Original

Comparison of conventional radiography with cone beam computed tomography for detection of vertical root fractures: an *in vitro* study

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Abstract: To assess the diagnostic accuracy of cone beam computed tomography (CBCT) in comparison with conventional radiography for vertical root fractures, 50 of 100 teeth were subjected to vertical root fracture (VRF) and then placed in dry mandibles. 3D scans were obtained for all teeth, and conventional radiographs were used as control images. All the images were assessed by 6 observers, who determined the presence of root fractures by using a 5-point confidence rating scale. The mean area under the curve (Az) for CBCT was 0.91, and that for conventional radiography was 0.64. The difference between the modalities was statistically significant ($P = 0.003$). On the basis of interclass coefficient, inter-observer agreement for CBCT was 0/750, and that for conventional radiography was 0/637. Thus CBCT was shown to be significantly better than conventional periapical radiography for diagnosis of vertical root fractures *in vitro*. (J Oral Sci 52, 593-597, 2010)

Keywords: VRF; CBCT; conventional radiography.

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Introduction

According to the American Association of Endodontists, Vertical Root Fracture (VRF) is a fracture that extends longitudinally from the root apex to the crown (1). Horizontally, VRF may expand from the root canal wall to the root surface, involving only one aspect of the root (incomplete fracture) or both sides (complete). The fracture line may also be complete or incomplete vertically (2,3). VRFs are often iatrogenic; root canal treatment being the most frequent culprit (4).

The prevalence of VRF reportedly varies between 3.7% and 30.8% for endodontically treated teeth (5-8). After endodontic therapy and tooth restoration, the maxillary and mandibular premolars and mesial root of mandibular molars are most susceptible to VRF (9). As the prognosis of root fractures worsens with time, and the risk of root fragmentation increases, it is vital to diagnose VRF before endodontic and restorative treatment. The clinical and radiological features of VRF are not characteristic, and definitive diagnosis is only possible by observing the fracture line with or without surgical intervention (10-12).

The radiographic features of VRF were described by Natkin and Pitts for the first time in 1983 (13). Radiographic diagnosis of VRF is based on two signs: a radiolucent fracture line on the dentin, and bone loss around the tooth root or crown (14). The fracture line in radiographs is visible

when the path of the X-ray is parallel to the plane of fracture (15); otherwise, the fracture will not be visible on two-dimensional radiographs, especially in the primary stages when the fracture is a tender crack without detached fragments.

Superimposition of other structures is also a factor that limits the sensitivity of radiography for diagnosis. Moreover the two-dimensional nature of conventional radiographs renders three-dimensional observation of the fracture line impossible. Thus, three-dimensional imaging may allow better diagnosis of VRF.

Several studies have evaluated three-dimensional (3-D) imaging techniques for diagnosis of VRF, and these include tuned aperture computed tomography (TACT), which is a technique that uses two-dimensional radiographs to reconstruct 3-D images, and conventional computed tomography. It has been shown that 3-D techniques improve the diagnosis of VRF in comparison with conventional radiography (16-18).

With the recent emergence of cone beam computed tomography (CBCT) in dentistry and its advantages over conventional CT, including a shorter exposure time, high resolution, and low radiation dose, researchers have been encouraged to assess this relatively new technique for the detection of VRF (19-21).

As only a few studies have assessed this new technique, the purpose of this *in vitro* investigation was to determine the accuracy of CBCT for diagnosis of VRF.

Materials and Methods

One hundred single-rooted human teeth comprising incisors, canines and premolars that had been extracted for orthodontic treatment or because of periodontal disease were used in this study.

The crowns were cut 2 mm below the CEJ and the coronal sections of the canals were pre-flared with #2 or #3 Gates Glidden burs. Filing was performed with 15-50 K-files using the circumferential method. Then flaring of the canals was performed using the step-back technique up to a #80 file size. Vertical root fracture was then induced in 50 of the teeth. A thin coat of red wax was placed around the roots, and half the length of each root was mounted in an acrylic block 20 mm in height. Fractures were created using a Zwick/Roell Z020 Universal Testing Machine (Zwick GmbH & Co. KG, Ulm, Germany), employing a method similar to that used by Sedgley and Messer (22). A pin was inserted into the root canal, and increasing pressure was applied to the pin until VRF occurred.

The teeth were subsequently removed from the acrylic blocks and the progression of the fracture was inspected;

only teeth with a non-displaced fracture were accepted. The 50 remaining teeth were used as a control group. Except during fracture induction and radiographic scanning, all samples were kept hydrated in 0.05% Chloramine liquid during the study.

To determine a gold standard, all samples were stained with 1% methylene blue. After drying the teeth, the dye was poured into the canals, and in cases where a fracture was present, the dye was observed from the root surface. Absence of fracture in the control group was confirmed by the same method.

