RESEARCH

Value of cone beam CT in detection of dental root fractures

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Objective: The primary objective of this investigation was to evaluate the detection of root fracture using cone beam CT (CBCT) images and compare these findings with real samples of extracted teeth. A second aim was to determine the importance of reconstructed images in the diagnosis of root fracture.

Methods: Conventional periapical radiographs and CBCT images of 10 cases, each with a suspected diagnosis of root fracture, were evaluated in accordance with a pre-established scoring system by a maxillofacial radiologist who was unaware of the clinical symptoms of the patients. Then, the radiologist and an endodontist, aware of patient symptomatology, performed a second evaluation by cross-comparison of these images with clinical findings. Final patient results were based on direct visualization of each extracted tooth and its colourization.

Results: CBCT shows good potential for use in the detection of root fracture as it ensures a high level of diagnostic score accuracy. Reconstructed axial views were more effective in confirming specific diagnoses than other reconstructed views. Combining the clinical and radiographic findings further improved the results.

Conclusions: CBCT can be an ideal alternative in the diagnosis of root fracture in the field of endodontics. This option may also increase assurance of dentists and oral surgeons obtaining an accurate diagnosis of their patients' problems and help decrease the potential failure of treatment and/or the prescription of unwarranted dental procedures.

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Introduction

Excessive and improper forces during root canal procedures may result in fatigue and can cause vertical root fractures (VRFs) or cracks that in turn induce inflammation in the adjacent periodontium. Generally, fractures occur in the facial–lingual dimensions and extend from the cervical towards the apical regions.¹

These fractures may possibly start from the inner part of the root and extend towards its outer surface. These fractures can also be partial. The most important sign of root fracture is pain on mastication. Clinical views of root fractures may resemble periodontal lesions or abscesses. The presence of fistulas is another sign of root fracture. However, many teeth with root fracture demonstrate normal periodontal probing patterns and depth.²

Root fracture may not be seen in conventional radiographs because the undamaged segment may superimpose itself on the fractured segment.^{1–3} In these cases, the diagnosis of root fracture could present itself as a clinical problem. When comparing various types of fractures, distinguishing a horizontal fracture is easier than recognizing a vertical one, because in horizontal fractures there is no masking effect of root canal filling. The penetration of the central ray through the fracture line makes the diagnosis of root fractures or cracks easier.

Angular bone loss from the apical portion of the root toward its lateral surface and a lateral lucency that can be halo-like extending toward the furcation region may be a radiographic sign of root fracture. The causes of fractures or cracks include (a) the presence of posts inside the root canal, (b) long periods of ultrasonic vibrations, (c) occlusal impacts, (d) improper instrumentation usage and (e) the exertion of undue pressure at the time of root filling.⁴

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Undoubtedly, being able to determine the position, direction and size of the fracture line is of the greatest value in choosing a proper treatment plan. When diagnosing root fracture, the clinical symptoms of the patient take precedence over conventional radiographic findings. In general, conventional radiographic findings in the diagnosis of root fracture are not always specific.

A good way to confirm the diagnosis of VRF is to perform exploratory surgery. Since many of the affected teeth are ultimately beyond repair and must be extracted, being able to make a positive diagnosis prior to extraction is of utmost importance. This leads dental practitioners to consider the value of developing advanced techniques in the diagnosis of root fracture.^{5,6}

Low-dose cone beam CT (CBCT) and its observed effectiveness in the field of dentistry have resulted in the ever-growing usage of this technology in various endodontic diagnostic procedures, including the assessment of root fractures. In CBCT, voxel sizes vary from 0.125 mm to 2 mm. Multiplanar (axial, sagittal and coronal) image reconstruction capability along with minimal metallic artefact interference make this modality highly important in the assessment of maxillofacial structures.

High resolution three-dimensional (3D) images can further improve the ability to diagnose root fractures; however, limited studies presently exist regarding the value of CBCT in diagnosing root fracture.⁶⁻⁸ The purpose of this investigation was to evaluate conventional radiographic and CBCT findings of patients with an uncertain diagnosis of root fracture. In addition, their clinical findings and colourized teeth were evaluated to confirm or rule out the probable diagnosis. Further attention was paid to defining a CBCT protocol to further enhance its diagnostic efficacy and accuracy.

