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In vitro efficacy of reverse contrast and sharpen enhancement filters for detection of small-size broken files in root canals on digital intraoral radiographs

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ABSTRACT

Background and Objectives: Considering the gap of information regarding the efficacy of enhancement filters of digital radiography for detection of broken instruments in root canals, this study aimed to assess the efficacy of reverse contrast and Sharpen enhancement filters for detection of small-size broken files in root canals on digital intraoral radiographs. *Materials and Methods*: In this in vitro, diagnostic study, 80 extracted single-canal teeth were randomly divided into four groups (n=20). Following access cavity preparation, #8, #10 and #15 K-files were introduced into the canals of teeth in groups 1-3, respectively, from their apex and were intentionally broken such that 3 mm of the file length remained in the canal. A control group without a broken file was also considered. The teeth were then mounted in sheep's jawbone and digitally radiographed using photostimulable phosphor (PSP) plate. Using SCANORA software, each image was enhanced once with the Sharpen and once with reverse contrast enhancement filter. Two observers evaluated the images for presence/absence of broken file and the sensitivity and specificity values were calculated for the three image types and compared using chi-square test. *Results*: No significant difference was found in diagnostic sensitivity or specificity of original, sharpened and reverse contrast images for detection of broken files in the canals ($P>0.05$). *Conclusion*: Digital radiographs enhanced with Sharpen or reverse contrast enhancement filters have similar efficacy to original digital radiographs for detection of small-size broken files in the root canal of single-rooted teeth.

Keywords: Broken Instrument, Digital Radiography, Reverse Contrast, Sharpen, Enhancement Filters.

1. INTRODUCTION

Advent of digital radiography revolutionized dental imaging due to its advantages such as lower patient radiation dose, smaller size and easier image transfer compared to conventional radiography. The conventional imaging modalities have some short comings related to chemical processing of the films since inadequate film processing can adversely affect the quality of diagnosis (Sturdevant et al., 2014; White & Pharoah, 2014). The main advantage of digital radiography is the ability to enhance digital images by the enhancement filters. Several enhancement filters are available that can enhance the quality of digital images and facilitate diagnosis by eliminating the confounding factors (Haiter-Neto et al., 2009; Nair & Nair, 2007). Moreover, clinicians can adjust the contrast and brightness of digital radiographs to better serve their diagnostic purpose (Wenzel, 2000; Haak et al., 2001). Image enhancement algorithms are also suitable for efficient transfer of digital data (Kheddache et al., 1991). Reverse contrast and Sharpen are among the commonly used enhancement filters. Reverse contrast enhances the gray scale images by converting the lower (dark) pixels to higher (bright) pixels and vice versa (Oliveira et al., 2012). Conventional radiographs are inverted (bones appear white); however, this can be reversed in grayscale digital radiographs by the reverse contrast enhancement filter (bones appear black) (Sheline et al., 1989; Oestmann et al., 1988; Buckley et al., 1991). Sharpen is another enhancement filter that improves the image quality by eliminating blurring and noise (Sturdevant et al., 2014). Despite the advances in this respect, the diagnostic accuracy of different enhancement filters is still a matter of debate and the results of studies regarding the diagnostic accuracy of enhancement filters such as reverse contrast and Sharpen have been controversial (Tofangchiha et al., 2012; Kositbowornchai et al., 2004; Mehralizadeh et al., 2015; Kamburoğlu et al., 2010).

Instrument breakage in the root canal system is a common occurrence in endodontic treatment (Coutinho Filho et al., 1998). Canal curvature serves as a risk factor for breakage of endodontic files since it causes flexural stresses in them (Moushekhian et al., 2016). Breakage of endodontic instruments may be categorized into two groups of torsional fractures and flexural fatigue fractures. Torsional fracture occurs when the tip or any other part of the instrument is locked inside the canal while the shank is rotating. The elasticity threshold of the instrument is exceeded as such and plastic deformation occurs, which is associated with instrument fracture. Fatigue fracture occurs as the result of wear of metals due to over use. Such instruments are easily introduced into a curved canal until they reach the curvature and then break. Torsional fatigue is believed to play an important role in fracture of rotary nickel-titanium files (Sattpan et al., 2000).

