Dental Traumatology

Dental Traumatology 2012; **28**: 478–482; doi: 10.1111/j.1600-9657.2012.01120.x

Detection of vertical root fractures using digitally enhanced images: reverse-contrast and colorization

Maryam Tofangchiha[1], Mahin Bakhshi[2], Mahsa Shariati[3], Solmaz Valizadeh[4], Mamak Adel[5], Farhad Sobouti[6]

[1]Department of Oral Radiology, Faculty of Dentistry, Qazvin University of Medical Sciences, Qazvin; [2]Department of Oral Medicine, Faculty of Dentistry, Shahid Beheshti University of Medical Sciences; [3]Faculty of Dentistry, Orthodontics Department of Tehran Azad University of Medical Science; [4]Department of Oral Radiology, Faculty of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran; [5]Department of Endodntics, Faculty of Dentistry, Qazvin University of Medical Sciences, Qazvin; [6]Faculty of Dentistry, Orthodontics Department of Tehran University of Medical Science, Tehran, Iran

Key words: vertical root fracture; digital image; enhancement

Correspondence to:
Mahsa Shariati, Faculty of Dentistry, Orthodontics Department of Tehran Azad University of Medical Science, No 25, Golnar Ave North Africa BLVD Elahie Street 1915969811, Tehran, Iran
Tel.: 00989123577159
Fax: 009821222888077
e-mail: mahsa.shariati@gmail.com

Accepted 7 January, 2012

Abstract – Root fracture diagnosis is a clinical difficulty that in most cases can only be detected through radiography. The objective of this study was to compare the diagnostic accuracy of two types of digitally enhanced images (reverse-contrast and colorization) with original digital radiographies in detecting experimental root fractures. Two hundred extracted single-rooted human teeth were endodontically instrumented and then divided in two groups, one control group and one test group, including fractured teeth. Vertical root fractures were experimentally made in the fractured group. The digital image of each tooth was taken, using the paralleling technique. There were three groups of images: (i) original, (ii) reverse contrast, and (iii) colorized. Three experienced dental specialists examined the images with no prior knowledge of the distribution of the root fractures. Two-way analysis of variance was used to assess the differences in accuracy, sensitivity, and specificity of each technique in detecting root fractures. Cohen's kappa coefficients were calculated to investigate the degree of interobserver agreement. The accuracy, sensitivity, and specificity of original images were 67.4%, 66.7%, and 68%, respectively; these amounts were 61.5%, 61%, and 65.5% in reverse contrast images and 66.4%, 70.7%, and 62% in colorized digital radiography. The original images had the best inter observer kappa coefficients (between 0.45 and 0.55). The results showed that the accuracy of original images is better than reverse contrast and colorized images. Use of reverse-contrast and colorization digital images in root fracture detection should be regarded as an adjunct to other diagnostic methods not as a highly critical diagnostic aid.

Vertical root fractures (VRFs) are longitudinally oriented cracks, which are difficult to diagnose clinically as the symptoms are non-specific and resemble post-treatment disease following root canal treatments or periodontal diseases (1). VRFs may be accompanied by various kinds of problems, including pain, swelling, mobility, isolated periodontal pockets, and sometimes sinus tracts (1–5). As VRFs inevitably lead to the extraction of the affected tooth, diagnosis of root fracture is an important process in determining the prognosis of an individual tooth and choosing the appropriate treatment. Intraoral radiography (IOR) is the most widely used imaging modality to detect root fracture (6, 7). Because there is multi advantage of digital radiography, such as low-absorption dose to patient, ability to manipulate the images, and artifact reduction by image processing, it has been recommended in several field of dentistry (8).

Digital imaging has the advantage of real-time display and a potential for image enhancement and processing (9). Many years, these systems have become an alternative to film-based radiography (10). Most studies have found the diagnostic accuracy of digital systems comparable with that of dental films (9, 11–16). It is claimed that digital image enhancement greatly improves visibility (17) and increases diagnostic accuracy (18). Reverse-contrast is another electronic image processing tool that changes the radiographic positive image into a radiographic negative image that can affect the perception of the observers. As more details can be detected by the human eye in colored models rather than the gray-scale images, manipulation of digital images could lead to a more accurate diagnosis (17). This study was designed to compare the accuracy, specificity, and the sensitivity of enhanced digital images with those without manipulation.

