
The ability of cone-beam computerized tomography to detect vertical root fractures in endodontically treated and nonendodontically treated teeth: a report of 3 cases

Xiaoying Zou, DDS, MD,^a Denggao Liu, DDS, SMD,^b Lin Yue, DDS, PhD,^c and Minkai Wu, PhD,^d Beijing, China; and Amsterdam, The Netherlands
PEKING UNIVERSITY SCHOOL AND HOSPITAL OF STOMATOLOGY,
UNIVERSITY OF AMSTERDAM AND VU UNIVERSITY

A definitive diagnosis of vertical root fracture (VRFs) is often a challenging task for clinicians. Two-dimensional periapical radiographs (PRs) may be not helpful in such a diagnosis when the x-ray beam is not parallel to the plane of the fracture line. This report presents a set of 3 cases in which 1 endodontically treated and 2 nonendodontically treated mandibular molars were diagnosed with VRFs based on findings from clinical, radiographic, and cone-beam computerized tomographic (CBCT) examinations. After extraction, VRFs were confirmed in all of the teeth. Deep and narrow periodontal pockets were detected in 2 molars. A widening of the root canal space was observed in the PR of 1 molar only, and crown cracks were detected in none of these cases. However, in all 3 molars, fracture lines were visible on the CBCT images. Thus, CBCT provided useful information in diagnosing VRFs in both endodontically treated and nonendodontically treated teeth, especially when VRFs could not be confirmed by clinical findings and PRs. (*Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2011;111:797-801)

Vertical root fractures (VRFs) are usually characterized by an incomplete or complete fracture line that extends along the long axis of the root to different levels of the root.¹⁻³ Both endodontically treated teeth and non-endodontically treated teeth can be involved.⁴ The prognosis of VRFs is poor, and tooth extraction should be considered in most cases.⁵

VRFs in nonendodontically treated teeth, known as spontaneous VRFs,⁴ are not commonly reported, but they are not rare in the Chinese population over the age of 40 years.^{4,6} The reason for the susceptibility of these virgin teeth to fracture is not clear, but moderate to severe occlusal attrition is often observed on these teeth.⁴ The signs and symptoms of spontaneous VRFs may be consistent with an irreversible pulpitis or apical periodontitis. In the early stages, the tooth can still be responsive and might exhibit thermal sensitivity, indicating that the pulp of the fractured root might be in an

inflamed condition; gradually, the tooth becomes unresponsive to pulp sensitivity tests, indicating necrosis of the pulp.⁴

Recognition and definitive diagnosis of VRFs is a great challenge to the clinician. Although deep periodontal pockets and vertical bone loss are the most predominant clinical and radiographic signs,³ neither of these signs is specific for VRFs. Untreated lateral canals or root perforations can also result in periodontal pockets with similar characteristics.³ Vertical bone loss may not be visible when the buccal cortex is thick.⁷ Widening of the root canal space, which indicates separation of the root fragments and is often observed in teeth with spontaneous VRFs,⁴ is not always detectable, depending on the angle of the x-ray beam in relation to the plane of fracture.⁴

In both clinical^{8,9} and ex-vivo¹⁰⁻¹³ studies, computerized tomography was used to detect VRFs. And cone-beam computerized tomography (CBCT) detected twice as many teeth with VRFs as periapical radiographs (PRs).^{8,12} Therefore, when CBCT is not used, teeth with VRFs, especially in the early stages, may be undiagnosed, and the low prevalence of VRFs estimated previously⁴ could be underestimated. Many cases of VRFs could not be definitively diagnosed until tooth extraction.¹ However, teeth with undiagnosed VRFs are likely to receive endodontic treatment or retreatment, leading to a potential risk of endodontic failure. VRFs are often diagnosed or suspected only after endodontic failure. Unfortunately, these VRFs are usually considered to be a consequence of the endodon-

^aResident, Department of Cariology, Endodontology, and Operative Dentistry, Peking University School and Hospital of Stomatology.

^bAssociate Professor, Department of Oral and Maxillofacial Radiology, Peking University School and Hospital of Stomatology.

^cProfessor, Department of Cariology, Endodontology, and Operative Dentistry, Peking University School and Hospital of Stomatology.

^dSenior Scientist, Department of Endodontology, Academic Center of Dentistry Amsterdam (ACTA), University of Amsterdam and VU University.