Materials and methods

The study was conducted on 10 patients (9 females and 1 male, aged 21–70 years) with endodontically treated teeth and a suspected diagnosis of root fracture. We originally obtained the approval of the ethical board of the research foundation of Guilan University of Medical Sciences in Rasht, Iran, to conduct this investigation (Ethics Approval Number 3073). All patients had clinical symptoms such as pain on mastication and/or after percussion, swelling in the apical region or on other surfaces extending towards the cervical region or repetitive fistulas. In these patients, the fracture line or crack was neither recognizable nor positively identifiable in their periapical radiographs (PRs).

Their conventional radiographic findings were a simple widening of periodontal ligament (PDL) space, a halo-like lucency, an apical and/or a lateral lucency along the root surface and/or angular crestal bone loss

in either diffuse or defined forms without well-defined corticated borders. All patients insisted on obtaining a perfect diagnosis before consenting to additional treatments such as extraction and/or implant treatment.

Upon informing the patients and obtaining their written consent, individual patients' CBCT scans were taken to gain a higher assurance of each diagnosis. CBCT images for all patients were obtained with New-Tom VG equipment® (QR SRL Company, Verona, Italy) in HiRes zoom mode at 110 kV, 5.5 mA and 5.4 s. Two scout images, *i.e.* lateral and posterior–anterior views taken in accordance with the patient's position, were prepared initially and a 360° scan was acquired afterwards. The total scan time was 18–20 s. The time required for the reconstruction of volumetric images after the patient's complete exposure was 4 min.

Then, to reconstruct study images from the volumetric images, the plane was selected in such a way to ensure that it was perpendicular to the selected tooth axis. Axial images with a thickness of 0.4 mm and an interval of 0.4 mm were prepared. Cross-sectional images with a thickness of 1 mm and an interval of 0.15 mm to 0.5 mm perpendicular to the mesiodistal, buccopalatal and buccolingual axes were prepared. Next, a maxillofacial radiologist and an endodontist, *i.e.* the co-investigators, who were familiar with CBCT and who each had more than 10 years of professional work experience, assigned the following patient scores and examined the results: score 0—unrecognizable, *i.e.* too poor for diagnosis; score 1—poor, but diagnosable; score 2—adequate for diagnosis; score 3—optimal for obtaining diagnostic information.

Initially, the radiologist, unaware of the clinical symptoms of the patients, independently studied the CBCT images and conventional radiographs. Subsequently, the radiologist and an endodontist who was aware of the patients' symptoms performed a second evaluation. Cross-comparisons with clinical findings by consensus of these two practitioners were performed at that time.

Final patient results were based on direct visualization of the extracted tooth and its colourization. Extraction decisions were made on the presence of root fracture. The dentists or oral surgeons were asked to extract each patient's tooth without using excessive force, to prevent breakdown of the affected roots.

In addition, the dentists or surgeons were requested to colourize the patients' teeth with methylene blue dye and report the presence of fracture lines. Later, they sent us the extracted teeth or their photos to confirm the location and presence of the fracture lines they had previously reported.

This was done in all instances except in Case 7. In that case, after removing the filling material and upon directly visualizing the pulpal floor, a horizontal fracture line in the base of the pulpal floor was confirmed. Ultimately, however, the sample in Case 7 was lost owing to tooth fracture following extraction.

Results

Table 1 presents the scores assigned by the radiologist to define root fracture observed on CBCT and conventional radiographs before and after cross-comparison with clinical findings. In this study, the teeth in 8 of 10 cases were proven to be fractured after extraction and tooth colourization. In this study, upon the initial blind review of the CBCT images and conventional radiographs for each patient by the maxillofacial radiologist, 5 of the 10 cases were assigned a diagnostic score of 2, and in 2 cases, the diagnostic score was 1. After cross-comparison with the endodontist who was aware of each patient's clinical findings, the number of diagnostic scores of three increased from three to five and one of the initial two cases receiving a score of one was rescored as two.

Figures 1–4, which correspond to Cases 1, 4, 5 and 9 shown in Table 1, reveal fractures on 3D scans that could not be detected on conventional radiographs. In these scans, the different patterns of root fractures from complete buccopalatal, buccolingual or mesiodistal root fractures to curved partial (incomplete) root fractures were presented.

Root canal treatment of all teeth except for Case 1 was good. In nine cases, the teeth were colourized. These cases were then checked to determine whether the CBCT findings were positive (detectable) or negative (undetectable). In Case 7, the patient's tooth could not be colourized owing to a breakage that occurred during the extraction process. However, before extraction, the

diagnosis made was based on the direct inspection of the pulpal floor.

