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Detection of vertical root fractures in non-endodontically treated molars using cone-beam computed tomography: a report of four representative cases

CASE REPORT

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Abstract – Vertical root fractures (VRFs) in teeth without endodontic treatment are relatively uncommon. The diagnosis is based on clinical and radiographic presentations. It might be difficult to detect VRFs in non-endodontically treated molars by conventional radiographs in certain situations because of the limitations of 2D images and many others factors such as the VRFs being in their early stages. Root morphology variation and the orientation of VRFs can influence conventional radiographic detection and the interpretation of a radiolucent fracture line. The four case reports presented here describe and discuss the use of cone-beam computed tomography (CBCT) in successfully diagnosing VRFs based on direct visualization of radiolucent lines, especially those suspected from routine conventional radiographs, as well as their symptoms and clinical findings. CBCT also provides more information on the presence of VRFs.

Vertical root fractures (VRFs) are longitudinal fractures that begin at the roots of teeth; these fractures occur primarily in the facial-lingual plane (1). VRFs in teeth without endodontic treatment are relatively uncommon; they are more common in the posterior teeth of people over 40 years of age and may be caused by excessive forces from mastication or occlusion (2–6). The diagnosis of tooth root fracture is important to assess prognosis and to determine the appropriate treatment for an individual tooth, it is based on clinical and radiographic examination. Conventional and digital intraoral radiography are the most commonly used methods for the detection of root fractures in routine clinical practice. The direct visualization of a radiolucent fracture line on radiographs is its explicit feature for detecting VRFs. However, they may not be visible radiographically, especially in their early stages. Conventional radiographs are 2D images of three-dimensional anatomic structures; therefore, the superimposition of adjacent tissues, morphologic variations, surrounding bone density, x-ray angulations, and radiographic contrast can influence radiographic interpretation (7).

Cone-beam computed tomography (CBCT) is a new radiographic method that has been applied in several clinical cases for investigative purposes in endodontic areas, such as the diagnosis of pathology of endodontic origin, assessment of root canal morphology, and evaluation of root fractures. CBCT imaging provides clinicians with sub-millimeter spatial resolution images of high diagnostic quality and a reported radiation dose markedly lower than those of conventional CT scans, which is equivalent to that needed for 4–15 panoramic radiographs (8). An advantage of the CBCT is that the images can be studied using different representations, and they can be rotated in any spatial plane without superimposition of the anatomic structures (7, 9–12). CBCT was shown to be superior to conventional and digital radiography in the diagnosis of VRF *in vitro* and *in vivo* (9, 10). However, there are limited data on the advantages of CBCT for the detection of VRFs in non-endodontically treated molars (11).

The following cases describe images obtained by CBCT (Sirona Dental Systems GmbH, Bensheim, Germany) for the detection of VRFs in molars without endodontic treatment. The fractures selected for this report cannot be easily diagnosed by normal conventional radiography. CBCT scans were made with an exposure volume of $15 \times 15 \times 15$ cm^3 at 0.3/0.5 mm 3D resolution isotropic voxel size; the unit operated at 85 kV and 5/7 mA. According to the manufacture, an effective dose of CBCT is 29 μSv, which is dependent on field size and mA and kV technique factors. All of the images were evaluated by three observers (two endodontists and one radiologist) at different sessions. Each observer evaluated the CBCT images using the tangential, cross-sectional, and axial sections.

Case reports

Case 1

A 41-year-old man complained of a dull toothache involving the maxillary right second molar and the mandibular left first molar when chewing food. The symptoms lasted for approximately 3 years. He said that he consulted dentists several times, but they failed to provide a definitive diagnosis. Clinically, no overt extraoral or intraoral swelling was observed. The mandibular left first molar and the maxillary right second molar were slightly mobile and were both slightly sensitive to percussion; no pockets around the teeth were detected, and the responses of the teeth to cold and electric pulp testing were within normal limits. A routine panoramic radiograph taken 2 days prior to our clinic showed no evidence of periapical lesions or root fractures on the molars (Fig. 1). Based on the patient's dental history, signs and symptoms, tooth infractions were strongly suspected. After obtaining informed consent from the patient, the teeth were submitted for CBCT examination. Axial CBCT images clearly revealed fractures in both the palatal root of the maxillary right second molar and the mesial root of the mandibular left first molar in the buccolingual direction (Fig. 2a,b). The treatment options offered to the patient included extraction of the maxillary right second molar and hemisection of the mandibular left first molar.

