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Evaluation of three imaging techniques for the detection of vertical root fractures in the absence and presence of gutta-percha root fillings

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Abstract

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Aim To compare the accuracy of digital radiography (DR), multidetector computed tomography (MDCT) and cone beam computed tomography (CBCT) in detecting vertical root fractures (VRF) in the absence and presence of gutta-percha root filling.

Methodology The root canals of 100 extracted human single-rooted teeth were prepared and randomly divided into four groups: two experimental groups with artificially fractured root and two intact groups as controls. In one experimental and one control group, a size 40, 0.04 taper gutta-percha cone was inserted in the root canals. Then DR, MDCT and CBCT were performed and the images evaluated. Statistical analyses of sensitivity, specificity and accuracy of each imaging technique in the presence and absence of gutta-percha were calculated and compared.

Results In the absence of gutta-percha, the specificity of DR, MDCT and CBCT was similar. CBCT was the most accurate and sensitive imaging technique ($P < 0.05$). In the presence of gutta-percha, the accuracy of MDCT was higher than the other imaging techniques ($P < 0.05$). The sensitivity of CBCT and MDCT was significantly higher than that of DR ($P < 0.05$), whereas CBCT was the least specific technique.

Conclusions Under the conditions of this *ex vivo* study, CBCT was the most sensitive imaging technique in detecting vertical root fracture. The presence of gutta-percha reduced the accuracy, sensitivity and specificity of CBCT but not MDCT. The sensitivity of DR was reduced in the presence of gutta-percha. The use of MDCT as an alternative technique may be recommended when VRF are suspected in root filled teeth. However, as the radiation dose of MDCT is higher than CBCT, the technique could be considered at variance with the principles of ALARA.

Keywords: cone beam computed tomography, digital radiography, multidetector computed tomography, vertical root fracture.

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Introduction

Vertical root fracture (VRF) is a longitudinal root fracture, extending from the root canal to the periodontium (Pitts & Natkin 1983). It has also been defined as a longitudinal or diagonal fracture, originating in the crown or root surface (Tamse 1988). Chen *et al.* (2008) in a 5-year follow-up of root filled teeth reported that the prevalence of vertical root fracture was 32.1%. In addition, Fuss *et al.* (1999) evaluated the prevalence of VRF in extracted root filled teeth and concluded that one of the major reasons for their extraction was VRF.

Clinical symptoms and radiographic signs of VRF can imitate periodontal disease or post-treatment endodontic

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pathosis; therefore, diagnosis of VRF is challenging (Meister *et al.* 1980, Pitts & Natkin 1983, Tamse *et al.* 1999).

Intra-oral conventional and digital radiography (DR) provide a two-dimensional representation of the anatomical structures and cause superimposition of any structure between the X-ray source and the image receptor. In addition, the fracture may not be visible if the beam does not pass along the fracture line. These problems mean that intraoral radiography has limited value in the detection of VRF (Morfis 1990, Weine *et al.* 1991, Nair *et al.* 1998, Fuss *et al.* 1999). Rud & Omnell (1970) in a clinical study evaluated 468 root-fractured teeth and demonstrated that radiographic examination could reveal only one-third of them.

Three-dimensional diagnostic imaging technique may be useful for the detection of VRF. Computed tomography (CT) overcomes many of the problems associated with conventional radiographic methods, such as magnification, distortion and anatomical superimposition of structures (Youssefzadeh *et al.* 1999). However, CT equipment is costly, and the radiation dose is relatively high (Ludlow & Ivanovic 2008, Hassan *et al.* 2009). Multidetector computed tomography (MDCT) is similar to CT that provides quicker imaging with reduced movement artefact (Imhof *et al.* 2003).

Cone beam computed tomography (CBCT) provides a high-resolution image with a lower radiation dose compared with MDCT (Mah *et al.* 2003, Tsiklakis *et al.* 2005). Previous studies have shown that CBCT is superior to DR for the detection of VRF in the absence of root fillings (Kamburoglu *et al.* 2010, Ozer 2010).

As VRF has been considered as one of the major reasons for the extraction of root filled teeth (Chen *et al.* 2008), it is important to assess the influence of the gutta-percha root fillings on the diagnosis of VRF. Hassan *et al.* (2009) evaluated the effect of gutta-percha root fillings on the accuracy of CBCT and DR in detecting VRF and concluded that the presence of gutta-percha did not influence the sensitivity of CBCT scans although it reduced the specificity. The aim of this *ex vivo* study was to compare the sensitivity, specificity and accuracy of DR, MDCT and CBCT and the influence of gutta-percha root filling for the detection of VRF.