Materials and methods

Tooth preparation

The study material comprised 200 extracted human single-rooted teeth with closed apices. Teeth were completely sound without fractures or having internal or external resorption and without acutely curved roots. The extracted teeth were disinfected and placed in 24°C distilled water. The crowns were reduced 2 mm above CEJ with a paper disk. Afterward, the roots were mounted in red compound impression material, while the coronal and apical ends remained uncovered; and the buccal surfaces were marked with ink. The root canals were prepared with file numbers 15–45. All teeth were given a number and divided into two groups: A control group of 100 teeth with no fractures and a test group of 100 with VRFs. VRFs were created as described by Monagham et al. (19). A bur was used to form a conical wedge shape in a number 45 finger spreader. Then, the spreaders were driven into the root canal apically until there was a sharp 'cracking' sound.

Radiographic procedure

Radiographic images of all teeth were exposed using a Planmeca dental X-ray unit (Planmeca, Helsinki, Finland) operated at 63 KVp, 8 MA and recorded using a charge coupled device (CCD; Trophy Radiologie, Vincennes, France) direct digital intraoral receptor size 2 of fifth generation RVG (RadioVisioGraphy). The radiographs of each tooth were obtained in the faciolingual direction using the paralleling technique. For each tooth, the exposure time was adjusted so that the density and contrast of all radiographs would be similar. The focus- object distance was 20 cm, and the objects were positioned on the receptor with their long axis parallel to the surface of the receptor. The three groups of the digital images (original, reverse-contrast and colorized) were set. The procedure was carried out using Trophy viewer soft ware (Trophy, Marne La Vallee Cedex 2, France) 17″ SVGA monitor.

Radiographic evaluation

All images were evaluated separately in a dimly lit room by three observers (two oral radiologists and one endodontist that who had more than 6 years experience in their specialty) without prior knowledge of the distribution of the root fractures. First, the observers viewed the original images. Then, the reverse-contrast and colorized images were evaluated by 2 weeks intervals, respectively. The colorized and reverse-contrast images were extracted from the original ones using a Trophy viewer by a person not involved in evaluating the images. The observers were allowed to manipulate (density and contrast) the digital images. They recorded their diagnosis for the presence or absence of a fracture line in data forms. Examples of typical images are shown in Figs 1, 2 and 3.

Data analysis

Data were analyzed using SPSS version 15.0 (SPSS, Chicago, IL, USA) for Windows. The accuracy (percent of correct scores), sensitivity (cumulative percent of VRF identified among those that had VRF), and specificity (cumulative percent of sound identified among those that were sound) of each method were determined in detecting the VRF. Two-way analysis of variance was used to assess differences in accuracy, sensitivity, and specificity. The level of significance was set at $\alpha = 0.05$.

The weighted kappa coefficients were calculated to assess interobserver agreement for each method. Two-way analysis was used to assess differences between the methods. The level of significance was set at $\alpha = 0.05$.

Result

Tables 1, 2 and 3 show the degree of agreement between reality and each of the three methods in detecting VRF. The average percent of accuracy, sensitivity, and specificity were, respectively, 67.4%, 66.7%, and 68% for original images, 66.4%, 70.7%, and 62% for colorized digital images and 61.5%, 61%, and 65.5% for inverted contrast group.

The interobserver kappa coefficients ranged from 0.45 to 0.55 for original images, 0.40–0.50 for inverted contrast images and 0.42–0.49 for colorized images. First observer detected 66% of total fractured cases and 55% of total intact cases correctly with original images. In inverted contrast images, 54% of total fractured cases and 49% of total intact cases were detected correctly and in colorized images, 59% of total fractured cases, and 48% of total intact cases detected correctly. The second observer detected 63% of total fractured cases and 81% of total intact cases correctly with original images. In inverted contrast images, 76% of total fractured cases and 74% of total intact cases were detected correctly. In colorized images, 78% of total fractured cases and 71% of total intact cases were detected correctly. The third observer detected 71% of total fractured cases and 68% of total intact cases correctly with original images. In contrast inversion images, 53% of total fractured cases and 73% of total intact cases were detected correctly. In colorized images, 75% of total fractured cases and 67% of total intact cases were detected correctly.

No significant differences ($P > 0.05$) were found between accuracy, sensitivity, and specificity original images with colorized images (respectively, 0.8, 0.38, and 0.2) and with inverted contrast images (respectively, 0.2, 0.25, and 0.59).

