Different Representations of Vertical Root Fractures Detected by Cone-Beam Volumetric Tomography: A Case Series Report

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Abstract  
Introduction: Vertical root fractures (VRFs) pose a clinical dilemma and a challenge to clinicians. Definitive diagnosis is often complicated by the lack of consistent signs and symptoms and the low sensitivity of conventional radiographs in the detection of VRFs. New radiographic imaging systems have recently become available for use in dentistry. Among these new imaging technologies is cone-beam volumetric tomography (CBVT). CBVT technology allows the precise visualization and evaluation of teeth with VRFs. The use of CBVT has great potential as a diagnostic tool to assist in the detection of VRFs. Methods: Seven cases are presented to demonstrate the use of CBVT in detection of VRFs in endodontically treated teeth. Results: Five specific findings on CBVT exam were consistent with confirmed VRFs. Conclusions: As demonstrated in this case series, CBVT can provide valuable additional diagnostic information in the detection of VRFs and may help prevent unnecessary treatment. (J Endod 2012;38:1435–1442)

Key Words  
CBVT, cone beam CT, vertical root fracture

Vertical root fractures (VRFs) pose a clinical dilemma and a challenge to clinicians (1). Definitive diagnosis is often complicated by the lack of consistent signs and symptoms and the low sensitivity of conventional radiographs in the detection of VRFs (2). Dental history (especially previous root canal treatment), presence of localized pain or swelling, an isolated deep periodontal pocket, and the radiographic appearance of a characteristic lateral root surface radiolucency are all consistent but not pathognomonic for VRFs. Because of the difficulty in reaching an accurate diagnosis, exploratory surgery and/or extraction are often recommended treatment options.

New radiographic imaging systems have recently become available for use in dentistry. Among these new imaging technologies are medical computed tomography (CT), cone-beam volumetric tomography (CBVT), and magnetic resonance imaging (MRI). In 2000, the U.S Food and Drug Administration approved the first CBVT unit for dental use in the United States (3). As of 2007, there were at least 12 cone-beam systems specifically designed for dental use. Cone-beam technology uses a cone-shaped beam of radiation to acquire a digital volume that is used for 3-dimensional (3D) reconstruction and visualization of the target area. CBVT systems are available in different fields of view (FOVs): CBVT limited (dental) or medium and full (ortho or facial) CBVT. The limited CBVT ranges in diameter from 40–100 mm, whereas the FOV of full CBVT ranges from 100–200 mm. The voxel size is generally smaller for the limited version (0.076 mm) versus for medium and large FOVs (0.1–0.2 mm and 0.3–0.4 mm, respectively), thus offering higher resolution and potentially greater utility for endodontic applications (4–9).

CBVT technology allows the precise visualization and evaluation of teeth with VRFs. The detection of VRFs by CBVT has already been demonstrated by previous studies (10–14). CBVT has great potential to become a valuable diagnostic and treatment planning tool in the modern endodontic practice. CBVT imaging has been a routine part of our diagnostic evaluation for all retreatment and surgery consultations since approximately January 2010, unless it was possible to reach a definitive conclusion regarding the etiology and prognosis for the tooth after initial clinical exam and 2-dimensional (2D) imaging. The Kodak 9000 3D (Carestream Dental LLC, Atlanta, GA) with limited FOV was the system used in the following cases. The intent of the following case series report is to demonstrate the different typical representations of VRFs detected by CBVT.

Case 1

A 33-year-old woman was referred for consultation and treatment of tooth #30, with a chief complaint of the following: “My tooth hurts to biting. My dentist told me I might need my root canal redone.” Dental history revealed that root canal therapy on tooth #30 was completed approximately 10 years ago. The patient’s medical history was noncontributory. The tooth was tender to percussion, palpation, and biting. Periodontal probing depths were 2–3 mm, and there was no evidence of swelling or sinus tract. A periapical radiograph of #30 showed periradicular radiolucency in relation to the mesiobuccal (MB) root (Fig. 1A). A widened periodontal ligament space on the distal root was noted on the radiograph. The CBVT imaging demonstrated MB bone loss at mid-root level in the axial and coronal views and 3D reconstruction (Fig. 1B, D, and F). A diagnosis of previously treated tooth with symptomatic apical periodontitis was reached. A VRF of the MB root was established as the etiology of treatment failure, and the tooth was scheduled for extraction and
socket preservation. A VRF was confirmed by buccal flap reflection before extraction of tooth #30 (Fig. 2A and B).