In endodontic treatment, a small-size file is used to negotiate the canal orifices and determine the initial working length following access cavity preparation (Johnson & Williamson, 2015; Shooshtari et al. 2020). The smallest file size recommended for radiographic working length determination is #15. Smaller files are used for initial instrumentation of narrow, curved or calcified canals to prevent perforation or ledge formation in the canal. However, the tip of small-size files is not clearly visualized on radiographs, and digital radiographs have a poorer performance in visualization of the tip of a #10 file compared to a #15 file (Ingle et al., 2008). Also, small-size files have a higher risk of fracture due to their smaller diameter. Therefore, it is particularly important to detect broken pieces of small-size files locked in the root canals. The small diameter of these files complicates their radiographic detection and may lead to misdiagnosis. Therefore, several techniques and modalities have been suggested to enhance detection of small-size broken files in the root canals.

Considering the increasing use of digital radiography in endodontics, the significance of early detection of broken instruments in the canals and the existing controversy regarding the efficacy of enhancement filters for this purpose, this study aimed to assess the efficacy of reverse contrast and Sharpen enhancement filters for detection of small-size broken files in root canals.

2. MATERIALS AND METHODS

This in vitro, experimental study evaluated 80 single-canal teeth, extracted as part of orthodontic treatment or due to periodontal problems in 2019 (Chart 1). The study was approved in the ethics committee of Ahvaz Jondishapur University of Medical Sciences. Minimum sample size was calculated to be 77 according to a previous study (Plotino et al., 2012). To compensate for the possible dropouts, 80 samples were included in this study.

The inclusion criteria were single canal teeth with no fracture or crack and no internal or external root resorption. The teeth were randomly divided into four groups (n=20) using a table of random numbers. Standard access cavity was first prepared with a fissure bur and high-speed hand-piece. In group 1, #8 K-file (Mani, Tokyo, Japan) was introduced into the canal from the apex and it was then intentionally broken and separated such that 3 mm of the file length remained in the canal. The same was repeated in group 2 with #10 K-file and in group 3 with #15 K-file. Group 4 served as the control group and no file was used in this group. The teeth were then mounted in sheep's jawbone to simulate the clinical setting and underwent digital radiography with the exposure settings of 70 kVp, 8 mA and 0.32 s time. Digital radiographs were obtained using a photostimulable phosphor (PSP) plate, which was held by a holder at 10 cm distance from the X-ray tube. The teeth had equal distance from the X-ray tube and PSP plate. All teeth were radiographed under the same conditions. Radiographs were taken using the parallel technique by a dental X-ray unit (DeGotzen) and processed in a digital processor (Digora Optime, Soredex, Finland).

