In Vitro Efficacy of Reverse Contrast and Sharpen Image Processing Filters of Indirect Digital Radiography for Calculus Detection

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Abstract

Background and Objectives

Early detection and elimination of dental calculus are imperative for prevention and management of periodontal disease. This study aimed to assess the efficacy of reverse contrast and sharpen image processing filters of indirect digital radiography for calculus detection.

Materials and Methods:

In this in vitro, experimental study, 95 extracted human premolars were mounted in a sheep mandible, and underwent digital radiography. Pieces of calculus measuring 0.5 mm in diameter were then adhered to the cementoenamel junction of the teeth and they underwent digital radiography again. Next, the radiographs were enhanced once with the sharpen, and once with the reverse contrast image processing filter. All radiographs were then observed by two observers. The sensitivity, specificity, and positive (PPV) and negative (NPV) predictive values were calculated.

Results:

The sensitivity, specificity, PPV and NPV of original radiographs, those enhanced with sharpen, and those enhanced with reverse contrast were 31%, 96%, 88% and 58%, 41%, 96%, 91%, and 62%, and 33%, 99%, 97% and 59%, respectively. The sharpen filter resulted in higher sensitivity than original images and those enhanced with reverse contrast. Reverse contrast resulted in higher specificity than the other two image types. However, none of these differences were statistically significant (P>0.05).

Conclusion:

Reverse contrast and sharpen image processing filters could not significantly enhance the detection of calculus on digital radiographs.

Keywords: Calculus; Radiography, Dental, Digital; Reverse Contrast; Sharpen; Image Processing Filters.

Introduction

Difficult interpretation of intraoral radiographs and radiographic detection of oral and dental lesions in early stages is a common problem for many dental clinicians [1]. Due to the adverse effects of inadequate film processing on diagnostic quality of images, and difficulties encountered in chemical film processing, the conventional film-based radiography is increasingly replaced with digital radiography [2]. Digital radiographs can be enhanced by the use of image processing filters to improve the quality of images and decrease the confounding factors that compromise image quality. Moreover, dental clinicians can adjust the contrast and brightness of images to make them more suitable for specific diagnostic purposes [3,4].

Image processing algorithms are used for digital images to optimize the interpretation of radiographic data [5]. Reverse contrast and sharpen are among the most commonly used image processing filters to improve the diagnostic value of images. Reverse contrast changes the gray scale of images by converting the dark pixels to light pixels and vice versa [6]. The conventional radiographic films are only available in reverse mode (bones appear white). However, the polarity of gray scale of digital images can be reversed by applying the reverse contrast filter (bones appear black) [7,8]. Sharpen is another image processing filter, which is used to improve the quality of images by elimination of blurring and noise [9].

Calculus is the mineralized form of dental plaque. Soft plaque is calcified by the deposition of mineral salts. Presence of microorganisms is not necessary for calculus formation. Calculus can form on natural teeth and prosthetic restorations. Also, calculus can be classified as supragingival and subgingival calculus depending on its location relative to the gingival margin. A positive correlation exists between the presence of calculus and gingival inflammation [10]. Calculus creates a suitable environment for further plaque accumulation, leading to periodontal disease. Supragingival and subgingival calculus in interproximal areas may be visualized and detected on radiographs with an opaque appearance. However, it should be noted that the sensitivity of radiography for calculus detection is often low [10].

Although definite diagnosis of calculus can be achieved by clinical examination, its early radiographic detection can be of great help to prevent the progression of periodontal disease. On the other hand, evidence shows that some residual calculus may remain in hard-to-reach areas after scaling of periodontal pockets deeper than 7 mm, even if performed by a periodontist [11]. Optimal-quality radiography may be able to reveal the residual calculus and enable more effective monitoring of the treatment quality. Also, image processing filters of digital radiography may be effective for this purpose. However, previous studies have reported controversial results regarding the diagnostic efficacy of reverse contrast and sharpen image processing filters [12-15].