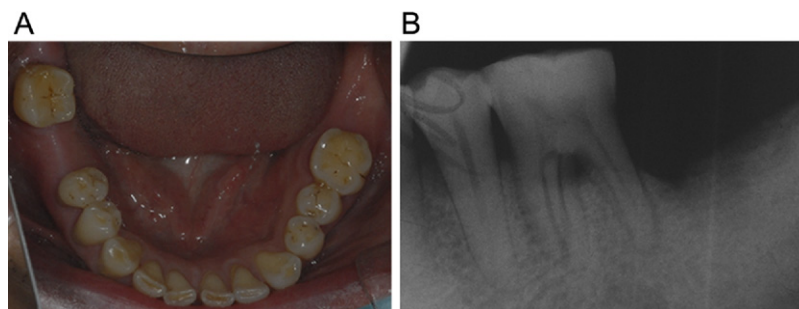


Fig. 1. **A**, Occlusal view of the mandibular teeth. Teeth nos. 18 and 30 are missing. **B**, Radiograph of tooth no. 19 in case 1 shows a widening of the mesial root canal, which is not filled.

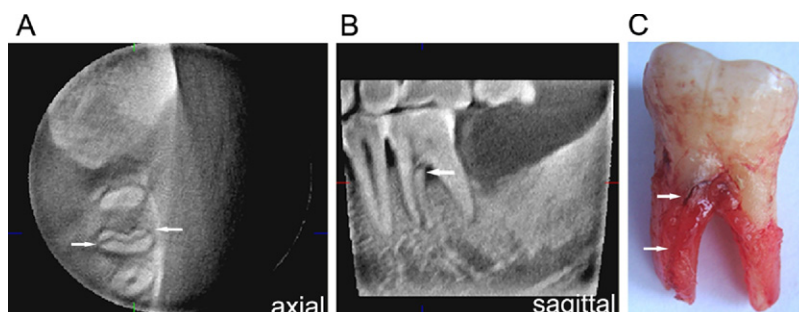


Fig. 2. The CBCT images in the (A) axial and (B) sagittal planes of tooth no. 19 in case 1 clearly show fracture lines in the mesial root (arrows). C, After extraction, a vertical fracture of the mesial root was confirmed (arrows).

tic or restorative procedures. With the help of CBCT and the recent progress made in CBCT techniques,¹⁴ VRFs can be detected quickly, which is essential for avoiding unnecessary and inappropriate treatments.

The present report presents 3 cases of patients who attended the Department of Cariology, Endodontology, and Operative Dentistry, School and Hospital of Stomatology, Peking University, Beijing, China. A diagnosis of VRF was made through the patients' dental histories as well as clinical, radiographic, and CBCT findings. The operating parameters for the 3DX Accutomo (J Morita Mfg. Corp., Kyoto, Japan) were 80 kVp, 5 mA, and an exposure time of 17.5 seconds. Scans were made according to the manufacturer's recommended protocol. Tomographic sections of 1 mm in 3 planes (axial, coronal, and sagittal) were created.

CASE REPORTS

Case 1

A 49-year-old man complained of pain on cold stimulus and on chewing associated with the mandibular left first molar (tooth no. 19) for 6 months with aggravated pain beginning 2 weeks before examination. There was no history of spontaneous pain, trauma, or chewing hard food. The intraoral examination revealed that 2 molars were missing (Fig. 1, A) and that there were no caries or cracks on the crown surfaces of tooth no. 19 detected by iodine-tincture

staining. But percussion sensitivity and pain of tooth no. 19 when biting with a cottonwood stick were sensed by the patient. In thermal pulp testing on this tooth, pain on cold stimulus lasting several seconds was reported. The periodontal examination revealed grade II mobility,¹⁵ a 2- to 4-mm recession, and grade 2 furcation involvement, whereas the pocket depth was within normal limits and no sinus tract was found. Radiographically, all root canals were unfilled; the mesial root canal space was pronouncedly radiolucent and wider from the canal orifice all of the way to the apex (Fig. 1, B). Alveolar resorption reached the middle part of the root with a thickened periodontal ligament space.

The CBCT scans, in both axial and sagittal slices, clearly showed a fracture line through the buccal and lingual canal wall of the mesial root (Fig. 2, A and B).

The tooth was extracted, and a vertical fracture of the mesial root and granulation tissue in the furcation region was clearly demonstrated (Fig. 2, C).