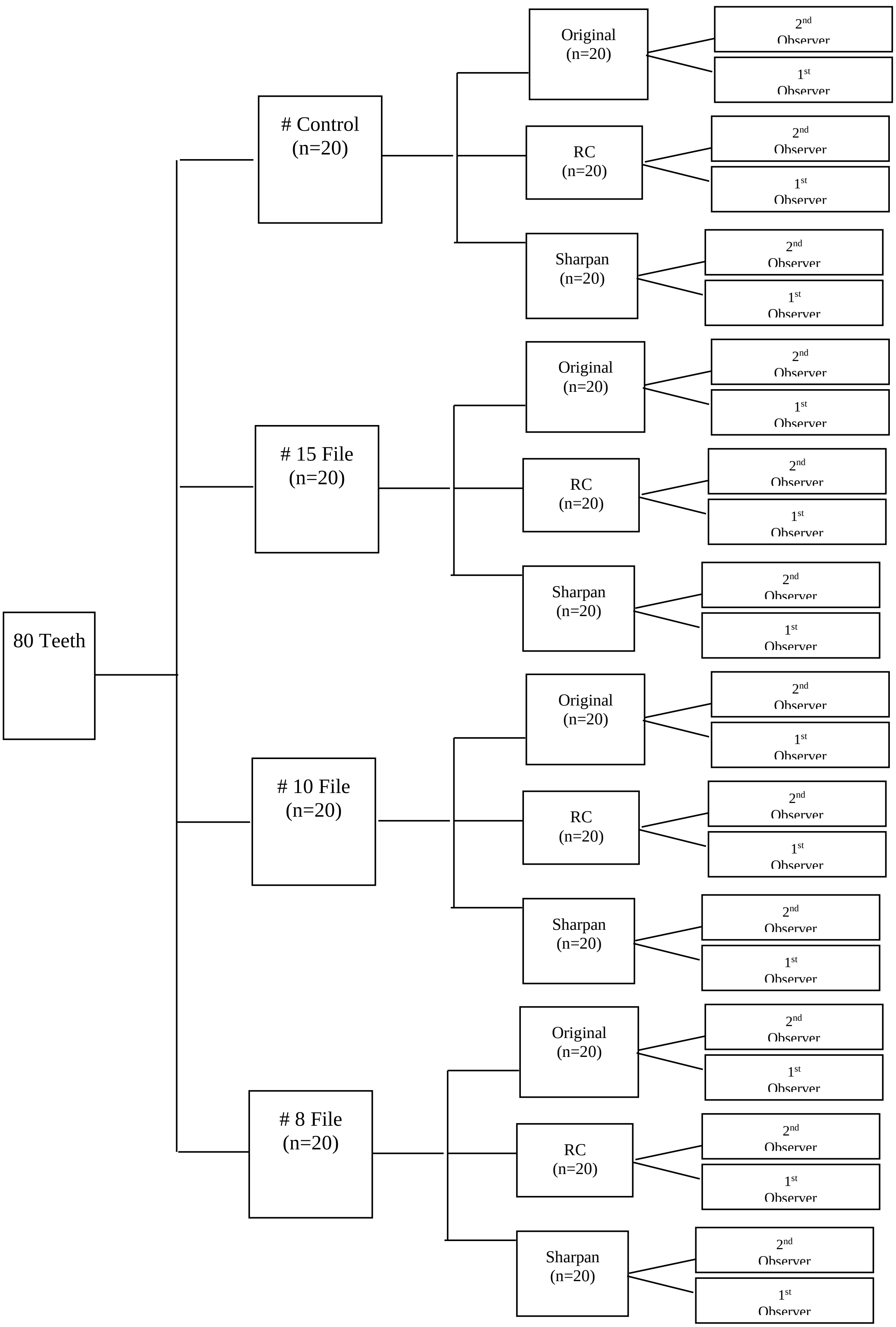

Chart 1 Methodology of Present Study

The images were saved and transferred to SCANORA software. Each image was enhanced once with Sharpen and once with reverse contrast filter and saved. Accordingly, three versions of each image were obtained: the original version, sharpened image, and the reverse contrast image. The images were then coded and randomly arranged in two separate PowerPoint files. An oral and maxillofacial radiologist and an endodontist with a minimum of two years of clinical experience in interpretation of digital radiographs observed the images twice with a two-week interval under the same lighting and environmental conditions. They expressed their opinion regarding presence or absence of file and recorded it in a datasheet.

Diagnostic sensitivity and specificity were calculated for all three image types separately for each file size. The receiver operating characteristic (ROC) curve was also drawn to assess the diagnostic accuracy. The kappa coefficient was calculated to determine the intraobserver agreement. Data were analyzed using SPSS version 22 (SPSS Inc., IL, USA) via chi-square test. P<0.05 was considered statistically significant.