Materials and methods

One hundred single-rooted, extracted adult human teeth were used. The teeth were inspected under a stereomicroscope (Zeiss Stemi SV6; Carl Zeiss, Göttingen, Germany) to confirm the absence of VRF or cracks. After access cavity preparation, the root canals were prepared with Mtwo rotary files (VDW, Munich, Germany) to an apical size of 40, .04 taper. The teeth were mounted in acrylic resin (Acropars; Marlik Co., Tehran, Iran) after the root surfaces had been covered with four layers of nail varnish to allow the teeth to be removed. The teeth were then divided into four groups of 25 teeth: two experimental and two control groups. In the experimental groups, a size 70 spreader was inserted in the canals and tapped gently with a hammer to induce a visible VRF on the external surface of the root extending into the crown. The progression of the fracture was monitored by removing the teeth from the acrylic resin. The teeth in the control groups remained intact. A size 40, .04 taper gutta-percha cone was inserted in the root canals of the teeth in one experimental and one control groups. The teeth in each group were coded and submitted to imaging. Images of the teeth were obtained with three imaging modalities as follows.

Digital radiography was carried out using a complementary metal-oxide semiconductor (CMOS) detector (Trophy advance technology, Marne la Valée, France), which is a solid state detector. The exposure used a standard dental X-ray unit (Prodental Equipmentos Odontológicos Ltda, Ribeirão Preto, Brasil) operating at 70 kVp, 0.2 s and 10 mA. The distance between the tooth and X-ray cone was 25 cm. Each tooth was placed parallel to image receptor, so that the X-ray beam was perpendicular to tooth and image receptor; two radiographs, one straight and another with a 20° mesial angulation, were taken for each tooth.

The MDCT unit was the VCT GE 64-slice machine (General Electric Co, Milwaukee, WI, USA). Sixty-four axial scans of 0.6-mm thickness were obtained in each rotation (120 kVp, 282 mA and 6.64 s). All MDCT scans were reformatted into sagittal and coronal planes. The voxel dimensions were 0.62 mm.

Cone beam computed tomography was performed using a Promax 3D unit (Planmeca, Roselle, IL, USA) at 70 kVp, 4 mA, 10 s and with the 8×8 cm field of view (FoV) selection. The data set consisted of axial, sagittal and coronal reconstructions; the size of the reconstructed voxels was 0.16 mm.

All images from the three modalities were displayed on a 17-inch flat panel screen (Sony Electronics, Inc., Park Ridge, NJ, USA) with a 1024×768 pixel resolution. MDCT and CBCT scans were assessed in axial, sagittal and coronal planes using the software packages

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provided. Images were evaluated individually by three observers (one endodontist and two radiologists). To achieve complete intra-observer consistency, they were trained and calibrated in a pilot study using the images of 10 randomly selected teeth of each group, which were observed twice at two different periods of time.

Images obtained by each technique scored for the presence or absence of a fracture. The interobserver agreement was calculated using weighted Kappa analysis. In cases of disagreement, all the observers examined the images and reached consensus following discussion. The radiographic feature for detecting VRF on DR was a radiolucent line, which traversed the trunk of the tooth on one or both of the images. Detection of VRF on MDCT and CBCT scans was determined by the presence of a radiolucent line, which traversed the tooth surface and separated it either completely or partially in two fragments, which continued on at least two consecutive slices. The accuracy, sensitivity and specificity of each technique were calculated in the presence and absence of gutta-percha in the root canals. As the distribution of data was not normal; the Friedman test was employed to detect differences across all groups. Then Mann–Whitney *U* test was performed to detect the difference between two techniques.

Results

The results are shown in Table 1. Intra-observer reliability of calibration study was 100%. The mean values of interobserver agreement were 0.980, 0.973 and 1.000 in CBCT, MDCT and DR, respectively. No interobserver difference was observed.

In the absence of gutta-percha

The accuracy of CBCT was significantly higher than that of MDCT and DR ($P = 0.003$). In fractured teeth without gutta-percha, the sensitivity of CBCT was significantly higher than that of MDCT ($P = 0.006$) and DR ($P = 0.003$). Specificity of all techniques was not different in the absence of gutta-percha ($P > 0.05$).