Considering the gap of information on this topic, this study aimed to assess the efficacy of reverse contrast and sharpen image processing filters of indirect digital radiography for calculus detection.

Materials and Methods

This in vitro, experimental study evaluated 95 freshly extracted human premolars. The teeth had no calculus and were extracted for orthodontic purposes. The study was approved by the ethics committee of Ahwaz University of Medical Sciences (IR.AJUMS.REC.1397.221).

Sample size was calculated to be 95 in each of the test and control groups according to a previous study by Sharifi et al, [16] assuming alpha=0.05 and d=0.1.

After disinfection, the teeth were mounted in a sheep mandible. For soft tissue simulation, two layers of wax were placed between the X-ray tube and the sheep mandible. The teeth then underwent digital radiography with the parallel technique by an intraoral X-ray unit (Xgenus DC de Gotzen, Italy) with the exposure settings of 70 kVp, 8 mA, and 0.32 s time. Indirect digital photostimulable phosphor plate (PSP) sensors were used in this study. The PSP sensors were held by a holder at 10 cm distance from the X-ray tube. The mounted teeth had equal distance from the PSP sensor and the X-ray tube. Original radiographs obtained from the teeth served as the control group. Next, pieces of calculus measuring 0.5 mm in diameter were adhered to the teeth in their cervical area below the alveolar crest and the teeth underwent indirect digital radiography again with the same exposure settings. The obtained radiographs were processed by a scanner (Digora Optime, Soredex, Finland). The images were saved and transferred to Scanora version 3.1.1 software. Using the processing software, each image was processed once with the sharpen filter by 2 degrees and once by the reverse contrast, and saved. Thus, eventually, three versions of each image were obtained: the original version, the radiograph enhanced with the sharpen filter, and the radiograph enhanced with the reverse contrast filter. The images of the teeth with and without calculus were coded and randomly arranged in a PowerPoint slide show. Two oral and maxillofacial radiologists with a minimum of 2 years of experience in interpretation of digital images observed the slide show twice with a 2-week interval on a 14-inch LED monitor (Sony Vaio; Sony, Japan) with 1366 x 768 resolution under similar lighting and environmental conditions.

The observers expressed their opinion regarding presence/absence of calculus using a 5-point scale (0: definitely no calculus, 1: probably no calculus, 2: Uncertain, 3: Probable presence of calculus, 4: Definite presence of calculus). The data were recorded in a checklist and analyzed using SPSS version 22 (SPSS Inc., IL, USA). The sensitivity, specificity, accuracy, positive predictive value (PPV) and negative predictive value (NPV) of each imaging mode were calculated and reported. The Kappa statistics was used to analyze the intra- and inter-observer agreements regarding the diagnoses. The receiver operating characteristic (ROC) curve was drawn to determine the sensitivity and specificity values.

In this study, sensitivity was defined as the ability to correctly detect the presence of calculus. Specificity was defined as the ability to correctly detect the absence of calculus.

Results

Diagnostic parameters of original digital radiographs for detection of calculus:

Table 1 shows the sensitivity, specificity, accuracy, PPV and NPV of original digital radiographs for detection of calculus. The Kappa coefficient showed a significant agreement between the two observers in interpretation of original radiographs (kappa coefficient: 0.197, P=0.006).

Table 1. Sensitivity, specificity, accuracy, positive predictive value (PPV) and negative predictive value (NPV) of original digital radiographs for detection of calculus

Observer	Diagnosis	Tooth: Absence of calculus	Tooth: Presence of calculus	Total	Sensitivity	Specificity	Accuracy	PPV	NPV
First	Absence of calculus	86	63	149	0.34	0.91	0.62	0.78	0.58
	Presence of calculus	9	32	41					
	Total	95	95	190					
Second	Absence of calculus	91	66	157	0.31	0.96	0.63	0.88	0.58
	Presence of calculus	4	29	33					
	Total	95	95	190					

Diagnostic parameters of digital radiographs enhanced with the sharpen filter for detection of calculus:

Table 2 shows the sensitivity, specificity, accuracy, PPV and NPV of digital radiographs enhanced with the sharpen filter for detection of calculus. The Kappa coefficient showed a significant agreement between the two observers in interpretation of digital radiographs enhanced with the sharpen filter (kappa coefficient: 0.505, P<0.001).