Discussion

Restorations or treatments of the root can lead to the removal of dentine and may consequently weaken the root structure and thus increase its susceptibility to root fracture. Root fractures occur mainly on the posterior teeth.⁹ In the present investigation, the majority of the teeth under investigation were either single or double-rooted teeth.

There are many studies on the value of different imaging methods such as charge coupled device (CCD),³ tuned aperture computed tomography (TACT),⁵ CT¹⁰ and CBCT^{6–8} for diagnosis of root fracture or crack. In evaluating the value of CT in diagnosing VRF, Youssefzadeh et al¹⁰ showed that the average sensitivity of CT approximated 70% while conventional radiography averaged 23%. The limitations of the Youssefzadeh et al study were the presence of beam-hardening artefacts produced between the post and gutta-percha that resulted in reduced spatial resolution and high false-negative readings as well as the high doses of radiation used.

Volumetric computed tomography (VCT) or CBCT are new technologies used in endodontic treatments. In this type of imaging, a cone beam instead of fan-shaped radiation is used.¹¹ Having the ability to

Table 1 Patient data and respective scores assigned by radiologist during evaluation of cone beam CT before and after cross-comparison with clinical findings

Case number	Sex	Age	Tooth number	Clinical findings	Score upon initial review by radiologist (blind to patient symptomology)	Proper cuts for diagnosis	Score after cross-comparison with endodontist (aware of patient symptomology)	Final diagnosis after extraction and colourization
1	F	48	35	Buccal swelling at mid-root level	3	Axial and MD cross-sections	3	Detected
2	F	61	15	Pain upon mastication	2	Axial and MD cross-sections	2	Detected
3	F	44	25	Pain upon mastication and fistula at mid-root level	2	Axial and MD cross-sections	3	Detected
4	F	70	24	Buccal swelling and pain upon mastication	2	Axial and BP cross-sections	2	Detected
5	F	26	21	Painful buccal and cervical swelling	3	Axial and BP cross-sections	3	Detected
6	F	64	14	Recurrent fistula and pain	2	Axial and MD cross-sections	2	Detected
7	F	33	11	Buccal and cervical fistula	1	Axial and BP cross-sections	2	**
8	F	32	47	Pain upon mastication	3	Axial and BL cross-sections	3	Detected
9	F	22	36	Buccal fistula	2	MD and BL cross-sections	3	Detected
10	M	21	21	Apical fistula	1	MD cross-sections	1	Undetected

BL, buccolingual; BP, buccopalatal; MD, mesiodistal

**Sample lost owing to tooth fracture during extraction

Figure 1 (a) Conventional radiography of the left mandibular second premolar tooth shows a halo-like radiolucency and an uncertain fracture line near the cervical third of the root. (b, c, d) Axial and cross-sectional images reveal a buccopalatal fracture line that extends from the cervical third to the end of the middle third of the root. (e) Extracted tooth after colourization

prepare high resolution images and isotropic images is a distinct advantage of using CBCT compared with medical CT images. CBCT provides adequate speed in image acquisition and reconstruction.¹¹ Likewise, the added ability to make 3D images and the ease of manipulating images furnished by this system may be advantageous when using this technique in endodontics. Thus, considering the advantages offered by CBCT to diagnose root fracture, this method was specifically selected for use in this investigation.

In this study, upon the initial blind review of the CBCT images and conventional radiographs for each patient by the radiologist, 3 of 10 cases were assigned a score of 3. After cross-comparison with clinical findings, an additional two cases scored a three, representing a 20% increase in the ability to detect VRF. The changes observed in the percentage of diagnostic scores given at

the two different review stages, therefore, underscores the importance of co-evaluation of clinical and radiographic findings.

Mora et al⁷ obtained favourable results in diagnosing VRF by using laboratory local CT in comparison with conventional periapical (PA) radiography.⁷ In addition, Bernardes et al⁸ emphasized the superiority of using CBCT in diagnosing VRF compared with conventional radiographs.⁸ Flat panel detector–volume computed tomography (FD-VCT) has also made the observation and assessment of cracks possible.⁶

Hassan et al¹² reported that the sensitivity and accuracy in detecting VRF lines were significantly higher in CBCT scans than in PRs. However, root canal filling did not reduce the accuracy of CBCT.¹² Moreover, the same study further showed an overall higher accuracy (0.86) for CBCT scans than PRs (0.66) in detecting

Figure 2 (a) Proper endodontic treatment of the left maxillary first premolar tooth before post and crown treatment. (b) Axial view from the mid-root portion reveals a fine oblique crack line extending from the mesial to the distal portions of the buccal root of the left maxillary first premolar tooth. (c) Cross-sectional views of the mesial side confirmed an oblique fine root crack in the middle third of the buccal root

VRF.¹² The present investigation also confirms the accuracy of using CBCT to diagnose root fractures and their patterns similar to previous studies.