3. RESULTS

Table 1 presents the sensitivity, specificity and accuracy of the two observers in detection of broken files on the three image types. The first observer correctly detected the broken file in the canals on original, reverse contrast and sharpened images in 97%, 87% and 98% of the cases, respectively. The kappa coefficient for the first observer was 0.592, 0.527 and 0.525 for the original, reverse contrast and sharpened images, respectively, which were all significant (P<0.001). The second observer correctly detected the broken file in the canals on original, reverse contrast and sharpened images in 100%, 100% and 99% of the cases, respectively. The kappa coefficient for the second observer was 0.6, 0.6 and 0.596 for the original, reverse contrast and sharpened images, respectively, which were all significant (P<0.001). Table 2 compares the sensitivity and specificity values between the two observers. Overall, the sensitivity, specificity, accuracy and kappa coefficient of the second observer were higher than those of the first observer. The sensitivity of the second observer for reverse contrast images was significantly higher than that of the first observer (P=0.003) but the difference between the two observers in other diagnostic parameters was not statistically significant (P>0.05). Since the sensitivity, specificity, accuracy and kappa coefficient of the second observer were higher than those of the first observer, the rest of the results were analyzed based on the data collected from the second observer.

Table 1 Sensitivity, specificity and accuracy of the two observers in detection of broken files on the three image types

Observer	Mode	Presence/absence of file	Presence of broken piece	Presence of broken piece	Sensitivity	Specificity	Accuracy
First observer	Original	Presence of broken piece	0	58	0.97	1	0.98
		Absence of broken piece	20	2			
	Reverse contrast	Presence of broken piece	1	52	0.87	0.95	0.91
		Absence of broken piece	19	8			
	Sharpen	Presence of broken piece	2	59	0.98	0.90	0.94
		Absence of broken piece	18	1			
Second observer	Original	Presence of broken piece	0	60	1	1	1
		Absence of broken piece	20	0			
	Reverse contrast	Presence of broken piece	0	60	1	1	1
		Absence of broken piece	20	0			
	Sharpen	Presence of broken piece	0	59	0.98	1	0.99
		Absence of broken piece	20	1			

The sensitivity and specificity of the second observer for detection of broken files (#8, #10 and #15) separately and altogether and correct diagnosis of absence of filein the canal on original images were both 1. The sensitivity and specificity of the second observer for detection of broken files (#8, #10 and #15) separately and altogether and correct diagnosis of absence of file in the canal on reverse contrast images were also 1. The specificity of the second observer for detection of broken files (#8, #10 and #15) separately and altogether and correct diagnosis of absence of file in the canal on sharpened images was 1. The sensitivity value was also 1 except for detection of #10 file (specificity of 0.95) and all files together (sensitivity of 0.98). The difference in sensitivity and specificity values were not significant among the original, reverse contrast and sharpened images (P>0.05). Pairwise comparisons did not reveal any significant difference either (P>0.05).

Table 2 Sensitivity and specificity of the two observers for detection of broken files on the three types of images

Image	Diagnostic parameter	First observer	Second observer	P value
Original	Sensitivity	0.97	1	0.154
	Specificity	1	1	1.000
	Accuracy	0.98	1	0.719
Reverse contrast	Sensitivity	0.87	1	0.003
	Specificity	0.95	1	0.311
	Accuracy	0.91	1	0.224
Sharpen	Sensitivity	0.98	0.98	1.000
	Specificity	0.90	1	0.920
	Accuracy	0.94	0.99	0.715

Figures 1-3 show the ROC curve for the diagnostic accuracy of the observer for detection of broken file on original, reverse contrast and sharpened images. In this curve, the farther the curve from the diagonal reference line and the greater the area under the curve, the more accurate the diagnosis of the observer would be. The area under the curve for original and reverse contrast images was 1, which indicated completely accurate diagnosis. This value was 0.992 for sharpened images, which also showed high diagnostic accuracy.