In the presence of gutta-percha

The accuracy of MDCT was significantly higher than that of CBCT and DR ($P < 0.001$). The accuracy of CBCT was also significantly higher than that of DR ($P = 0.009$). In fractured teeth with gutta-percha, sensitivity of DR was significantly lower than MDCT ($P = 0.005$) and CBCT ($P = 0.002$), but there was no significant difference between MDCT and CBCT. Specificity of DR and MDCT was similar but significantly higher than that of CBCT ($P = 0.003$).

Accuracy, sensitivity and specificity of CBCT were significantly reduced in the presence of gutta-percha although gutta-percha had no effect on accuracy, sensitivity and specificity of MDCT. Furthermore, in DR, the sensitivity was only significantly reduced ($P < 0.05$). Examples of images obtained using each technique are shown in Fig 1.

Discussion

The present study compared the accuracy, sensitivity and specificity of DR, MDCT and CBCT in detecting simulated VRF in extracted human teeth. CBCT and MDCT were selected as both imaging modalities provide three-dimensional information, which is a distinct advantage over conventional radiography (Youssefzadeh *et al.* 1999). In clinical situations, VRF could remain undetected because of the two-dimensional nature of intraoral radiography, which causes superimposition of neighbouring structures (Mora *et al.* 2007, Kamburoglu *et al.* 2009).

In the present study, vertical root fractures (VRF) were produced artificially by inserting a size 70 spreader inside the root canals and tapping it gently with a hammer. To keep the fractured segments as close to each other as possible, the teeth were mounted initially in acrylic resin blocks. The methodology was

Table 1 Sensitivity, specificity and accuracy of digital radiography (DR), multidetector computed tomography (MDCT) and cone beam computed tomography (CBCT) techniques in the absence and presence of gutta-percha

Group (*n* = 50)	Sensitivity (%)	Specificity (%)	Accuracy (%)
DR without gutta-percha	52	92	72
MDCT without gutta-percha	56	88	72
CBCT without gutta-percha	92	88	90
DR with gutta-percha	28	100	64
MDCT with gutta-percha	68	88	78
CBCT with gutta-percha	80	64	72

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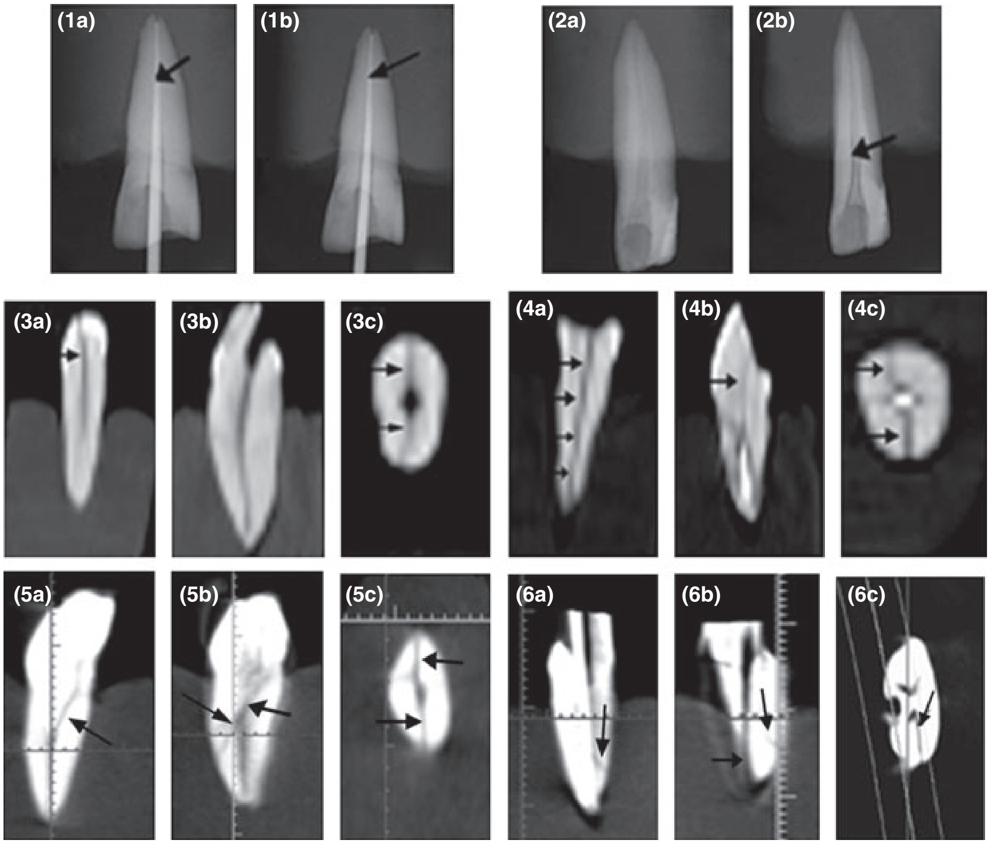