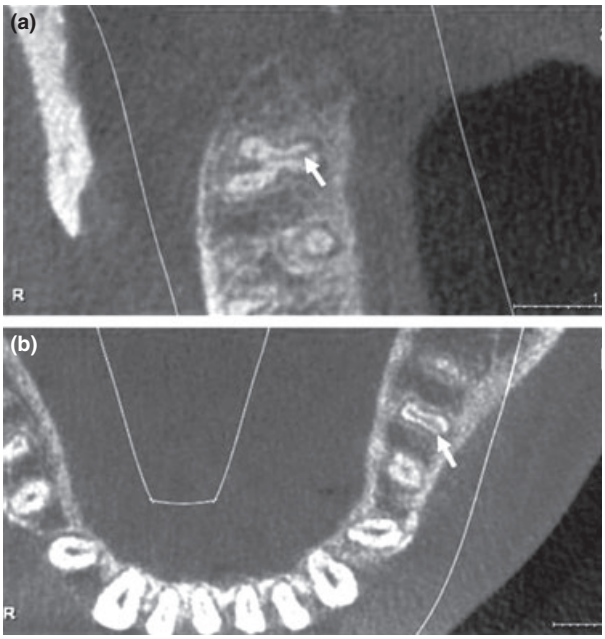

Fig. 2. Case 1: Axial cone-beam computed tomography images clearly show fractures in both the palatal root of the maxillary right second molar (a) and the mesial root of the mandibular left first molar (b) in the buccolingual direction (arrow indicates the fracture).

Case 2

A 57-year-old woman complained of spontaneous pain in the mandibular right first molar area for about 20 days. She habitually chewed hard food. Clinical examination revealed the presence of occlusal wear on the mandibular right first molar. The periodontal examination disclosed a 4-mm pocket on the mesiolingual surface of the tooth, and the tooth was slightly sensitive to percussion and cold pulp testing. There tooth was not mobile. The radiograph clearly showed a thickening of the periodontal ligament space around the surface of the mesial root with rarefaction in the furcation region, and the mesial root canal space was vague (Fig. 3a). Based on the patient's dental history, signs and symptoms, tooth infractions were strongly suspected. After obtaining informed consent from the patient, the teeth were submitted for CBCT examination. The axial CBCT images clearly revealed a fracture in the mesial root of the mandibular right first molar in the buccolingual direction (Fig. 3b). The extracted tooth exhibited a complete buccolingual fracture of the mesial root (Fig. 3c). To test whether the detection of VRF on this tooth *in vitro* by conventional radiographs can be made when the cone-image shift technique is used, three radiographs of the extracted tooth were taken including the normal view and 30° mesial and distal from parallel. Only the radiograph taken from the mesial projection clearly showed evidence of vertical fracture with widening of the root canal space of the mesial root (Fig. 3d–f).

Fig. 1. Case 1: Initial panoramic radiograph.

Case 3

A 58-year-old man complained of localized swelling in the area of the maxillary right second molar. The swelling had persisted for approximately 10 days. He reported pain on mastication in the tooth and stated that it had persisted for approximately 3 months; he habitually chewed hard food. Clinical examination showed a sinus tract and some discharge of pus and exudates in the lingual region of the tooth (Fig. 4a). A gutta-percha point was inserted through the tract to determine the origin of the chronic abscess. The tooth was sensitive to percussion and palpation, and the tooth's response to electric pulp testing was within normal limits. The tooth was not mobile. Periodontal examination disclosed a 5-mm pocket on the lingual surface of the tooth. Radiographic examination showed a vertical translucent

