, the following results were obtained based on the observer's perception: According to the diagrams, the sensitivity and specificity of the radiographs have been investigated in the presence of different filters. Assessing the ability of the observer to detect furcation involvement in indirect digital radiography (PSP) without using any filter: The sensitivity of the indirect digital radiograph (PSP) for diagnosis of grade I and II was 53.7% and 70.7% respectively and specificity of detection healthy teeth was assessed 63.4%. Kappa coefficient is used to check the agreement between two observers and the agreement between them was considered as 100%. The ability of the observer to recognize condition of furcation area by viewing PSP radiographs was effective in diagnosis of control group, grade I, and II involvement respectively (Table 1 and Figure 2).

Table 1 Assessing the ability of the observer to detect furcation involvement in indirect digital radiography (PSP) without using any filter

Golden Standard	Observer detection		
	Normal	grade I	grade II
Normal N= 41 100%	26* 63.4%	15 36.6%	0 0.0%
grade I	16		

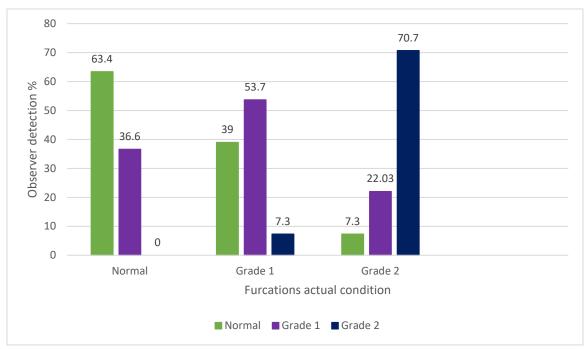| N= 41 100%	39.0%	22 * 53.7%	3 7.3%
grade II N= 41 100%	3 7.3%	9 22.03%	29 * 70.7%
P value≤0.001			

Figure 2 Assessing the ability of the observer to detect furcation involvement in indirect digital radiography (PSP) without using any filter

Evaluation of the ability of observer to detect furcation involvement using reverse contrast filter in indirect digital radiography (PSP): sensitivity of the PSP in diagnosis of grade I and II was 46.3% and 73.2%, and specificity of detection healthy teeth was assessed 73.2%.The ability of observer to detect the condition of furcation area by observing PSP images using reverse contrast filter was significantly higher in the detection of the healthy group, grade II and I, respectively (Table 2 and Figure 3).

Table 2 Evaluation of the ability of observer to detect furcation involvement using reverse contrast filter in indirect digital radiography (PSP)

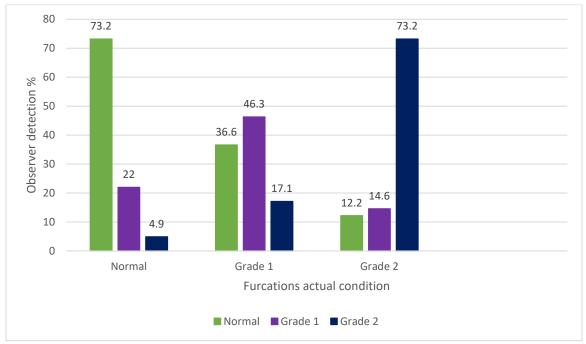| Golden Standard	Observer detection		
	Normal	grade I	grade II
Normal N= 41 100%	30 * 73.2%	9 22 %	2 4.9 %
grade I N= 41 100%	15 36.6 %	19 * 46.3 %	7 17.1 %
grade II N= 41 100%	5 12.2 %	6 14.6 %	30 * 73.2 %
P value≤0.001			

Figure 3 Evaluation of the ability of observer to detect furcation involvement using reverse contrast filter in indirect digital radiography (PSP)

Evaluating the ability of observer to detect furcation involvement by using Sharpen filter in indirect digital radiography (PSP):
The sensitivity PSP in diagnosis of grade I and II was 39% and 82.9% and specificity of detection healthy teeth was assessed 82/9%. The observer's ability to detect conditions of furcation area by observing the images of the PSP radiographs which processed by Sharpen filter was higher for the detection of healthy teeth group, grade II involvement and after that, grade I group (Table 3 and Figure 4).
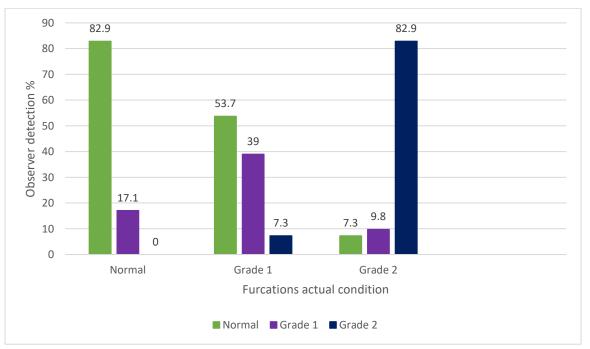