As shown in the Mora et al *in vitro* study, the absence of compounds such as root fillings or posts can make the diagnosis of induced root fractures easier.⁷ Also, Hassan et al reported that the presence of root canal fillings did not have a negative effect on diagnosis of root fracture.¹² Similarly, in this study, the co-investigators did not experience any serious problems in diagnosing root fracture when compounds such as root fillings or posts were present.

Youssefzadeh et al encountered the limiting factor of beam hardening artefacts produced between the post and gutta-percha in using CT.¹⁰ However, in the current investigation, the effects of beam hardening artefacts were minimized because CBCT was used instead.

One of the limitations of the present study relates to asking the dentists and oral surgeons involved in these cases not to use excessive force when extracting the patient's tooth. It must be kept in mind that excessive use of force might have produced additional crack lines. The fracture line extending from the inner portion to the superficial area indicated that the line might have been incomplete. Thus, another limitation is associated with the colourization of the partial crack line. In this instance, *i.e.* case number 10, the absence of a colourized line may be related to the

above-mentioned reason and does not indicate that the root structure is intact. The variety of radiographic outcomes from normal radiographic findings to other diffuse areas of radiolucency, which is restricted to only one of the molar roots, is reported. A lateral bony lesion with a markedly asymmetrical radiographic J-shaped appearance is an important indication of root fracture. Accordingly, this factor in the diagnosis of root fracture must be considered.¹³ But, in this study, Cases 1 and 3 showed a halo-like or J-shaped radiolucency.

In only one case (number 1), the patient's tooth was the abutment for a bridge. In all other cases the patients' teeth did not bear any additional load, which in turn may explain the lack of presence or delay in creating a halo-like lucency.

In the majority of the patients, swelling, pain and fistula were the main complaints. This observation concurred with the findings reported by Bernardes et al⁸ and Moule and Kahler.¹⁴

However, the fracture line was not clear in the conventional radiographs of their cases. This limitation was also consistent with prior observations made by Moule and Kahler¹⁴ as well as Rud and Ommell.¹⁵ In Cases 2, 3, 4 and 7, the VRF lines had curved patterns, *e.g.* extending from the proximal portion to the buccal, palatal or lingual sides. This curved pattern of fracture therein, however, increases the chance of missing the

Figure 3 (a) Apical bone rarefaction in the apical portion of the left maxillary incisor tooth and also a small radiolucent area in the mesio-cervical portion of the root. (b) Root resorption in the mesiopalatal surface of the root and also a fracture line extending in the buccopalatal direction in axial view (arrows). (c) A vertical root fracture (VRF) extends from the cervical to the apical portion and also shows an apical lucency extending towards the palatal side that can be found in cross-sectional views

detection of this fracture line in conventional radiographs.

One of the limitations of CT in dental diagnostics is the high dose of radiation used. Typically, the average effective dose in the NewTom VG is 36.9 μSv .¹⁶ However, reduction of the selected field of view (FOV) could be effective in reducing the dose received by the patient. Another reason CBCT is not widely used in dental diagnostics, especially in the field of endodontics, is the lack of training and adequate knowledge of dentists to interpret images.

The high contrast resolution provided by CBCT as well as its high bit depth and spatial resolution distinguishes it from conventional PA radiography. Conventional CT has a resolution of 500 μm that only provides an inadequate spatial resolution for diagnosing hairline cracks. Studies have shown that for the assessment of VRF, a spatial resolution of 140 μm is required.⁶ The NewTom VG is one of the CBCT systems that can have a spatial resolution close to this level by using a flat panel detector (FPD) and small-sized voxels. Among

different CBCT systems, the FPD-based system is superior to other types in the diagnosis of VRF.¹⁷

However, focusing radiation on the region under study using this technology can be highly effective in aiding endodontic treatment as well as in reducing the dose of radiation received by the patient. The most important point in this study is the improvement obtained in making a positive diagnosis of root fracture upon the selection of a plane that is perpendicular to the root axis. This technique can result in making axial images that are of great value in diagnosing root fracture in such a way that an 80% positive diagnosis of fractures becomes possible. This finding concurs with that of the Hassan et al study¹⁷ that showed axial images are more accurate than coronal and sagittal ones in the detection of VRF. In addition, the reconstruction of cross-sectional images in which a 1 mm thickness and 0.15 mm to 0.5 mm interval in the mesiodistal, buccopalatal or buccolingual dimensions is an important property of using CBCT in diagnosing the details of root fracture in comparison with those seen in conventional images.