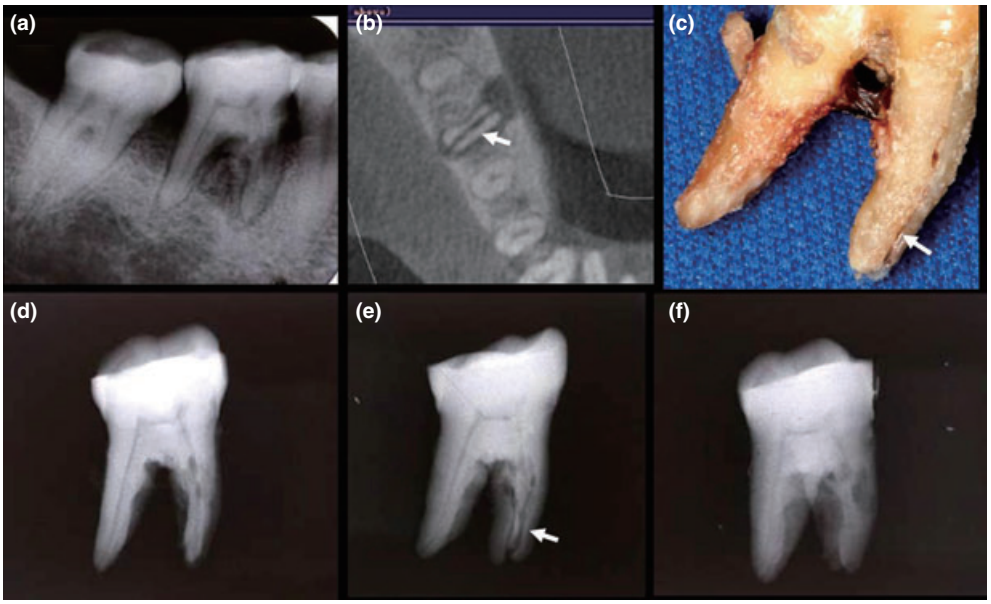

Fig. 3. Case 2: (a) Radiograph of the mandibular right first molar. (b) Axial cone-beam computed tomography image clearly showing a fracture in the mesial root of tooth (arrow indicates the fracture). (c) Upon extraction, a completed crack in the buccolingual direction in the mesial root was observed (arrow indicates the fracture). Radiographs of the extracted tooth were taken including the normal view (d) mesial (e) and distal (f) angled. The only radiograph taken from the mesial projection showed widening of the root canal space of the mesial root (arrow).