Figure 4 Evaluating the ability of observer to detect furcation involvement by using Sharpen filter in indirect digital radiography (PSP)

Table 3 Evaluating the ability of observer to detect furcation involvement by using Sharpen filter in indirect digital radiography (PSP)

Golden Standard	Observer detection		
	Normal	grade I	grade II
Normal N= 41 100%	34 * 82.9 %	7 17.1 %	0 0.0 %
grade I N= 41 100%	22 53.7 %	16 * 39 %	3 7.3 %
grade II N= 41 100%	3 7.3 %	4 9.8 %	34 * 82.9 %
P value≤0.001			

Evaluate and compare the observer's ability in the diagnosis of furcation involvement (grade I & II) by viewing the indirect digital radiographies (PSP): Radiographic image sensitivity was 76.8% in diagnosis of grade I & II and the specificity was 63.4% in detection of healthy group.

Evaluate and compare the observer's ability in the diagnosis of furcation involvement (grade I & II) by using reverse-contrast filter in indirect digital radiography (PSP): The sensitivity of the reverse contrast processed images was evaluated 75/6% for detection of grade I &II and specificity of the detection of control group was 73.2% so this filter is efficient for detecting both healthy and grade I & II of involvement.

Evaluate and compare the observer ability in diagnosis of furcation involvement (grade I & II) by using sharpen filter in indirect digital radiography (PSP): Sensitivity of digital radiographs by applying Sharpen filter in the diagnosis of grade I & II was estimated 69.5% and specificity for detecting the control group was 82.9%, which indicates the efficacy of this filter in detection of control group versus grade I & II.

Comparison of sensitivity and specificity of indirect digital radiography images (PSP) with and without filter application: G-1) Evaluation and comparison of sensitivity of using reverse contrast filter in PSP with unprocessed images: sensitivity of the radiographic image by applying the filter to unprocessed image in grade I (P≤0.49), grade II (P≤0.796) and grade I, II (P≤0.93) was not significant. G-2) Evaluation and comparison of specificity of the images that processed by reverse contrast filter in PSP with unprocessed images: The percentage of radiographic image specificity does not show a meaningful increase (P≤0.278) by applying reverse contrast filter in compared with unprocessed image. G-3) Evaluation and comparison of sensitivity of Sharpen filtered images in indirect digital radiography (PSP) with unprocessed images: Sensitivity changes were not significant in sharpen filtered radiographs in compared with unprocessed images in grade I (P≤0.15), grade II (P≤0.18) and grade I, II (P≤0.423). G-4) Evaluations and comparison of specificity of sharpen filtered images in indirect digital radiography (PSP) with unprocessed images: The percentage of specificity in sharpen filtered radiographic image in compared with unprocessed image shows a significant increase (P≤0.017).

4. DISCUSSION

Image processing methods are used for improving diagnosis in digital technology. Purpose of these methods is changing one or more image properties, and according to the diagnostic goals, the type of filter would be selected to increase diagnostic value of images. In fact, with the aim of improving the diagnostic feature of digital radiographs, various filters have been used in this technology, but to date, comprehensive studies have not taken place to reach overall conclusion about the use of filters. In a few studies, other specific methods have been used and the use of filters has been less considered. Perhaps improper application of filters and lack of specific criteria for improving the image quality are the barriers to have a clear conclusion of these studies. Considering that early diagnosis of periodontal disease especially furcation involvement, due to the specific position, which is hard to detect in radiographic images, is important; in this study comparison and evaluation of the efficiency of image processing by reverse contrast and Sharpen filters in indirect digital radiography (PSP) to detect Grade I and II Furcation involvement. So 41

extracted first and second molar teeth from lower jaw selected and simulation of furcation involvement Grade I and II artificially performed on them. Then an indirect digital periapical radiography (PSP) was prepared by paralleling technique and these all images were documented and each image was processed once with the Sharpen and once with Inversion filter and then saved. The collected data included the images of healthy and furcation involved teeth were evaluated by two oral and maxillofacial radiologists. It was concluded that there was not statistically significant difference between the sensitivity of unprocessed radiographs, the use of reverse contrast and Sharpen filter for the detection of involvement in the furcation area.

There was no statically significant difference between the specificity of unprocessed radiographs and the reverse contrast filter, but the Sharpen filter specificity was significantly more in processed images in compare with unprocessed radiographs. Quantitative similar studies have been conducted on dental problems; Talaee Pour et al., in 2015, studied about evaluation the accuracy of direct digital radiography by processing with sharpen filter for defection dental caries in premolar teeth. They mounted 80 extracted healthy premolars in blocks, so that there were 2 teeth in the upper jaw and two in the lower, they simulated caries then took direct digital bitewing radiographs then used Sharpen filter of digital software on radiographs and new images were recorded too. 80 images were printed on a film then they evaluated by an oral maxillofacial radiologist. The statistical results showed that Sharpen filter in digital radiography does not increase the ability of detection of interdental enamel caries. Their results are similar to the current study while they used direct digital radiography and researched on enamel carries so the same results of two studies showed that Sharpen filter has not a significant role in detecting dental problems (Talaeipour et al., 2015).