Table 1. The number of root fractures correctly detected from original digital method by three observers

		Actual condition		
Observer	Original digital method	Fractured	Intact	Total
First	Fractured	66	45	111
	Intact	34	55	89
	Total	100	100	200
Second	Fractured	63	19	82
	Intact	37	81	118
	Total	100	100	200
Third	Fractured	71	32	103
	Intact	29	68	97
	Total	100	100	200

Table 2. The number of root fractures correctly detected from contrast inversion method by three observers

		Actual condition		
Observer	Contrast inversion method	Fractured	Intact	Total
First	Fractured	54	51	105
	Intact	46	49	95
	Total	100	100	200
Second	Fractured	76	26	102
	Intact	24	74	98
	Total	100	100	200
Third	Fractured	53	27	80
	Intact	47	73	120
	Total	100	100	200

Table 3. The number of root fractures correctly detected from colorized inversion method by three observers

		Actual condition		
Observer	Colorized inversion method	Fractured	Intact	Total
First	Fractured	59	52	111
	Intact	41	48	89
	Total	100	100	200
Second	Fractured	78	29	107
	Intact	22	71	93
	Total	100	100	200
Third	Fractured	75	33	108
	Intact	25	67	92
	Total	100	100	200

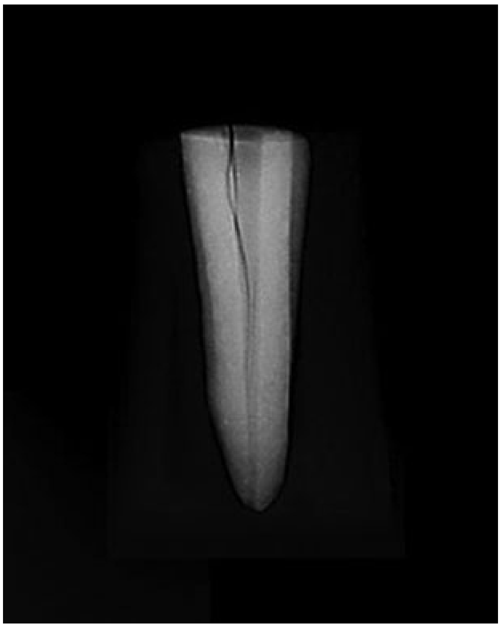

Fig. 1. Vertical root fracture in original image.

Fig. 2. Vertical root fracture in reverse-contrast image.

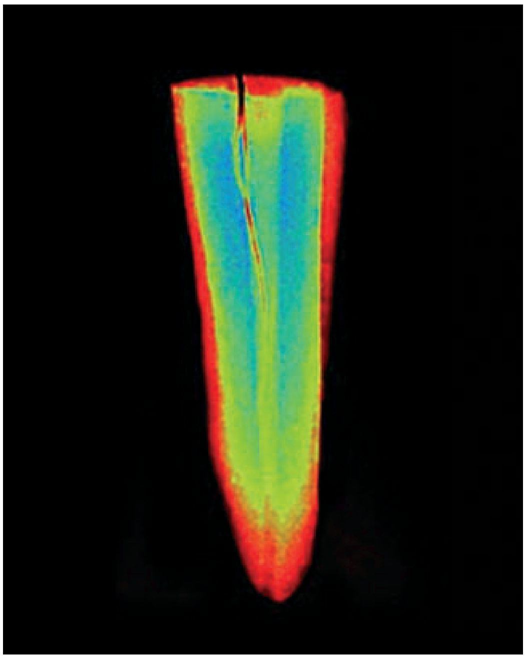

Fig. 3. Vertical root fracture in colorized image.

Discussion

This study compared the use of two methods of enhancing digital images (reverse-contrast and colorization method) with original images in the detection of VRF by three observers who belonged two different disciplines in dentistry.

Although our study tried to mimic the clinical situation, differences invariably arose between *in vitro* and *in vivo* detection of root fractures. *In vitro* studies of an extracted tooth with or without either bone or soft tissue equivalents may react differently to radiation beam than a tooth within the oral cavity. The observers in our study were allowed to adjust contrast and brightness at will to compensate loss of image clarity. The diagnostic value of different enhancement tools provided by digital imaging software package is controversial (20). Statistical analysis in the present study showed that the average sensitivity of colorized images is better than the other two techniques, which implies its more ability in detecting root fracture. Original images had the best specificity among others; therefore, false-positive results are reduced with this technique. However; there was no significant difference with original images.

The lowest sensitivity belonged to contrast reverse images in the present study, which is in agreement with Ludlow study and Huang study (21, 22). Kositbowornchai et al. (23) showed no significant improvements in the detection of VRFs using image manipulation with zoom function of software at 1:1, 1:2, and 2:1 magnifications. Our findings are analogous to another study, which found that none of the used filters improved the diagnostic outcome in digital images, which did not show clearly visible root fractures before application of eight different convolution filters (24).