Table 2. Sensitivity, specificity, accuracy, positive predictive value (PPV) and negative predictive value (NPV) of digital radiographs enhanced with the sharpen filter for detection of calculus

Observer	**Diagnosis**	**Tooth:** Absence of calculus	**Tooth:** Absence of calculus	**Total**	**Sensitivity**	**Specificity**	**Accuracy**	**PPV**	**NPV**
First	Absence of calculus	88	55	143	0.42	0.93	0.67	0.85	0.62
	Presence of calculus	7	40	47					

	Total	95	95	190					
Second	Absence of calculus	91	56	147	041	0.96	0.68	0.91	0.62
	Presence of calculus	4	39	43					
	Total	95	95	190					

Diagnostic parameters of digital radiographs enhanced with the reverse contrast filter for detection of calculus:

Table 3 shows the sensitivity, specificity, accuracy, PPV and NPV of digital radiographs enhanced with the reverse contrast filter for detection of calculus. The Kappa coefficient showed a significant agreement between the two observers in interpretation of digital radiographs enhanced with the reverse contrast filter (kappa coefficient: 0.313, P<0.001).

Table 3. Sensitivity, specificity, accuracy, positive predictive value (PPV) and negative predictive value (NPV) of digital radiographs enhanced with the reverse contrast filter for detection of calculus

Observer	**Diagnosis**	**Tooth**		**Total**	**Sensitivity**	**Specificity**	**Accuracy**	**PPV**	**NPV**
		Absence of calculus	Absence of calculus						
First	Absence of calculus	92	76	168	0.20	0.97	0.58	0.86	0.55
	Presence of calculus	3	19	22					
	Total	95	95	190					
Second	Absence of calculus	94	64	158	0.33	0.99	0.66	0.97	0.59
	Presence of calculus	1	31	32					
	Total	95	95	190					

Since the accuracy and intra-observer agreement of the second observer in use of reverse contrast and sharpen imaging processing filters and also for original radiographs were higher than the first observer for calculus detection, only the results of the second observer were further analyzed as follows:

Comparison of original images and those enhanced with reverse contrast and sharpen filters regarding their diagnostic parameters for detection of calculus:

Table 4 compares the diagnostic parameters of original digital images and those enhanced with sharpen and reverse contrast filters for calculus detection. As shown, no significant difference was noted among the three imaging modes in any diagnostic parameter with regard to calculus detection (P>0.05).

Table 4. Comparison of the diagnostic parameters of original digital images and those enhanced with sharpen and reverse contrast filters for calculus detection

Diagnostic parameter	**Radiographs**		**P value**
Sensitivity	0.31 = Original	0.41 = Sharpen	0.130
	0.31 = Original	0.33= Reverse contrast	0.755
	0.41 = Sharpen	0.33 = Reverse contrast	0.229
Specificity	0.96 = Original	0.96 = Sharpen	1.000
	0.96 = Original	0.99= Reverse contrast	0.174
	0.96 = Sharpen	0.99 = Reverse contrast	0.174
PPV	0.88 = Original	0.91 = Sharpen	0.925
	0.88 = Original	0.97= Reverse contrast	0.786
	0.91 = Sharpen	0.97 = Reverse contrast	0.844
NPV	0.58 = Original	0.62 = Sharpen	0.726
	0.58 = Original	0.59= Reverse contrast	0.888

	0.62 = Sharpen	0.59 = Reverse contrast	0.831

PPV: Positive predictive value; NPV: Negative predictive value

ROC curve:

In ROC curves, the farther the curve from the reference diametrical line and the larger the area under the curve, the more accurate the diagnosis of the observer would be. Figure 1 shows the ROC curve for determination of sensitivity and specificity of original digital radiographs, and in use of sharpen and reverse contrast filters for calculus detection by the first observer. The area under the curve was 0.62 for original digital radiographs, 0.67 for original digital radiographs enhanced with the sharpen filter, and 0.58 for original digital radiographs enhanced with the reverse contrast filter.