Case 2

A 56-year-old woman was referred for consultation and treatment of tooth #12, with a chief complaint of the following: "I feel pressure in my tooth. When I put my finger on my gums it is sore. It never felt good even after the root canal was done." Dental history revealed that root canal therapy on tooth #12 was completed approximately 3 years ago. The patient’s medical history was noncontributory. Tooth #12 was tender to palpation. Periodontal probing depths were 2–3 mm, and there was no evidence of swelling or sinus tract. A periapical radiograph and the sagittal CBVT view of #12 revealed a widened periodontal ligament space (Fig. 3A). The CBVT imaging demonstrated intact buccal bone in the coronal one-third of the buccal root as well as buccal bone loss at the mid-root to the apex level in the axial and coronal views and 3D reconstructed view (Fig. 3B–E). A diagnosis of a previously treated tooth with symptomatic apical periodontitis was reached. A VRF of the buccal root was determined, and the tooth was scheduled for extraction and socket preservation. A VRF was confirmed by buccal flap reflection before extraction of tooth #12. The buccal root fracture of tooth #12 can be identified in Figure 3F.

Case 3

A 36-year-old man was referred for consultation and treatment of tooth #8, with a chief complaint of the following: “My front tooth hurts when it touches my lower teeth. I have a bad taste sometimes.”
Dental history revealed that root canal therapy on tooth #8 was completed approximately 1 year ago. The patient's medical history was noncontributory. Tooth #8 was tender to percussion and on palatal palpation. Periodontal probing depths were 2–3 mm except for a 7-mm periodontal probing on the mid-palatal aspect of tooth #8. There was no evidence of swelling or sinus tract. A periapical radiograph revealed a widened periodontal ligament space (Fig. 4A). The CBVT imaging demonstrated palatal bone loss (Fig. 3). Dental history revealed that root canal therapy on tooth #8 was completed approximately 1 year ago. The patient’s medical history was noncontributory. Tooth #8 was tender to percussion and on palatal palpation. Periodontal probing depths were 2–3 mm except for a 7-mm periodontal probing on the mid-palatal aspect of tooth #8. There was no evidence of swelling or sinus tract. A periapical radiograph revealed a widened periodontal ligament space (Fig. 4A). The CBVT imaging demonstrated palatal bone loss (Fig. 3).
coronal, mid-root, and apical levels in the axial views and 3D reconstruction (Fig. 4B–D). The sagittal view demonstrated a space between the palatal root and the palatal alveolar process (Fig. 4E). A diagnosis of a previously treated tooth with symptomatic apical periodontitis was reached. A VRF was determined to be the etiology, and the tooth was scheduled for extraction and socket preservation.

**Figure 5.** (A) Periapical radiograph of tooth #10 with gutta-percha tracing a sinus tract. (B–D) Axial views at the coronal, mid-root, and apical root levels demonstrating the horizontal root fracture at the different levels (arrows). (E) Sagittal view demonstrating the complexity and extent of the root fracture that cannot be detected in the periapical radiograph. Arrows identify the extent of the root fracture. (F) 3D reconstructed view.

**Figure 6.** (A) Periapical radiograph of tooth #19. Line corresponds to the level of axial section view in (C). (B) Clinical photograph demonstrating the periodontal 9-mm probing. (C) Axial view demonstrating the buccal bone loss at mid-root level (blue arrow) and initial lingual coronal bone loss (red arrow). (D) Coronal view demonstrating the two thirds buccal bone loss related to the distal root (blue arrow) and lingual coronal bone loss (red arrow). (E) 3D reconstructed view demonstrating the periodontal defect and buccal bone loss in relation to distal root (arrow).
root fracture extending down the palatal surface of tooth #8 can be identified in Figure 4G.

**Case 4**

A 28-year-old man was referred for consultation and treatment of tooth #10, with a chief complaint of the following: “I have a bubble on my gums that comes and goes. I am not in pain now.” Dental history revealed a history of trauma (sports-related) at the age of 7 years. Root canal therapy on tooth #10 was completed approximately 20 years ago. The patient’s medical history was noncontributory. Tooth #10 was tender to percussion and on palatal palpation. Periodontal probing depths were 2–3 mm. There was no evidence of swelling. A sinus tract on the buccal attached gingiva was detected and traced with gutta-percha (Fig. 5A). Radiographic examination revealed periradicular radiolucency in relation to an incompletely developed root of tooth #10 (Fig. 5A). The CBVT imaging demonstrated buccal plate bone loss in relation to the distal root in the axial and coronal views and 3D reconstructed view (Fig. 5C–E). The beginning of lingual bone loss in the coronal aspect of the distal root was detected as well (Fig. 6D). A diagnosis of previously treated tooth with chronic apical periodontitis was reached. A VRF of the distal root was determined, and the tooth was scheduled for extraction and socket preservation.