Before radiography, all samples were placed randomly into dry mandibles with empty tooth sockets. Three dry mandibles including one full mandible and two hemi-mandibles were used. The teeth were fixed with wax into the tooth sockets; for soft tissue simulation, mandibles were covered by double layers of boxing wax. Each jaw was then scanned three times. Conventional images were acquired using a Gendex Dental X-ray set (Dentsply International Inc. Des Plaines, IL, USA), operating at 7 mA and 65 kV. The exposure time was 0.03 s for the incisor region, 0.04 s for the premolar region, and 0.05 s for the molar region. A CCD sensor (Trex-Trophy Radiology Inc., Marne-la-Valee, France) was used for preparing the images.

The CBCT images were prepared using Promax 3D (Planmeca, Helsinki, Finland) set at 76 kV and 6 mA. Exposure time was 12 s, the field of view (FOV) was 8×8 cm, and the image resolution was 0.16 mm.

Volume reconstruction was performed with Romexis viewer (Planmeca) software. Five maxillofacial radiologists and a resident of maxillofacial radiology were recruited as observers. The images were displayed on a 19-inch LCD monitor (LG, FLATRON L 1752S) (Figs. 1 and 2). The observers were able to modify the contrast and brightness of the images, and there was no time limit for observation. The observers recorded their opinion using a 5-point confidence rating scale as follows: 1, fracture definitely not present; 2, fracture probably not present; 3, uncertain whether fracture is present or not; 4, fracture probably present; 5, fracture definitely present.

Data were analyzed using the SPSS software package (version 16). Paired *t*-test was used for assessing the correlation between the two imaging modalities. Agreement among observers was computed using the inter-class correlation (ICC) index, and ROC curves were constructed for each observer and each modality.

Results

A significant difference between the two imaging methods was demonstrated by *t*-test ($P < 0.001$). Figure

3 shows the ROC curve for all observers based on imaging modality. The area under the curve (Az) for each observer and modality are given in Table 1; Az values for CBCT were higher than those for conventional imaging. Az values did not vary widely among observers. In terms of the ICC index, the agreement among observers for conventional imaging was 0.637 and that for CBCT imaging was 0.750. Az for CBCT was between 0.8 and 1 with an average of 0.90, while this value for digital peri-apical

Table 1 Areas under the ROC curve (Az) based on imaging modality

Observer	Conventional	CBCT
1	0.64	0.91
2	0.64	0.87
3	0.51	0.90
4	0.55	0.89
5	0.62	0.89
6	0.64	0.95
Mean	0.64	0.91
SD	0.06	0.03

ROC, receiver operating characteristic
CBCT, cone beam computed tomography

Fig. 1 Conventional digital radiograph of a tooth with a vertical root fracture. The fracture is not visible.
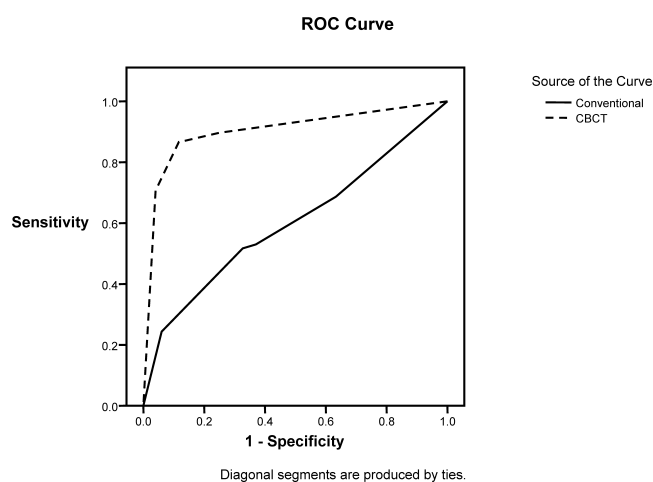

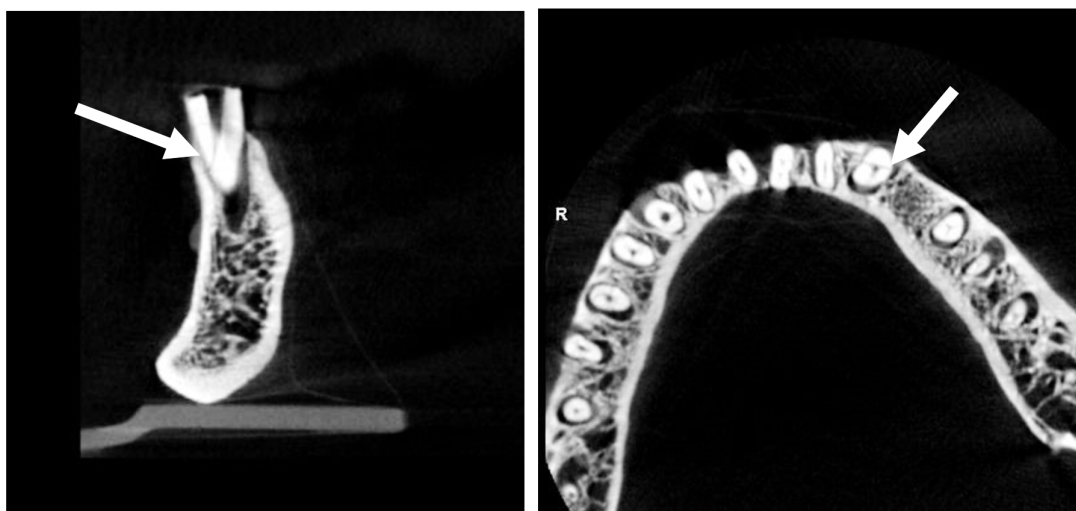Fig. 3 Receiver operating characteristic curves for all observers based on imaging modality.