Case 2

A 55-year-old man complained of recurrent pain and swelling in the mandibular right molar region. An intraoral examination revealed that 3 molars, teeth nos. 2, 19, and 18, were missing. The mandibular right first molar (tooth no. 30) exhibited severe occlusal attrition and a deep V-shaped defect at the cervical portion of the buccal surface (Fig. 3, A) but had no caries or cracks in the tooth crown after staining with iodine-tincture. This tooth exhibited percussion sensitivity,

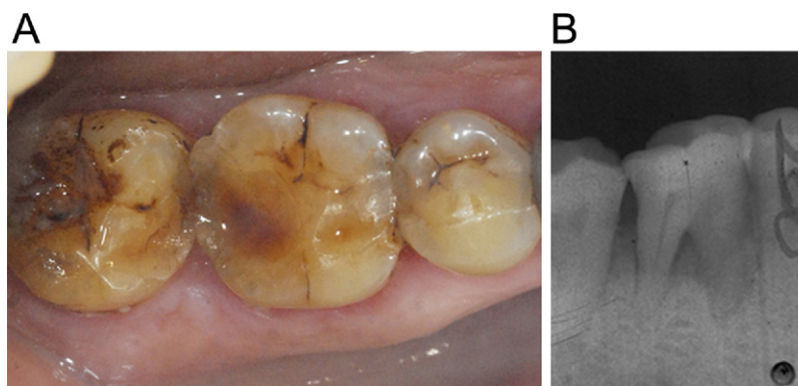


Fig. 3. **A**, Tooth no. 30 in case 2 exhibits severe occlusal attrition. **B**, Root canals are not filled, and a widening of the root canal space is not observed in the radiograph.

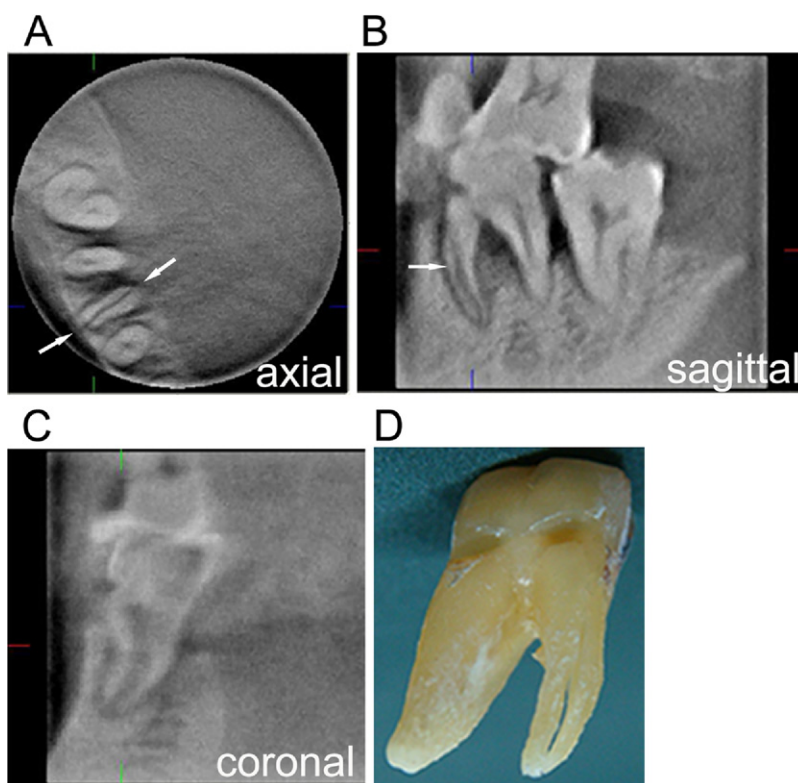


Fig. 4. **A, B, C**, A fracture line in the mesial root of tooth no. 30 (case 2) is observed on the CBCT images in both axial and sagittal sections; the fracture extends longitudinally throughout the entire root (*arrows*). **D**, Tooth no. 30 after extraction. The fractured fragments exhibit a complete buccolingual fracture of the mesial root.

pain to bite-test using a cottonwood stick, and grade I mobility. The electronic pulp test on tooth no. 30 was negative, whereas the adjacent healthy tooth gave normal responses. Periodontal examination disclosed an 8-mm narrow pocket at the mesiobuccal aspect of the root, whereas the other sites were within normal limits. No sinus tract was found. A radiograph showed that the root canals were not filled. Alveolar resorption reached the apical third of the mesial and distal roots with rarefaction in the furcation region, and the

periodontal ligament space was vague (Fig. 3, B). Based on the clinical signs and symptoms, VRF was suspected in this nonendodontically treated tooth; however, the PRs of tooth no. 30 failed to show any fracture lines.