**Case 5**

A 46-year-old man was referred for consultation and treatment of tooth #19, with a chief complaint of the following: “I have swelling in my gums.” Dental history revealed that root canal therapy on tooth #19 was completed approximately 5 years ago. The patient’s medical history was noncontributory. Tooth #19 was tender to percussion, palpation, and biting. Probing depths were 2–3 mm except for a 9-mm probing associated with the distal root (Fig. 6B). There was no evidence of a sinus tract. A periapical radiograph of #19 revealed normal bone trabeculation and intact periodontal ligament space around both the mesial and distal roots (Fig. 6A). The CBVT imaging demonstrated buccal plate bone loss in relation to the distal root in the axial and coronal views and 3D reconstructed view (Fig. 6C–E). The beginning of lingual bone loss in the coronal aspect of the distal root was detected as well (Fig. 6D). A diagnosis of previously treated tooth with chronic apical periodontitis was reached. A VRF of the distal root was determined, and the tooth was scheduled for extraction and socket preservation.

**Case 6**

A 62-year-old woman was referred for consultation and treatment of tooth #14, with a chief complaint of the following: “My tooth hurts to biting. It throbs after eating. I had my sinuses checked and they were fine.” Dental history revealed that root canal therapy on tooth #14 was completed approximately 5 years ago. The patient’s medical history was noncontributory. Tooth #14 was tender to percussion and biting. Probing depths were 2–3 mm, and there was no evidence of swelling or sinus tract. A periapical radiograph of #14 revealed normal bone trabeculation and intact periodontal ligament space around the MB, distobuccal, and palatal roots (Fig. 7A). The CBVT axial and coronal views demonstrated mid-root radiolucency in relation to the palatal root at the apical level of the post (Fig. 7C and E). Intact palatal bone was observed coronal and apical to the mid-root level (Fig. 7B and D). A diagnosis of previously treated tooth with symptomatic apical periodontitis was reached. A VRF of the palatal root was determined, and the tooth was scheduled for extraction and socket preservation.

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**Figure 7.** (A) Periapical radiograph of tooth #14. The 3 lines correspond to the axial section views in (B–D). Note mid-root radiolucency (C) in relation to the palatal root at the apical level of the post (arrow). Intact palatal bone was observed coronal and apical to the mid-root level (B and D). (E) Coronal view showing the distobuccal and palatal roots of #14. Arrow demonstrates the lateral radiolucency in relation to the palatal root.
Case 7

A 58-year-old man was referred for consultation and treatment of tooth #30, with a chief complaint of the following: “A few months ago, my tooth started to hurt on biting. Now it is getting worse and I can’t even bite on soft food.” Dental history revealed that root canal therapy on tooth #30 was completed approximately 15 years ago. The patient’s medical history was noncontributory. Tooth #30 was tender to percussion, buccal palpation, and biting. Probing depths were 2–3 mm, and there was no evidence of swelling or a sinus tract. A periapical radiograph and the axial CBVT view of #30 revealed apical radiolucency in relation to the apical and lateral aspects of the mesial root (Fig. 8 A and B). The distal root area demonstrated normal bone trabeculation and intact periodontal ligament space (Fig. 8A). CBVT imaging demonstrated a space between the mesial root and the buccal cortical plate in the coronal views and 3D reconstructed view (Fig. 8C and D). A diagnosis of previously treated tooth with symptomatic apical periodontitis was reached. A VRF of the mesial root was determined, and the tooth was scheduled for extraction and socket preservation. On flap reflection, a VRF was confirmed before extraction of tooth #30 (Fig. 8E and F). The extent of the root fracture could be seen on the mesial root after extraction (Fig. 8G).

Discussion

The present case series demonstrates the diagnostic ability of CBVT in detecting VRFs. Each of these cases is representative of a larger number of cases with similar findings treated in our clinical practice. Five findings on CBVT exam were consistent with confirmed VRF (Table 1).

The prevalence of VRFs reported in the literature ranges from 10.9%–12.9% (15). The most commonly affected teeth were mandibular molars (16). Risk factors for VRF are history of root canal treatment and extensive restoration. Posts in root canals were associated with 61.7% of root fractures. Of all fractured roots, fracture lines in 67.5% were in the buccolingual direction, and 32.5% were in the mesiodistal direction (12).