Fig. 2 Images of the same tooth as that in Fig. 1 obtained by CBCT (arrows indicate the fracture) : left, axial image; right, cross sectional image.

images was between 0.5 and 0.7 with an average of 0.60.

Discussion

This study demonstrated that CBCT achieves a more accurate diagnosis of VRF in comparison to digital radiographs. The present results were compatible with those of an *in vivo* study by Bernardes et al. (20) and an *in vitro* study by Hassan et al. (21). The present findings were also similar to those of Mora et al. (19), although they used LCT (prototype CBCT) which was not applicable clinically. The Az values they obtained for digital images were slightly higher than those of the present study (mean Az = 0.7). As the authors did not place the teeth completely into the sockets, superimposition of hard and soft tissue was not present in the 2-D images. For our investigation, we placed the whole length of roots into the tooth sockets, and surrounded them with simulated hard tissue to mimic clinical conditions. In order to prevent artifact formation on CBCT images, no posts or metal materials were used in the root canals. Further studies with intracanal posts are recommended provided that the artifacts are controlled, in order to simulate clinical conditions.

There are a number of difficulties with 2-D radiography for diagnosis of VRF, including orientation of the fracture line on the teeth, the angle of X-ray incidence relative to the fracture line, superimposition of the overlying structures, and inability to examine the images in the third dimension.

With CBCT however, the observer is able to see the images interactively in three dimensions. The thickness of the slices used in this study was 0.16 mm, which enables observation of the different planes (axial, coronal and sagittal) without superimposition.

Digital images were utilized rather than film-based images, as previous studies failed to demonstrate any marked difference between the two methods for detecting VRF (11,23). Moreover, the use of digital radiographs allows observers to control the imaging characteristics by changing the contrast and brightness, thus attaining similar conditions in all radiographs.

Before the application of CBCT to dentistry, other 3-D techniques such as conventional CT and tuned-aperture computed tomography (TACT) were evaluated. In an *in vivo* study, Youssefzadeh et al. (16) showed that conventional CT had greater diagnostic ability for detecting VRF than conventional radiography; however, the use of CT for detection of VRF is not justified because of the high radiation dose required (24). Several studies have shown that TACT is more accurate for detection of VRF (17-18), but the appearance of new methods such as CBCT has restricted its use.

To enclose tooth roots completely by the mandibular bone, the roots had to be selected to fit each socket. In spite of the advantages of this method, some disadvantages had to be tolerated, such as the selection of small roots for small sockets, causing difficulty in the detection of fractures, especially in the anterior mandible in axial sections.

Although magnification of images was possible, the resolution decreased as the images became pixilated. This was reflected in the observers' responses: correct answers for the anterior mandible were fewer than those for other regions due to the small tooth size in that region.

The present results indicated that the sensitivity and specificity of CBCT were higher than those for conventional imaging. In this study, the fracture lines were oriented in a buccolingual direction in the most of the fractured teeth. Mesiodistal fractures are difficult to detect on periapical radiographs (15). Therefore, the sensitivity and specificity of conventional radiography might have been lower if more mesiodistal fracture lines had been observed.

Interestingly, agreement among observers for CBCT imaging was 0.750 and that for digital imaging was 0.635. We may conclude that viewing of fracture lines in three dimensions created higher agreement among observers. Through a slight increase in patient radiation exposure, more information can be acquired by CBCT in comparison to conventional radiography. In most cases, therefore, the dose increase is justified; however, with the common use of plain films requiring a low dose that can meet diagnostic requirements, any unnecessary use of CBCT is a concern. Current studies are focusing on techniques that can reduce the exposure dose for CBCT while maintaining image quality. One such technique is to decrease the basis projection number, as Mora et al. (25) demonstrated in 2007. In addition to their previous study that investigated the accuracy of LCT for detection of longitudinal fractions (19), in another study (25) they concluded that a decrease of image numbers from 180 to 60 made little difference for diagnosis of root fractures, while achieving a considerable dose decrease. Because of the increasing popularity and use of CBCT, further studies may be necessary. Of course, further studies are also required to provide a greater body of data for this new field.

Thus, taken together with existing data, the present findings indicate that the CBCT technique has higher accuracy than 2-D radiography for *in vitro* diagnosis of VRF.

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