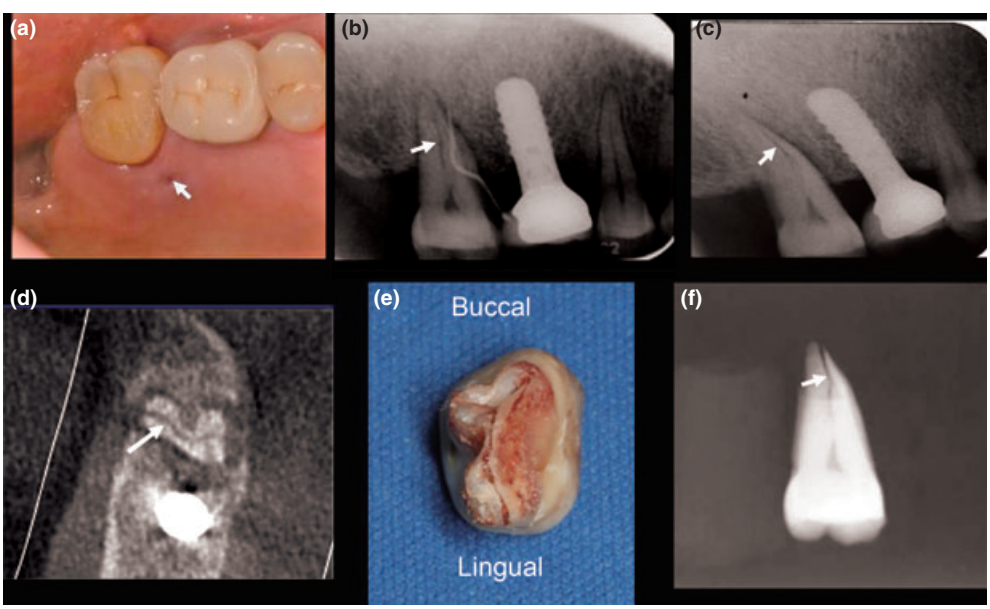

Fig. 4. Case 3: (a) A sinus tract on the lingual aspect of the maxillary right second molar (arrow). Radiograph (b) and a mesially angled radiograph (c) show a vertical translucent line (arrow). The axial cone-beam computed tomography image (d) clearly shows a fracture in the fused root of the tooth in the buccolingual direction (arrow indicates the fracture). (e) Fractured root after extraction. (f) Radiograph of extracted tooth (arrow indicates the fracture).

line, the examiners were not certain whether the translucent line was indicative of a root fracture or the roots outline (Fig. 4b). Another radiographic image was taken merely by shifting the horizontal angle of the cone mesial from the parallel; it showed a vertical translucent line on the mesial aspect of the root (Fig. 4c). To specify the affected roots and to obtain more information to develop an appropriate treatment plan, the patient was referred for CBCT imaging. An axial CBCT image revealed a fracture in the fused root of the maxillary right second molar in the buccolingual direction (Fig. 4d). The extracted tooth exhibited a buccolingual crack (Fig. 4e). It was difficult to differentiate the radiographic image of the VRF from the root anatomy *in vitro* (Fig. 4f).

Case 4

A 53-year-old woman complained of spontaneous pain from the maxillary left second molar for approximately 20 days; recently, there had been localized swelling in the area of the tooth. She reported that thermal sensitivity had occurred approximately 1 month ago. She habitually chewed hard food. Clinical examination revealed a severe abscess on the mesial side of the maxillary left second molar (Fig. 5a). The tooth demonstrated grade 2 mobility, and the tooth was sensitive to percussion and was non-responsive to pulp vitality testing. Periodontal examination disclosed a 10-mm pocket on the mesial side of the tooth. The radiograph clearly showed bone loss on the mesial surface of the mesiobuccal root to approximately the apex (Fig. 5b). Considering the clinical and radiographic findings, a root fracture was suspected. A mesially angled radiograph was taken; however, it failed to show any evidence of root fracture (Fig. 5c). After obtaining informed consent from the patient, the tooth was submitted for CBCT examination; the axial CBCT image clearly revealed a fracture in the palatal root of the tooth in an approximately mesiolingual direction with bone loss (Fig. 5d). The tooth was extracted and examined. A complete lingual root fracture in the mesiolingual direction was noted (Fig. 5e).

Discussion

VRFs in non-endodontically treated teeth begin at the root apex and occur primarily in the buccolingual direction. Symptoms are usually minimal or absent in the early stages. With time, dull pain on mastication may develop as a result of the separation of the fractured root segments (6).

Clinical diagnosis of VRFs is difficult because the symptoms are variable or non-specific; the clinical and radiographic findings are related to the extent and location of the fracture (2–6). Until today, the most common modalities for diagnosing VRF in routine clinical practice have been conventional and digital 2D intraoral radiography. Sometimes, diagnosis of VRF is a complicated problem for the clinician. If the initial radiographic examination did not show a radiolucent fracture line to provide a definite diagnosis, then proceeding can be difficult and an incorrect diagnosis is more likely.

One clinical study compared CBCT and intraoral images for the detection of root fractures and used clinical symptoms as indicators for the true presence of a fracture (9). The CBCT images were significantly more accurate than the periapical radiography images. This is because CBCT can offer the clinician clinically relevant information that cannot be gathered from conventional radiography. CBCT has also been found to be superior to intraoral conventional film and digital radiography in the detection of VRFs with separated fragments of different thicknesses simulated in extracted human teeth (12). The present study reveals that CBCT is an excellent option for the detection of VRFs in non-endodontically treated molars, especially those that are suspected from routine conventional radiograph as well as their symptoms and clinical findings.