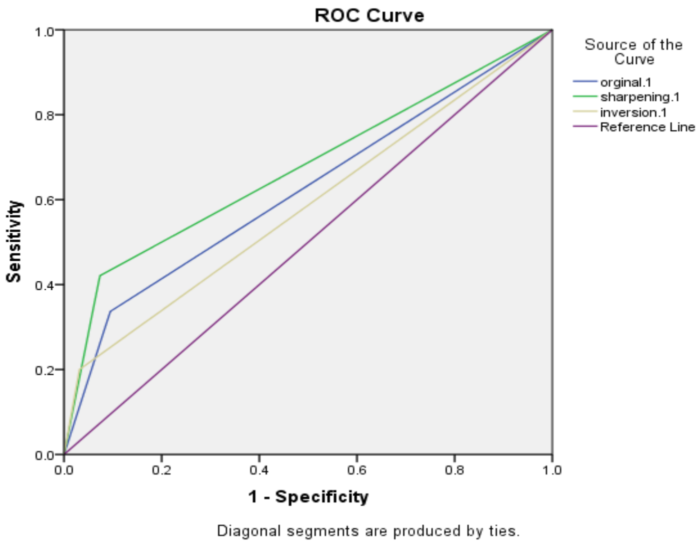

Figure 1. ROC curve for determination of sensitivity and specificity of original digital radiographs, and in use of sharpen and reverse contrast filters for detection of calculus by the first observer

Figure 2 shows the ROC curve for determination of sensitivity and specificity of original digital radiographs, and in use of sharpen and reverse contrast filters for calculus detection by the second observer. The area under the curve was 0.63 for original digital radiographs, 0.68 for original digital radiographs enhanced with the sharpen filter, and 0.66 for original digital radiographs enhanced with the reverse contrast filter.

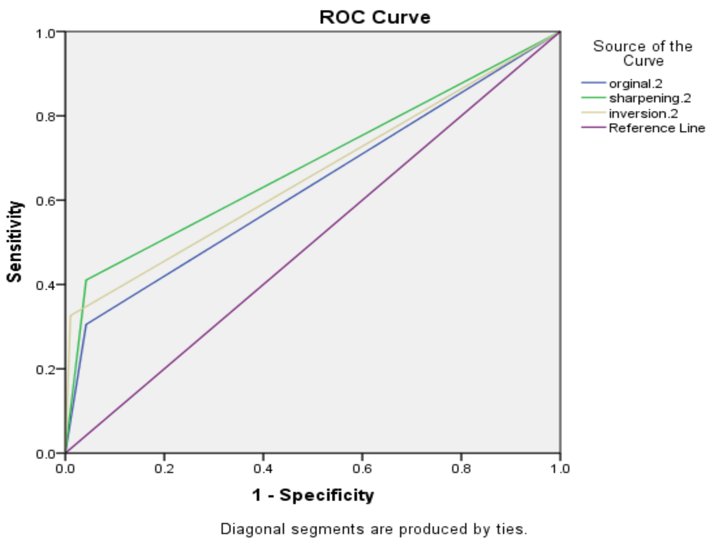

Figure 2. ROC curve for determination of sensitivity and specificity of original digital radiographs, and in use of sharpen and reverse contrast filters for calculus detection by the second observer

Discussion

Considering the significance of detection of subgingival and supragingival calculus in treatment of periodontal disease, this study assessed the efficacy of reverse contrast and sharpen image processing filters of indirect digital radiography for calculus detection. Since no significant difference was noted between the two observers in diagnostic parameters, and the accuracy and intra-observer agreement of the second observer were higher, we analyzed the data from the second observer. The results revealed no significant different among the three imaging modes in any diagnostic parameter.

