ORIGINAL ARTICLE

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Diagnostic accuracy of conventional, digital and Cone Beam CT in vertical root fracture detection

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INTRODUCTION: Vertical root fracture (VRF) is a common failure in endodontically treated teeth. Due to VRF's poor prognosis, a reliable and valid detection method is critical for treatment planning. Conventional and digital radiographs are limited in VRF detection. Recently, Cone Beam CT (CBCT) system has been introduced. This study aimed to compare the diagnostic accuracy of these three imaging modalities for VRF detection.
MATERIALS & METHODS: One hundred and twenty extracted single-rooted teeth were selected and sectioned through cementoenamel junction. The roots were divided in two groups; group one consisted of 60 teeth with induced root fracture and group two had 60 teeth with no fracture. In the first group the crack was made by instron system. All samples were imaged by the three imaging modalities. Diagnostic accuracy was then compared with methylene blue dye detection method. Kappa was used for statistical analysis.
RESULTS: CBCT showed the highest sensitivity (94.6%) and specificity (98.2%). Conventional radiography and digital radiography were not as accurate as CBCT.
CONCLUSION: According to our study, CBCT seems to be better than conventional and digital radiography in detecting VRF and provides the most reliable data in comparison with the two other modalities.

KEYWORDS: Cone Beam Computed Tomography, Radiography, Vertical root fracture.

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INTRODUCTION

Vertical root fracture (VRF) is one of the failures encountered in endodontically treated teeth; moreover its diagnosis encloses several problems (1,2). Vertical root fractures are reported in 3.69% of root canal treated teeth (3). Clinically, it is critical to detect this problem since it results in periodontal lesions and pocket formation. It is important to extract the fractured root or tooth immediately to cease the bone resorption (4,5). A reliable and valid detection method that diagnosis VRF seems indispensable to endodontics (4,6,7).

Clinical and radiographical signs of VRF are shared by several syndromes and may be similar to other endodontic failures or periodontal problems; therefore, the diagnosis should be conducted with great care (4,6,8-10).

Conventional radiography is a common method for determination of VRF; however there are several problems, particularly when fragments are not displaced (11). One third of VRFs are radiographically detectable; this is when the x-ray beam is perpendicular to a complete fracture line or there is fragment separation due to granulation tissue formation between the splinters (9). Since the X-ray beam is usually directed obliquely to the fracture line, repeating the radiographs with different angles is required. This results in increased patient radiation dose, and therefore conventional radiography is not ideal for VRF (2,4,9,12).

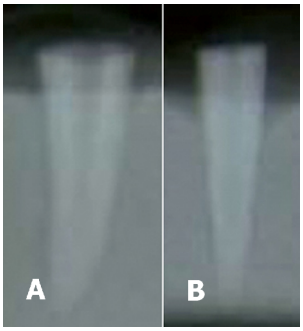

Figure 1. **Conventional image of A) fractured and B) non fractured root tooth**

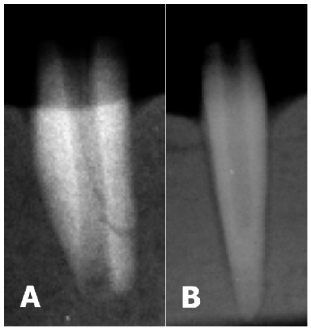

Figure 2. **Digital image of A) fractured and B) non fractured root tooth**

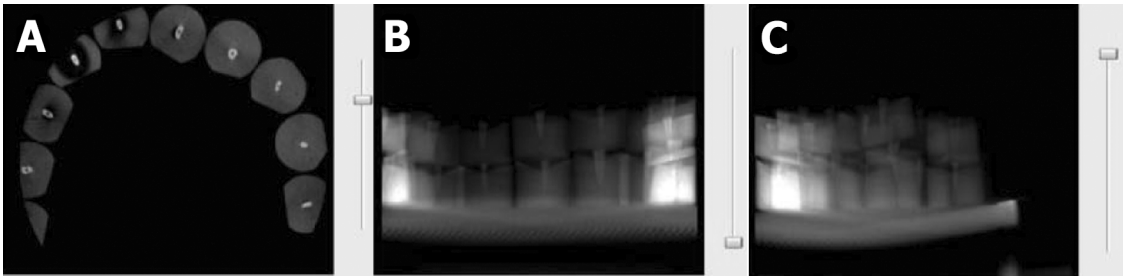

Figure3. **CBCT image of a ten-series of fractured and non-fractured teeth A) axial view, B) coronal view, and C) sagital view**

Digital radiography is a good alternative for conventional radiography (13,14). There is reduction in patient absorption dose, digital image quality enhancement/improvement, convenient application, electronic saving and transferring of the data and elimination of processing chemicals (15). There is still the beam angulation problem with these systems.