Kositbowornchai et al. (25) also found the use of sharpness, zoom, and pseudocolor functions provided no additional diagnostic value in the detection of occlusal caries. In another study, digitized images enhanced by reverse, histogram-averaging, high-pass, mean-value and spreading of gray values did not result in any statistically significant improvements over original digitized images in reproducibility or validity of the caries depth measurements (26). Although Moystad et al. (27) found a reduction in interobserver and intraobserver variability using the caries-specific Oslo enhancement procedure, the diagnostic outcome was not considered statistically significant. In the present study, enhancement of digital images did not result in any significant improvements in detection of VRF.

Some studies have found the use of image enhancements to improve the accuracy of VRF diagnoses. Reverse-contrast, brightness and edge enhancement algorithms have been found to improve accuracy of determining file length measurements using Photo stimulable phosphor plates (28). Enhancements of density, contrast and edges have been shown to improve caries detection, especially with low-density images (29). Contrast and brightness features were found to be the most effective factors in increasing the ability to detect periapical lesions (30).

In contrast, some studies have found that diagnostic accuracy decreases by image enhancements. Reverse-contrast direct digital radiography (DDR) images have also been found to be inferior to DDR stored images, DDR transmitted images and D-speed film in detection of artificial periapical lesions (31). Other studies have shown enhanced images to have lower diagnostic accuracy than unenhanced original images in caries detection (32, 33). The level of inter observer agreement for original images in our study ($K = 0.44–0.55$) was higher than for colorized and reveres contrast images ($K = 0.30–0.50$) which implies the superiority of original digital images in detection of VRF. This study found that the use of digitally enhanced images had no effect on inter-observer agreement in detection of VRF.

Conclusion

This study is only a part of an evaluation of the diagnostic value of the digital imaging in detection of the root fractures. The original images had the best inter-observer agreement, accuracy and specificity in detecting VRF, but the sensitivity of colorized images was better than original images.

Finally, the usage of reverse-contrast and colorization digital images in root fracture detection should be regarded as an adjunct to other diagnostic methods not as a highly critical diagnostic aid.

Acknowledgement

This research was supported in part by Departments of Research Qazvin University of Medical Science, Qazvin, Iran.

Conflict interest

No competing financial interests exist.

References

1. Tamse A. Iatrogenic vertical root fractures in endodontically treated teeth. Endod Dent Traumatol 1988;4:190–6.
2. Meister F Jr, Lommel TJ, Gerstein H. Diagnosis and possible causes of vertical root fractures. Oral Surg Oral Med Oral Pathol 1980;49:243–53.
3. Testori T, Badino M, Castagnola M. Vertical root fractures in endodontically treated teeth: a clinical survey of 36 cases. J Endod 1993;19:87–90.
4. Tamse A, Fuss Z, Lustig J, Kaplavi J. An evaluation of endodontically treated vertically fractured teeth. J Endod 1999;25:506–8.
5. Fuss Z, Lustig J, Tamse A. Prevalence of vertical root fractures in extracted endodontic ally treated teeth. Int Endod J 1999;32:283–6.
6. Nair MK, Nair UP, Gröndahl HG, Wallace JA. Accuracy of tuned aperture computed tomography in the diagnosis of radicular fractures in no restored maxillary anterior teeth: an in vitro study. Dentomaxillofac Radiol 2002;31:299–304.
7. Mora M, Mol A, Tyndall D, Rivera E. Effect of the number of basis images on the detection of longitudinal tooth fractures using local computed tomography. Dentomaxillofac Radiol 2007;36:382–6.
8. Mohtavipour ST, Dalili Z, Azar NG. Direct digital radiography versus conventional radiography for estimation of canal length in curved canals. Imaging Sci Dent 2011;41:7–10.
9. Yokata ET, Miles DA, Newton CW, Brown CE. Interpretation of periapical lesions using RadioVisioGraphy. J Endod 1994;20:490–4.
10. Welander U, Nelvig P, Tronje G, McDavid WD, Dove SB, Morner AC et al. Basic technical properties of a system for direct acquisition of digital intraoral radiographs. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1993;75:506–16.
11. Furkart AJ, Dove SB, McDavid WD, Nummikoski P, Matteson S. Direct digital radiography for detection of periodontal bone lesions. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1992;74:652–60.
12. Kositbowornchai S, Nuansakul R, Sikram S, Sinahawattana S, Sangmontri S. Root fracture detection: a comparison of direct