Several previous studies have evaluated the diagnostic efficacy of digital images and their enhancement filters for detection of different oral and dental conditions. Mehralizadeh et al. [14] evaluated the diagnostic accuracy of reverse contrast image processing filter for detection of vertical root fractures, and found that this filter could not increase the sensitivity, specificity or accuracy of detection of root fracture. Although they evaluated vertical root fractures instead of calculus, their result regarding inefficacy of reverse contrast filter for enhanced diagnosis was in agreement with our finding. Sharifi et al. [17] evaluated the efficacy of reverse contrast and sharpen image processing filters for linear measurements in teeth under endodontic treatment. They reported that reverse contrast had lower measurement error and yielded more actual values compared with sharpen, and no-filter radiographs. Difference between their results and ours can be due to the fact that they used filters for a different purpose. Although in our study the reverse contrast filter showed slightly higher specificity, it was not statistically significant. Sakhdari et al. [18] evaluated the efficacy of reverse contrast for detection of horizontal root fractures and found no significant difference between the original and enhanced radiographs regarding sensitivity, specificity, PPV and NPV. Although they evaluated horizontal root fractures, their result regarding inefficacy of reverse contrast for enhanced diagnosis was in line with ours. Sharifi et al. [16] used reverse contrast and sharpen filters for detection of grades I and II furcal involvement and reported that these filters did not enhance the detection of grades I and II furcal involvement. However, the sharpen filter had the advantage of higher specificity for correct detection of teeth without furcal involvement. Their results regarding the sensitivity values of enhanced images were in agreement with our findings. However, their finding regarding higher specificity of sharpen filter was different from ours, which may be due to the fact that they assessed furcal involvement while we assessed calculus detection.

In general, the results regarding the diagnostic efficacy of image processing filters of digital radiography for detection of oral and dental conditions have been controversial. For instance, De Araujo et al, [19] and Tyndall et al. [20] reported that enhanced images had lower diagnostic value than the original digital images for caries detection. Tofangchiha et al. [12] evaluated the efficacy of reverse contrast for detection of vertical root fractures, and reported that original images had significantly higher sensitivity, specificity and accuracy for this purpose. In our study, the difference in diagnostic parameters was not significant among the three image modes. Lee et al. [21] reported slightly, but insignificantly, higher specificity of reverse contrast compared with original images for detection of horizontal root fractures. Their results were in accordance with our findings; although they evaluated horizontal root fractures and not calculus. Miri et al. [22] evaluated the efficacy of reverse contrast filter for detection of interproximal dentin caries and found no significant difference between reverse contrast and original digital radiographs in this respect, which was in line with our results. Kamburoglu et al. [15] reported that use of sharpen and reverse contrast added no advantage to the detection of vertical root fractures. Similar results were reported by Brullmann et al [23].

In general, controversy in the results of studies can be due to a number of factors. Radiographic interpretation for the purpose of diagnosis is highly sensitive, and several factors can affect the judgment of the observers such as the imaging system (digital or conventional), characteristics of the display monitor, observation conditions, and experience and expertise of the observers [14,24]. Thus, the efficacy of digital image processing filters also depends on the experience, skills and mentality of the observer [12,14,24].

The majority of previous studies on the efficacy of digital image processing filters evaluated the detection of oral and dental conditions such as root fracture and dental caries. However, this study focused on calculus detection on digital radiographs, which has been less commonly addressed. This was a strength of this study.

This study had an in vitro design. Oral clinical conditions cannot be well simulated in vitro, which limits the generalization of results to the clinical setting [12]. This was a limitation of this study. Future studies are required to assess the efficacy of other digital image processing filters for calculus detection. Also, the efficacy of reverse contrast and sharpen filters for calculus detection should be evaluated in the clinical setting to obtain more generalizable results.

Conclusion

Within the limitations of this in vitro study, the results showed that reverse contrast and sharpen image processing filters could not significantly enhance the detection of calculus on digital radiographs.

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