Figure 4 (a) Proper endodontically treated left mandibular first molar tooth without pathological finding seen in conventional radiography. (b) A local buccal lucency is observed at the mid-root level and a curved buccolingual fracture line is apparent at the same level in buccolingual cross-sectional views, and (c) an apical lucency and a vertical root fracture appear in mesiodistal cross-sectional view

In conclusion, CBCT may be helpful in the assessment of the pattern of a fracture line and can help dentists and endodontists to make extraction and/or implant decisions that affect their patients by having reliable documentation and strong enough evidence. Moreover, an earlier diagnosis prevents additional bone loss and helps guarantee the success of alternative treatments such as implant placement. Despite the possible advantages of using this method, it should be borne in mind that CBCT still has a higher radiation

dose and this option should not be prescribed until after conducting a precise clinical examination.

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References

- Walton RE, Torabinejad M. Cracked tooth and vertical root fracture. In: Walton RE, editor. *Principles and practice of endodontics*. 4th edition. Philadelphia, PA: WB Saunders, 2009, pp 108–128.
- Meister F Jr, Lommel TJ, Gerstein H. Diagnosis and possible causes of vertical root fractures. *Oral Surg Oral Med Oral Pathol* 1980; **49**: 243–253.
- Tsesis I, Kamburoğlu K, Katz A, Tamse A, Kaff I, Kfir A. Comparison of digital with conventional radiography in detection of vertical root fractures in endodontically treated maxillary premolars: an ex-vivo study. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2008; **106**: 124–128.
- Satterthwaite JD, Stokes AN. Dentinal crack incidence following ultrasonic vibration to intra-radicular posts. *NZ Dent J* 2004; **100**: 105–109.
- Nair MK, Nair UP, Grondahl H-G, Webber RL, Wallace JA. Detection of artificially induced vertical radicular fractures using tuned aperture computer tomography. *Eur J Oral Sci* 2001; **109**: 375–379.
- Hanning C, Dullin C, Hülsmann M, Heidrich G. Three-dimensional non-destructive visualization of vertical root fractures using flat panel volume detector computer tomography: an ex vivo in vitro case report. *Int Endod J* 2005; **38**: 904–913.

7. Mora MA, Mol A, Tyndall DA, Rivera EM. In vitro assessment of local computed tomography for the detection of longitudinal tooth fractures. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2007; **103**: 825–829.
8. Bernardes RA, deMoraes IG, Duarte MAH, Azevedo BC, de Azevedo JR, Bramante CM. Use of cone-beam volumetric tomography in diagnosis of root fractures. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2009; **108**: 270–277.
9. Tamse A, Fuss Z, Lusti G, Kuplavi J. An evaluation of endodontically treated vertically fractured teeth. *J Endod* 1999; **25**: 506–508.
10. Youssefzadeh S, Gahleitner A, Dorffner R, Bernhart T, Kainberger FM. Dental vertical root fractures: value of CT in detection. *Radiology* 1992; **210**: 545–549.
11. Nair MK, Nair UP. Digital and advanced imaging in endodontics: a review. *J Endod* 2007; **33**: 1–6.
12. Hassan B, Metska ME, Ozok AR, van der Stelt P, Wesselink PR. Detection of vertical root fractures in endodontically treated teeth by a cone beam computed tomography scan. *J Endod* 2009; **35**: 719–722.
13. Bargholz C. Vertical tooth and root fractures. In: Hülsmann M, Schöfer E, editors. *Problems in endodontics, etiology, diagnosis and treatment*. 1st edition. London, England: Quintessence, 2009, pp 353–370.
14. Moule AJ, Kahler B. Diagnosis and management of teeth with vertical fractures. *Aust Dent J* 1999; **44**: 75–87.
15. Rud J, Ommell KA. Root fracture due to corrosion. *Scand J Dent Res* 1970; **78**: 397–403.
16. Miles DA. Basic principles. In: Miles DA, editor. *Color atlas of cone beam volumetric imaging for dental applications*. 1st edition. Hanover Park, IL: Quintessence, 2008, pp 12–13.
17. Hassan B, Metska ME, Ozok AR, van der Stelt P, Wesselink PR. Comparison of five cone beam computed tomography systems for the detection of vertical root fractures. *J Endod* 2010; **36**: 126–129.