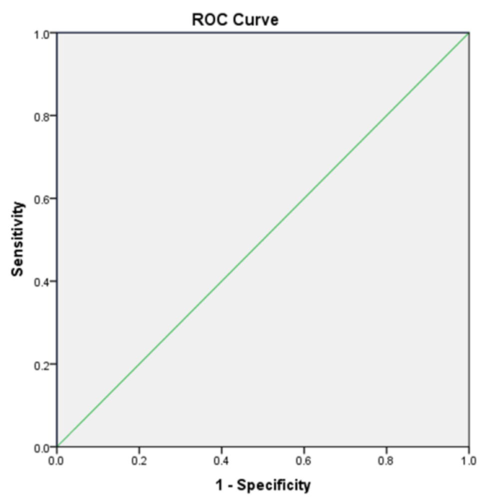

Figure 1 ROC curve for sensitivity and specificity of the second observer for detection of broken files on original digital images

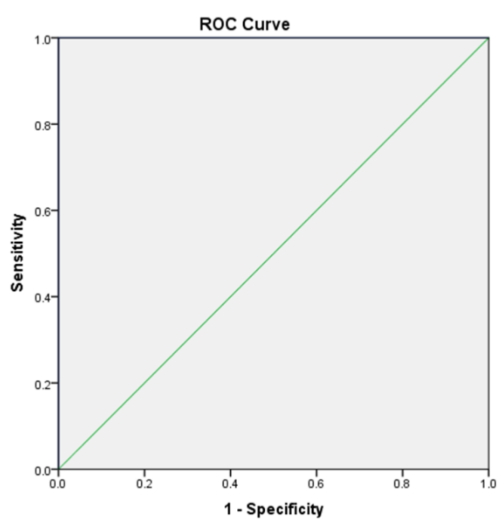

Figure 2 ROC curve for sensitivity and specificity of the second observer for detection of broken files on reverse contrast digital images

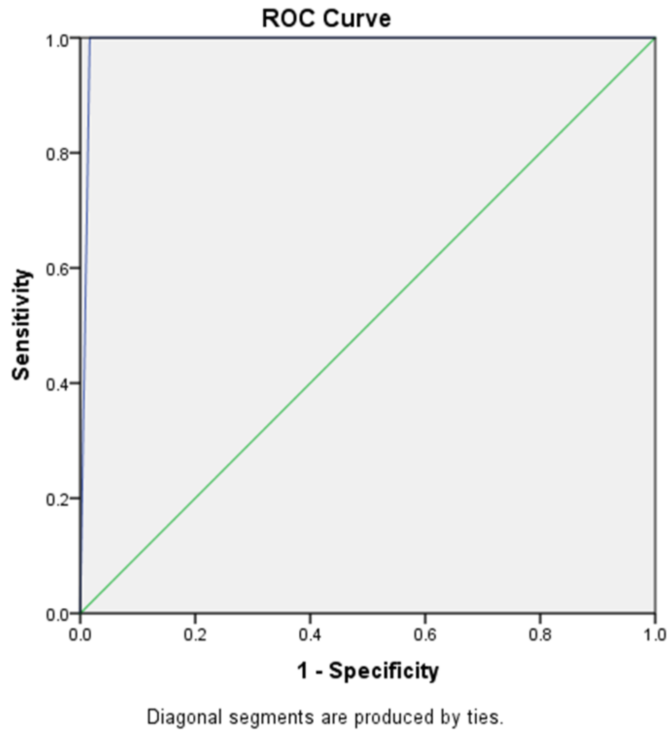

Figure 3 ROC curve for sensitivity and specificity of the second observer for detection of broken files on digital images enhanced with Sharpen

4. DISCUSSION

Endodontic file fracture during root canal treatment is a common occurrence, which interferes with adequate cleaning and shaping of the root canals. Radiographic modalities, particularly digital radiography, are commonly used for detection of broken instruments in the root canal system (Ingle & Baumgartner, 2008; Ferreira et al., 2007). This study assessed the efficacy of reverse contrast and sharpens filters in PSP digital radiography for detection of small-size broken files in the root canals. The results showed no significant difference in diagnostic sensitivity or specificity for detection of broken files in the canals on the three types of images. The two observers were not significantly different regarding diagnostic parameters and the sensitivity and specificity for detection of all three file sizes, separately and altogether on original and reverse contrast images were 1. The specificity for detection of broken files separately and altogether and correct diagnosis of absence of file on sharpened images was 1. The sensitivity value was also 1 except for detection of #10 file with a sensitivity value of 0.95 and all files together with a sensitivity value of 0.98. Moreover, the results showed that original, reverse contrast and sharpened images had equal diagnostic accuracy for detection of broken instruments. In other words, all three modes can be used for detection of a broken small-size file in the root canals.