digital radiography with conventional radiography. Dentomaxillofac Radiol 2001;30:106–9.
13. Nation M, Yuasa H, Toyama M, Shiojima M, Nakamura M, Ushida M et al. Observer agreement in the detection of approximal caries with direct digital intraoral radiography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1998;85:107–12.
14. Pass B, Furkart AJ, Dove SB, McDavid WD, Gregson PH. 6-Bit and 8-Bit digital radiography for detecting simulated periodontal lesions. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1994;77:406–11.
15. Syriopoulos K, Sanderink GCH, Velders XL, van der Stelt PF. Radiographic detection of approximal caries: a comparison of dental films and digital imaging systems. Dentomaxillofac Radiol 2000;29:312–8.
16. White SC, Yoon DC. Comparative performance of digital and conventional images for detecting proximal surface caries. Dentomaxillofac Radiol 1997;26:32–8.
17. Verdonschot EH, Kuijipers TMC, Polder BJ, De Leng-Worm MH, Bronkhorst EM. Effects of digital grey-scale modification on the diagnosis of small approximal carious lesions. J Dent 1992;20:44–9.
18. Versteeg CH, Sanderink GC, van der Stelt PF. Efficacy of digital intraoral radiography in clinical dentistry. J Dent 1997;25:215–24.
19. Monagham P, Bajalcaliev JG, Kaminski EJ, Lautenschlanger EP. A method for producing experimental simple vertical root fractures in dog teeth. J Endod 1993;19:512–5.
20. Kamburoglu K, Murat S, Pehlivan SY. The effects of digital image enhancement on the detection of vertical root fracture. Dent Traumatol 2010;26:47–51.
21. Lo SC, Huang HK. Compression of radiological images with 512, 1024 and 2048 matrices. Radiology 1986;161:519–25.
22. Ludlow J, Mol A. Digital imaging. In: Pharoah MJ, White SC, editors. Oral radiology. 5th edn. St Louis, MO: Mosby; 2004; Chap 12: p. 225–43.
23. Kositbowornchai S, Sikram S, Nuansakul R, Thinkhamrop B. Root fracture detection on digital images: effect of the zoom function. Dent Traumatol 2003;19:154–9.
24. Brullmann D, Witzel V, Willershausen B, D'Hoedt B. Effect of digital noise filters on diagnostic radiographs for the diagnosis of experimental root fractures. Int J Comput Dent 2008;11:107–14.
25. Kositbowornchai S, Basiw M, Promwang Y, Moragorn H, Sooksuntisakoonchai N. Accuracy of diagnosing occlusal caries using enhanced digital images. Dentomaxillofac Radiol 2004;33:236–40.
26. Eickholz P, Kolb I, Lenhard M, Hassfeld S, Staehle HJ. Digital radiography of interproximal caries: effect of different filters. Caries Res 1999;33:234–41.
27. Moystad A, Svanaes DB, van der Stelt PF, Grondahl HG, Wenzel A, van Ginkel FC et al. Comparison of standard and task-specific enhancement of Digora storage phosphor images for approximal caries diagnosis. Dentomaxillofac Radiol 2003;32:390–6.
28. Kal BI, Baksi BG, Dundar N, Sen BH. Effect of various digital processing algorithms on the measurement accuracy of endodontic file length. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;103:280–4.
29. Wenzel A, Fejersov O. Validity of diagnosis of questionable caries lesions in occlusal surfaces of extracted third molars. Caries Res 1992;26:188–94.
30. Kullendorff B, Nilsson M. Diagnostic accuracy of direct digital dental radiography for the detection of periapical bone lesions. II. Effects on diagnostic accuracy after application of image processing. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1996;82:585–9.
31. Mistak EJ, Loushine RJ, Primack PD, West LA, Runyan DA. Interpretation of periapical lesions comparing conventional, direct digital and telephonically transmitted radiographic images. J Endod 1998;24:262–6.
32. De Araujo EA, Castilho JC, Medici Filho E, de Moraes ME. Comparison of direct digital and conventional imaging with Ekta Speed Plus and INSIGHT films for the detection of approximal caries. JADA 2005;18:241–4.
33. Tyndall DA, Ludlow JB, Platin E, Nair M. A comparison of Kodak Ektaspeed Plus film and the Siemens Sidexis digital imaging system for caries detection using receiver operating characteristic analysis. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1998;85:113–8.