The CBCT images in the axial sections showed a fracture line throughout the buccal and lingual canal walls of the mesial root of tooth no. 30 (Fig. 4, A). The CBCT images in both coronal and sagittal planes showed that the whole length of the mesial root canal space became significantly wider and

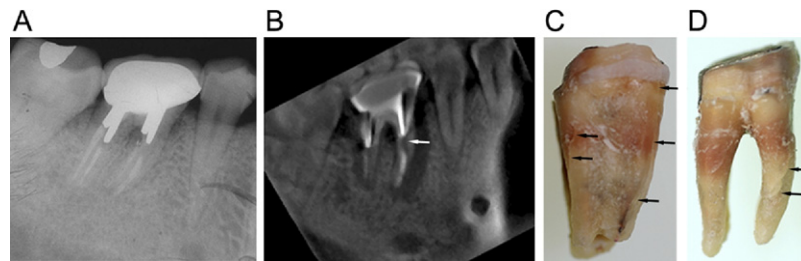


Fig. 5. **A**, Tooth no. 30 in case 3 is root-filled. **B**, A radiolucent line in the mesial root (*arrows*) and deep, localized, vertical bone loss around the root are clearly demonstrated in the sagittal plane. **C**, **D**, Views of the extracted tooth no. 30 demonstrate 2 root fracture lines (*arrows*).

Table I. Findings of clinical, periapical radiograph (PR), and cone-beam computerized tomographic (CBCT) examinations

Case	Presence of root fillings	Presence of a narrow deep periodontal pocket	Bite test	Staining results	Deep vertical bone loss	Widening of root canal space on PR	Fracture lines observed on CBCT*
1	–	–	+	–	–	+	+
2	–	+	+	–	+	–	+
3	+	+	+	–	+	–	+

*In either axial, coronal, or sagittal plane.

very radiolucent (Fig. 4, B and C). Tooth no. 30 was extracted, and the fractured fragments confirmed a complete buccolingual fracture of the mesial root (Fig. 4, D).

Case 3

A 39-year-old woman complained of discomfort in her right mandibular teeth on chewing. The dental history revealed that a root canal treatment had been performed on the mandibular right first molar (tooth no. 30) before a post and crown were placed one-half year before the examination. Periodontal examination revealed that a deep narrow pocket reached the apex of the mesial root at the mesiolingual aspect, and probing depth of the other teeth was within normal limits. The tooth exhibited percussion sensitivity, pain to bite-test with a cottonwood stick, and grade II mobility. The radiograph (Fig. 5, A) showed neither vertical bone loss nor root fracture lines. The CBCT scans (Fig. 5, B) showed deep vertical bone loss around both roots. In the sagittal sections, an arc-shaped fracture line was observed on the middle third of the mesial root between the post and root canal-filling materials, but no fracture line was observed in the axial sections. Based on the subjective and objective findings, a diagnosis of severe endodontic periodontal disease with a suspected VRF of the mesial root was made. Tooth no. 30 was extracted because of its poor periodontal condition. Two root fracture lines were observed on the mesial root of the extracted tooth no. 30 (Fig. 5, C and D).

DISCUSSION

The findings of the clinical, PR, and CBCT examinations are summarized in Table I. In case 1, pain to bite-test was revealed and a widening of the root canal space was observed on the PR (Fig. 1, B). A deep

periodontal pocket or crown cracks were not clinically detected. Based on clinical signs, symptoms, and PR, crown fracture was excluded and VRF was highly suspected. But none of these foregoing signs or symptoms is conclusive.¹⁶ Taking them in combination provides clinicians with valuable diagnostic information¹⁶; however, VRF could not be confirmed yet. Therefore, CBCT was ordered. The result, which clearly showed the fracture line on axial slices, could confirm the diagnosis of VRF.

Cases 2 and 3 demonstrated pain to bite with a cottonwood stick, deep and narrow periodontal pockets, and vertical bone loss. But no cracks on the crown were detected with staining in case 2, which excluded crown fracture. And the PRs failed to show a widening of the root canal space (Figs. 3, B, and 5, A). Therefore, further examination was indicated to determine the exact origin. A diagnosis of VRF was supported by the CBCT findings: Fracture lines were visible in the sagittal sections in all 3 cases and in the axial sections in cases 1 and 2 (Figs. 2 and 4).