Radiographic interpretation is a critical component in diagnosis, treatment, and evaluation of healing. Interpreting the film-based radiograph or digital image continues to be a somewhat subjective process. Goldman et al (17) showed that the agreement between 6 examiners was only 47% when evaluating healing of periapical lesions by using 2D periapical radiographs. In a follow-up study, Goldman et al (18) also reported that when examiners evaluated the same films at 2 different times, they only had 19%–80% agreement with their previous interpretations. In a recent study, interobserver and intraobserver reliability in detecting periradicular radiolucencies by using a digital imaging system was evaluated. Agreement among all 6 observers for

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<th>TABLE 1. These 5 Findings on CBVT Exam were Consistent with Confirmed VRF</th>
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<td>1. Loss of bone in the mid-root area with intact bone coronal and apical to the defect</td>
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<td>2. Absence of the entire buccal plate of bone in axial, coronal, and/or 3D reconstructed view</td>
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<td>3. Radiolucency around a root where a post terminates</td>
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<td>4. Space between the buccal and/or lingual plate of bone and root surface</td>
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<td>5. Visualization of the VRF on the CBVT views (Fig. 9)</td>
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all radiographs was less than 25%, and agreement for 5 of 6 observers was approximately 50% (19).

2D radiographs are of limited value for the diagnosis of VRFs and usually only provide indirect evidence of the presence of a VRF. The 3D nature of complex tooth anatomy and surrounding structures can make interpretation of 2D images challenging and unreliable. Various studies have evaluated and compared the sensitivity of conventional radiographs and direct digital films. Low sensitivity for conventional film-based images (38%) and direct digital images (48%) has been reported (20).

CBVT has the unique ability to provide high-resolution images in multiple planes of space, while eliminating superimposition of surrounding structures (4, 5, 8, 9). In a comparative study evaluating the sensitivity and specificity of CBVT and periapical radiographs in detecting VRFs, sensitivity and specificity for VRF detection of CBVT were 79.4% and 92.5%, respectively, and for periapical radiographs were 37.1% and 95%, respectively. In the same study it was reported that the specificity of CBVT was reduced in the presence of root canal filling material (12). In a recent study, the diagnostic ability of a CBVT scan to assess longitudinal root fractures in prosthetically treated teeth was evaluated (21). The presence of gutta-percha or cast-gold posts reduced the overall sensitivity and specificity. This was attributed to star-shaped streak artifacts that mimic fracture lines in axial views. One significant problem that can affect the image diagnostic quality and accuracy of CBVT images is the scatter and beam hardening caused by high-density neighboring structures such as enamel, metal posts, and restorations. If this scattering and beam hardening is associated close to or with the tooth being assessed, the overall sensitivity and specificity are dramatically reduced (22).

Clinically, a thorough dental history, classic clinical and radiographic signs and symptoms such as pain, swelling, presence of a sinus tract, and/or presence of an isolated deep periodontal pocket can be helpful hints to suggest the presence of a VRF. Radiographically, a combination of periapical and lateral root radiolucency (halo appearance) is valuable information indicating the possible presence of VRF. Several of the previously mentioned clinical and radiographic elements have to align to establish a presumptive diagnosis of VRF (2, 14); however, direct visual examination, usually requiring surgical exposure, is still often required for definitive diagnosis.

Some of these classic clinical and radiographic elements could be identified in the presented cases. Cases 1, 2, 6, and 7 demonstrated no periodontal probing because of the presence of coronal bone and intact epithelial attachment. Cases 3, 4, and 5 demonstrated periodontal probing that indicated loss of epithelial attachment. In these cases, the periodontal probing could be attributed to a combined endodontic/periodontal defect. The conservative and traditional treatment approach would be to initiate treatment and placement of an intracanal medication and reevaluation of the periodontal status. The CBVT images in cases 3, 4, and 5 demonstrated buccal and palatal bone loss that rendered the teeth unsalvageable. In case 1, the periradicular radiograph demonstrated periapical radiolucency related to the MB root. The CBVT images demonstrated a disruption of the buccal cortical bone at the mid-root level of the MB root, which is not a typical presentation for a tooth that is not responding to endodontic therapy. Another interesting finding in several cases that presented with a VRF was the space between the fractured root and the cortical plate adjacent to it (cases 3, 4, and 7). This representation was consistent with several cases that were extracted and VRF was confirmed. Another interesting representation was the radiolucency in relation to the post termination in the root canal (case 6) that was only detected in the coronal and axial views of the palatal root. Without such information from the CBVT imaging, the diagnosis of VRF would have been questioned, and unnecessary treatment would have been initiated. To the best of our knowledge, the ability of CBVT to detect VRFs in vivo has been reported in only 5 other studies to date (14, 23, 24). In a recent clinical study evaluating the detection of VRFs with CBCT, sensitivity of 88% and specificity of 75% were reported (12).

In conclusion, as in previous studies (12, 14, 20, 21, 23, 24), CBVT was demonstrated to be advantageous for detection of VRFs and valuable in providing diagnostic information to prevent possible unnecessary treatment. Five specific CBVT findings that were associated with the presence of a VRF are presented (Table 1).

Acknowledgments

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References