Figure 1 (1) Vertical root fracture as a radiolucent line in the presence of gutta-percha is visible on both mesial angulated (1a) and straight digital radiograph of the same tooth (1b). (2) Vertical root fracture is not visible on mesial angulated digital radiograph (2a) but is visible on straight radiograph of the same tooth (2b). (3) Multidetector computed tomography (MDCT) images of a fractured tooth without gutta-percha. (3a) Coronal, (3b) sagittal and (3c) axial. Fracture line is visible on two views. (4) MDCT images of a fractured tooth with gutta-percha. (4a) Coronal, (4b) sagittal and (4c) axial. (5) Cone beam computed tomography (CBCT) images of a fractured tooth without gutta-percha. (5a) Coronal, (5b) sagittal and (5c) axial. (6) CBCT images of a fractured tooth with gutta-percha. (6a) Coronal, (6b) sagittal and (6c) axial. The arrows show fracture lines.

similar to that of Shemesh *et al.* (2008) but not identical.

The presence of gutta-percha significantly reduced the accuracy of CBCT. This finding is in disagreement with other studies (Hassan *et al.* 2009, Melo *et al.* 2010) where the overall accuracy of CBCT scans was not reduced by the presence of root fillings. These different results might be attributed to the placement of teeth in dry human jaws rather than acrylic blocks that were used in the present study and the methodology of fracture induction (Hassan *et al.* 2009, Melo *et al.* 2010).

The results of the present study revealed that in the absence of gutta-percha, the sensitivity of CBCT in detecting VRF is significantly higher than MDCT and DR. Furthermore, in the presence of gutta-percha, sensitivity of MDCT and CBCT was significantly higher than that of DR. These results are in accordance with previous investigations which concluded that CBCT was superior to DR in detecting VRF (Hassan *et al.* 2009, Ozer 2010). Clearly, the three-dimensional nature of MDCT and CBCT allows visualization of fracture lines in various sections and angulations.

In the presence of gutta-percha, the specificity of DR was significantly higher than that of MDCT and CBCT. This could be explained by the fact that most fractures are not visible on DR (Hassan *et al.* 2009). The sensitivity and specificity of CBCT was significantly reduced in the presence of gutta-percha. This can be attributed to the fact that gutta-percha is radiopaque

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and may produce distinct star-shaped streak artefacts that may decrease observer confidence in diagnosing VRF (Hassan *et al.* 2009). The sensitivity of MDCT was similar to CBCT, and the presence of gutta-percha did not influence the sensitivity and specificity of MDCT.

The presence of gutta-percha significantly reduced the sensitivity of DR, which might result in fractures being missed. This may be due to the masking effect of the gutta-percha on the fracture line. Thus, use of MDCT as an alternative technique might be recommended in the presence of root fillings; however, the radiation dose of MDCT is higher than CBCT and may be considered against the principles of ALARA. In the clinical situation, teeth are surrounded by bone and soft tissues that might decrease the ability of an observer to detect VRF. Clearly, this laboratory study did not attempt to simulate these *in vivo* factors, and future work is required to evaluate further the potential differences between the various techniques.

Conclusion

In the presence or absence of gutta-percha, root filling CBCT and DR were the most sensitive and specific techniques, respectively. The presence of gutta-percha reduced the accuracy, sensitivity and specificity of CBCT but not MDCT although the sensitivity of MDCT and CBCT was similar. The presence of gutta-percha root fillings did not affect the accuracy and specificity of DR, but the sensitivity was reduced. The use of MDCT as an alternative technique can be recommended when VRF are suspected in root filled teeth; however, the radiation dose of MDCT is higher than CBCT, and its use may be considered against the principles of ALARA.

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