In a study by Mehralizadeh et al. (2015) reverse contrast enhancement filter did not significantly increase the sensitivity, specificity and accuracy of detection of vertical root fracture. Although they evaluated vertical root fractures, and not broken instruments, their results regarding inefficacy of reverse contrast filter was in line with ours. Sakhdari et al. (2011) evaluated the efficacy of digital enhancement filters for detection of horizontal root fractures and found no significant difference in diagnostic sensitivity and specificity of original, reverse contrast and sharpened images. Their finding regarding inefficacy of reverse contrast and Sharpen filters was in agreement with our results.

Tofangchiha et al. (2012) evaluated the efficacy of reverse contrast and colorization filters for detection of vertical root fractures. They found that original images had higher specificity and accuracy than the other two modes and the lowest sensitivity belonged to reverse contrast images. However, these differences were not statistically significant. Their findings were in accordance with ours.

Some other studies discussed that enhancement filters did not improve the diagnostic quality and even decreased it in some cases. For instance, Castilho et al. (2005) and Tyndall et al. (1998) reported that enhanced digital images had lower diagnostic accuracy than original images for caries detection. Lee et al. (2004) showed that reverse contrast images had higher diagnostic specificity for detection of horizontal root fractures. Although this difference was not statistically significant, the authors claimed that reverse contrast enhances the detection of horizontal root fractures. Miri et al. (2015) evaluated the efficacy of reverse contrast enhancement filter for detection of proximal dentincariesand found that original images had higher sensitivity, specificity, positive and negative predictive value and accuracy than reverse contrast images. Kositbowornchai et al. (2004) found that Zoom filter (1:1, 2:1 and 1:2) could not significantly improve the diagnostic accuracy of vertical root fractures. Kamburoglu et al. (2010) showed that none of the enhancement filters including contrast sharpness, Pseudo 3D, Zoom and Reverse could significantly improve the detection of vertical root fractures. Brullmann et al. (2008) reported that none of the filters used for noise reduction of digital images could significantly improve the detection of root fractures. Mistak et al. (1998) indicated that the diagnostic accuracy of images did not improve by the use of enhancement filters. Eickholz et al. (1999) reported that use of enhancement filters such as reverse contrast did not enhance the measurement of depth of carious lesions. The results of the afore-mentioned studies are all in agreement with our results. Small differences in the results are generally attributed to the sensitive nature of interpretation of radiographic findings and the effect of several factors on the results such as the imaging system (digital or conventional), the monitor characteristics, type of sensor, different enhancement filters, observation conditions and expertise and experience of the observer (Kositbowornchai et al., 2004; Mehralizadeh et al., 2015). Digital enhancement filters are also task-specific and their efficacy highly depends on the experience, expertise, preference and mentality of the observer (Tofangchiha et al., 2012; Kositbowornchai et al., 2004; Mehralizadeh et al., 2015).

Most previous studies have evaluated the diagnostic efficacy of enhancement filters for root fractures or proximal caries while the current study evaluated the efficacy of enhancement filters for detection of broken small-size files in the root canal system, which has not been comprehensively studied before; this was strength of this study. On the other hand, this study had an in vitro design and therefore, conditions were different from the clinical setting. Presence of soft tissue in the clinical setting affects the results (Tofangchiha et al., 2012), which cannot be perfectly simulated in vitro. Further studies are required to assess the efficacy of different enhancement filters for detection of broken instruments in the root canal of multi-rooted teeth.

5. CONCLUSION

Within the limitations of this in vitro study, digital radiographs enhanced with Sharpen or reverse contrast enhancement filters have similar efficacy to original digital radiographs for detection of small-size broken files in the root canal of single-rooted teeth.

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Conflict of Interest
There is no Conflict of Interest.

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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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