The only clinical study available to date that used CBCT to diagnose VRFs in endodontically treated teeth used no gold standard to confirm the presence of VRFs.⁸ The clinical use of CBCT in diagnosing VRFs in nonendodontically treated teeth has not been previously reported. In the present case report, all 3 teeth were extracted and the existence of VRFs confirmed.

In case 3, a VRF in a root-filled mandibular molar was confirmed after extraction. Because no fracture

lines were visible in the axial slices and the radiopaque root-filling materials and posts present in the root canals (Fig. 5, A and B) could have created artefacts,¹⁷ we were not completely confident in our diagnosis of VRF based on CBCT. However, the deep, localized, vertical bone loss around the root (Fig. 5, B) indicated either development of VRFs³ or poor periodontal conditions. The vertical bone loss was not visible on the PR (Fig. 5, A), where it was masked by the thick buccal cortex.⁷

It has been reported that when radiopaque materials are not present in the canal, the risk of false positives is very low.¹⁴ Therefore, CBCT scans provide reliable information for diagnosing VRFs in nonendodontically treated teeth. The axial slices of both molars in cases 1 and 2 exhibited fracture lines buccolingually throughout the root (Figs. 2, A, and 4, A). In case 2, the patient had lost 3 molars and presented severe occlusal attrition, and VRF was observed in tooth no. 30, which was overloaded. It seems that when clinical findings cannot explain pulp involvement, further investigation using PR and CBCT is required to rule out the existence of spontaneous VRFs.⁴

CONCLUSIONS

Clinical signs and symptoms are fundamental and important for the diagnosis of VRFs. When clinical findings and PRs failed to rule out the diagnosis of VRFs, auxiliary CBCT could be an excellent option for detection of root fractures in both endodontically treated and nonendodontically treated teeth.

REFERENCES

1. Tamse A, Fuss Z, Lustig J, Kaplavi J. An evaluation of endodontically treated vertically fractured teeth. *J Endod* 1999;25:506-8.
2. Walton RE, Michelich RJ, Smith GN. The histopathogenesis of vertical root fractures. *J Endod* 1984;10:48-56.
3. Pitts DL, Natkin E. Diagnosis and treatment of vertical root fractures. *J Endod* 1983;9:338-46.
4. Yang SF, Rivera EM, Walton RE. Vertical root fracture in nonendodontically treated teeth. *J Endod* 1995;21:337-9.
5. Cohen S, Blanco L, Berman L. Vertical root fractures: clinical and radiographic diagnosis. *J Am Dent Assoc* 2003;134:434-41.
6. Chan CP, Lin CP, Tseng SC, Jeng JH. Vertical root fracture in endodontically versus nonendodontically treated teeth: a survey of 315 cases in Chinese patients. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1999;87:504-7.
7. Huuononen S, Ørstavik D. Radiological aspects of apical periodontitis. *Endod Topics* 2002;1:3-25.
8. Bernardes RA, de Moraes IG, Duarte MA, Azevedo BC, de Azevedo JR, Bramante CM. Use of cone-beam volumetric tomography in the diagnosis of root fractures. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2009;108:270-7.
9. Youssefzadeh S, Gahleitner A, Dorffner R, Bernhart T, Kainberger FM. Dental vertical root fractures: value of CT in detection. *Radiology* 1999;210:545-9.
10. Hannig C, Dullin C, Hulsmann M, Heidrich G. Three-dimensional, nondestructive visualization of vertical root fractures using flat panel volume detector computer tomography: An ex vivo in vitro case report. *Int Endod J* 2005;38:904-13.
11. 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;103:825-9.
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;35:719-22.
13. Kamburoğlu K, Murat S, Yüksel SP, Cebeci AR, Horasan S. Detection of vertical root fracture using cone-beam computerized tomography: an in vitro assessment. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2010;109:e74-81.
14. 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;36:126-9.
15. Miller S. *Textbook of periodontia*. Philadelphia: Blakeston; 1950.
16. Cohen S, BR. *Pathways of the pulp*. 6th ed. St. Louis: Mosby; 1994. p. 20.
17. Zhang Y, Zhang L, Zhu XR, Lee AK, Chambers M, Dong L. Reducing metal artifacts in cone-beam CT images by preprocessing projection data. *Int J Radiat Oncol Biol Phys* 2007;67:924-32.

Reprint requests:

Dr. Lin Yue
Department of Cariology and Endodontology,
Peking University School and Hospital of Stomatology
22 Zhongguancun Nandajie, Haidian District
Beijing 100081
China
kqlinyue@bjmu.edu.cn