Sakhdari et al. researched on the efficiency of contrast inversion filter in direct digital imaging for diagnosis of horizontal root fractures. Their results indicated a higher sensitivity of digital radiography without any processing but the difference was not statistically significant also results of the current study showed that the difference between sensitivity of unprocessed digital radiographs and inverse processed images for detecting grade I and II of furcation involvement was not statistically significant. Although they used direct digital radiography and performed the study on root fractures, they used a similar software approach and obtained similar results with this study of us (Sakhdari et al., 2011). In a study by Kamboroglu et al., The effect of direct digital radiographic filters for detecting vertical root fractures was evaluated and images that processed by software options such as reverse contrast were compared with primary digital images. This study was performed on 64 mandibular premolar teeth which 32 of them had vertical fractures and 32 selected as control group. They concluded that there was no significant difference between these diagnostic methods. Although direct digital radiography was used in their research that is different from the current study but the results are similar, which questioned the use of reverse contrast processing in detection of various dental problems (Kamboroglu et al., 2010).

Mr. Baksi et al. also evaluated the effect of different image processing filters on the ability of demonstration of anatomical landmarks in panoramic radiography and concluded that conventional and indirect digital panoramic radiography (PSP-based) are equally effective in term of quality. Conventional panoramic images are the best for detecting low-contrast structures, and Sharpen filter had been suggested to improve the observation and detection of most anatomical structures in PSP-based panoramic radiographs. In our study, the Sharpen filter specificity was higher than unprocessed images and the difference was statistically significant. But the sensitivity of this filter was not significantly different from the unprocessed images (76.3%) in detection of furcation involvements. Although they used panoramics, while periapical images were used in our study and also they noted the normal landmarks but we studied on the Furcation involvement, considering that specificity refers to the healthy cases and anatomical landmarks are also indicate a healthy state so we can say that our results are similar to the results of the Baksi's study. Therefore, sharpen filter is more valuable to detect healthy cases (Baksi et al., 2010).

Dabaghi et al. also studied to compare the diagnostic quality of anatomical structures and the overall quality of the image by using various medical image processing techniques in direct digital panoramic radiography. They used Shadow, Sharpen, Sigmoidal, Exponential, Negative, Embossed 3D processing methods, and concluded that the best diagnostic quality for all anatomical landmarks and overall image quality was obtained by sharpen processing method. The second method for maxillary sinus landmark, dental canal space and (Dentino enamel Junction) DEJ was related to the Negative processing, and for general image quality, upper and lower end of mandibular canal, periodontal ligament space, mandibular lower cortex and bone trabecular pattern, unprocessed method was used. The results are different from the results of our study. Of course, in the current research, specificity of Sharpen filter was significantly different from unprocessed images, therefore, as in the Baksi's study, we may conclude that the results of this study are similar to Siahtiri's research, which their results were similar to ours in the diagnostic quality of anatomical landmarks which refers to healthy state. So as our results sharpen filter is more valuable to detect healthy cases (Siahtiri et al., 2018).

Ji-Unlee et al. studied to evaluate the precision of unprocessed direct digital radiography [CMOS] and inversed image for detecting vertical root fracture. This study was performed on 60 single-rooted teeth with closed apex, 30 of them had root fractures and 30 as control group. For performing radiography they used paralleling technique. Four observers examined the samples at three

times in four weeks. The final result showed that the sensitivity and specificity of digital radiography without using any filter and reverse processed ones were not statistically significant; therefore, their results are similar to the results of this study which shows that the sensitivity and specificity of the images that processed with inverse contrast filter are not significantly different from the unprocessed images. Although direct digital radiography (CMOS) is used in this study and differs from our method, the insignificance of their results, like the results of the present study, suggests that the inverse contrast processing method does not improve the diagnostic values (Lee et al., 2004).

According to the results of this study and previous researches, it seems that Sharpen and reverse contrast filters do not add any diagnostic value to detect the involvement of grade I and II by using indirect digital periapical radiography (PSP) so their only advantage is the Sharpen filter's superior specificity and the correct diagnosis of intact teeth.

5. CONCLUSION

According to the present study, there was no significant difference between the specificity and sensitivity while using the reverse contrast filter. However about the sharpen filter, there was not significant difference in sensitivity while using it or not too, but there was significant difference in the specificity of using it. So considering controversies in other articles results, it seems like there should be more researches on this subject of application of Sharpen and reverse contrast filters for detecting grade I and II furcation involvement in indirect digital radiography (PSP).

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Data and materials Availability

All data associated with this study are present in the paper.

Peer-review

External peer-review was done through double-blind method.

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