Recently, cone beam computed tomography (CBCT) systems were designed for maxillofacial imaging; these systems have the benefits of high image quality and resolution, less radiation dose compared to CT systems, and rapid scan time (16). CBCT provides high tissue contrast; it also eliminates blurring and overlapping of the structures, and is less expensive and reduces radiation in comparison with CT (17). The aim of this experimental study was to assess the diagnostic accuracy of CBCT along with conventional and digital radiography.

MATERIALS & METHODS

In this *in vitro* study, 120 extracted mature single-rooted teeth without root fracture were selected. Teeth were chosen irrespective of age or gender of the patient and reason for extraction; these inclusion criteria were based according to the previous data and epidemiologic studies (2,3). The extracted teeth were debrided and sectioned through cementoenamel junction. The remaining roots were prepared with pezzo number 2 and 3 and irrigated with normal saline. They were divided into two groups of 60 teeth each including teeth with induced root fracture and those with no fracture. Prefabricated posts with the same length were put in all prepared root canals. In the first group a fracture was induced with instron system (Zwcik/roell, GmbH & Co.KG, Germany). This system places an increasing force on the posts until a crack sound is heard, then the force is immediately aborted according to the diagram on the system monitor. The roots were covered with 1mm thickness of wax to simulate the periodontal membrane and were then randomly placed in acrylic blocks.

Conventional and digital radiographs were taken with a sensor holder (XCP; Dentsply, Elgin) using parallel technique with the ame exposure angle and image receptor position. The source-object and object-receptor distances were kept constant. The conventional and digital images were taken with 70 kVp and 8 Ma (conventional system: Gendex 765DC, Plaines, IL USA. Digital system: RVG Trophy, Kodak Company,

Table1. **Results of conventional radiographic diagnosis of root fractures**

Root fracture diagnosis	Present N (%)	Absent N (%)
Definitely present	27 (45)	3 (5)
Probably present	11 (18.3)	9 (15)
Unsure	3 (5)	8 (13.3)
Probably not present	–	4 (6.7)
Definitely not present	18(30)	38 (63.3)

Table2. **Results of digital radiographic diagnosis**

Digital Radiography	Root Fracture No. (%)	No Root Fracture No. (%)
Definitely present	30 (50)	1 (1.7)
Probably present	13 (21.7)	13 (21.7)
Unsure	2 (3.3)	1 (1.7)
Probably not present	No	4 (6.7)
Definitely not present	15 (25)	41 (68.3)

Table3. **Results of CBCT (Cone Beam Computed Tomography) diagnosis**

CBCT	Root Fracture No. (%)	No Root Fracture No. (%)
Definitely present	44 (73.3)	No
Probably present	9 (15)	1 (1.7)
Unsure	4 (6.7)	3 (5)
Probably not present	3 (5)	9 (15)
Definitely not present	No	47 (78.3)

France). The exposure time was 0.5 sec for conventional and 0.2 sec for digital radiographs. The soft tissue effect was provided by a layer of plexiglass sheet between the teeth and x-ray tube. The image receptors in conventional radiographs were the number 2 and E-speed periapical films (Agfa, Heraeus Kulzer GmbH; Hanau, Germany) which were processed automatically (Gendex; Clarimat300, London, England); digital radiography group used CCD receptors (Vme, Eastman Kodak Company, France). To take the CBCT images, all 10 blocks were placed in the form of arc in the chin rest of the system (New Tom 3G V.G.QR, Inc, Verona, Italy) so the total number of exposures was 12. These images were prepared using fix conditions, *i.e.* 110 kVp, 1.9 mA, scan time of 3.6 sec, 9 inch FOV and 0.3 mm resolution. The three sets of images (conventional, digital, and CBCT) were evaluated by a radiologist who was blind to the roots number and grouping (Figure 1-3).The observations were marked as definitely present, probably present, unsure, probably not present, and definitely not present. In order to have 95% accuracy, the number of samples was higher than other similar studies. A view box in a dark room was considered for conventional radiographs. The CBCT images were evaluated in three planes of axial, coronal and sagittal. The gold standard group was prepared by applying the methylene blue dye on each tooth on the fracture line.

The data were analyzed in respect of sensitivity (positive results when VRF is present), specificity (negative results when VRF is not present), false positive, false negative, positive or negative indicative values (the possibility of VRF existence in positive results and the possibility of loss of VRF in negative results). Kappa coefficient was used for statistical analysis.

RESULTS

In this study, 120 teeth were evaluated (60 with induced root fracture and 60 with no fracture). Every single rooted tooth was evaluated in CBCT, digital and conventional radiography. The results were as follow:

Conventional radiography: In 38 cases fractures were detected correctly, three cases were classified as "unsure" and 19 teeth were detected without fracture (false negative). So the sensitivity was 66.7% and false negative

was 33.3%. Forty teeth without fracture were correctly detected, eight were "unsure" and 12 were regarded as fractured (false positive). So the specificity was 76.9% and false positive was 23.1 % (Table 1).

Positive indicative value was 76.0; negative indicative value 67.8, kappa factor 0.433 and the area of the ROC was estimated 0.742.

Digital radiography: Forty three of sixty root-fractured teeth were diagnosed correctly, two cases were classified as "unsure" and 15 were diagnosed incorrectly, *i.e.* false negative. So the sensitivity was 74.1% and false negative was 25.9%. Forty five of cases with no fracture were detected correctly, one was "unsure" and 14 were interpreted as fractured (false positive). The specificity was 76.3% and false positive was 23.7 % (Table 2).

Positive indicative value was 75.4, negative indicative value was 75.0, kappa factor was 0.504 and the area under the ROC curve was estimated 0.796.

CBCT: In fifty three of sixty root fractured teeth, the presence of a fracture was correctly detected. Three cases were diagnosed as not probably present and four were left as "unsure". So the sensitivity was 94.6% and false negative was 5.4%. Fifty six of sixty non-fractured teeth were correctly detected, three were "unsure" and one was detected as fractured (false positive). The specificity was 98.2% and false positive was 1.8 % (Table 3).

Positive indicative value was 98.1, negative indicative value was 94.6, kappa factor was 0.929 and the area under the ROC curve was 0.989.

DISCUSSION

Radiographic evaluation is critical for diagnosis; several factors impact on radiographic interpretation such as imaging modality, analogue versus digital, image manipulation and improvement, characteristics of image presenting on monitor and film, experience of observers and the existing data for comparison. In this study, diagnostic accuracy of three methods; conventional and digital radiography and CBCT was assessed; CBCT was found to have the highest sensitivity (94.6%) and specificity (98.2%) in VRF detection.

Kambruroglu *et al.* performed a study for detecting horizontal root fractures by conventional and digital (CCD and PSP) radiography and CBCT, and showed that the highest efficiency was for CBCT as sensitivity and specificity were 92% and 97% respectively (18). Sensitivity and specificity were 71% and 95% for Digora system (PSP), 68% and 97% for CCD, and 76% and 96% for film based technique. Our results also follow those of Bernardes *et al.*'s study which was performed *in-vivo* (19). They reported that CBVT (cone beam volumetric tomography) has a higher diagnostic accuracy compared to conventional radiography in root fracture detection as it provides 3D images. A study also reported this superiority for local CT compared with periapical radiography for VRF detection *in vitro* (7). They showed ROC of 0.91 for local CT, while it was 0.70 for conventional imaging. Their study was conducted on unfilled root canals; however, this does not emulate the clinical situation. Detection should be performed on teeth with gutta percha filled roots or posts, which cause metallic like artifact on CBCT images. Their samples were without PDL or natural bone support, like ours, which can lead to better results because of elimination of the soft and hard tissues' superimposition. Nair *et al.* performed a study which compared Tunnel Aperture Computed Tomography (TACT) and digital radiography in VRF detection; they reported TACT system had a sensitivity of 55% and specificity of 82% which was more effective than digital system with 28% sensitivity and 33% specificity (20). TACT is a modality that provides reformatted 3D images using several 2D digital radiographs with different angles and has less patient radiation compared to conventional 3D system. With CBCT invention its application has been restricted. In 1999, it was reported that conventional CT has more ability in root fractures detection *in-vitro*, but there was false negative results because of beam hardening artifact between the post and gutta percha in root filled canals (8). CT also has the disadvantage of high dose radiation. In

contrast, no significant statistical difference was reported between conventional and direct digital radiography (CCD-Barseal) in VRF detection (2). However the degree of agreement was slightly higher in digital system which can be due to digital image processing. Density and contrast changes that can improve image quality and magnification is a helpful tool in image interpretation. One study showed that magnification in digital radiography leads to deterioration in proximal caries detection (21). Esmaeeli *et al.* compared conventional and digital radiography and found no special difference in diagnostic ability, but confirmed that image manipulation improves quality and interpretation in digital radiography (22). In 2005, three-dimensional flat panel volume detector computer tomography (FD-VCT) system was proposed for detection of VRF (9). Another study detected VRFs by conventional radiographs after two years and showed that only in 35.7% of cases fractured fragments were separated by granulation tissue (23).

Radiographic evaluation has been revolutionized by invention of CBCT. Only with a slight increase in patient radiation dose, images with higher quality and more accurate information can be obtained. However there would still be some limitations *e.g.* streaking and beam hardening artifacts, although these artifacts are less than those in CT and more soluble (17,24,25). CBCT follows the ALARA recommendation, that patient radiation dose should be as low as possible. According to Ludlow study (26), CBCT scans have 4.42 times more radiation than a panoramic examination and less field size leads to less patient radiation dose. This imaging system can be considered a reliable detection method for VRFs compared to the historic poor diagnosis of VRF.

CONCLUSION

CBCT is superior to conventional and digital radiography in detecting VRF and provides more reliable data.

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Conflict of Interest: 'none declared'.

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