The present cases are being reported for their unusual aspects. In case 1, the use of intraoral periapical radiographs for the detection of VRF is complicated by the buccolingual orientation of the fracture lines, which is a major problem in radiographic diagnosis. This can be explained by the fact that there are non-displaced VRFs, and thus, they are difficult to detect. Also, the

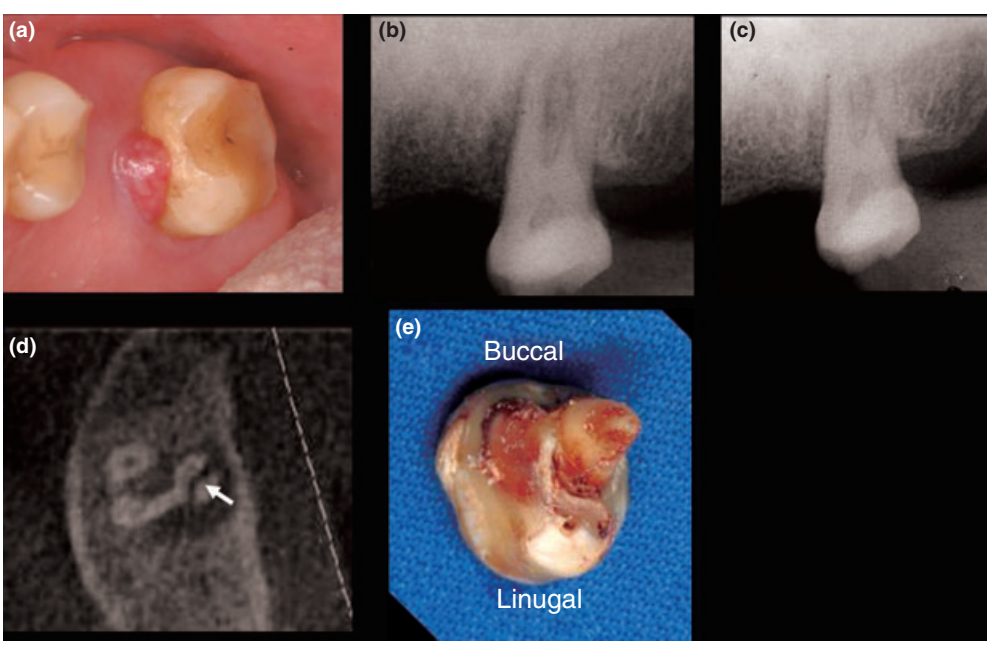

Fig. 5. Case 4: (a) Periodontal abscess on the mesial aspect of the maxillary left second molar. Radiograph (b) and a mesially angled radiograph (c) show bone loss the mesial surface of the mesiobuccal root. The axial cone-beam computed tomography image (d) clearly revealed a fracture in the palatal root of the tooth in an approximately mesiolingual direction with bone loss (arrow indicates the fracture). A complete lingual root fracture was confirmed after extraction (e).

radiographic images of the fracture lines overlie that of the root canals. This made the appearance of the fracture lines similar to the root canals.

In case 2, one limitation of the intraoral radiographs is the absence of radiographic signs when the x-ray beam is not parallel to the plane of the fracture. The images taken from three different angulations could increase detection ability in the intraoral images. Radiographs of this molar *in vitro* were taken including the normal view, mesial, and distal angled. The only radiograph taken from the mesial projection showed widening of the root canal space of the mesial root.

In case 3, although the conventional radiographs were obtained from two different angulations, the periapical images clearly show a vertical translucent line, which is the image of the VRF. The fractures occurred in the fused roots of the maxillary second molar. Radiopaque anatomic structures were superimposed on the apices and obscured them. That makes the interpretation of the radiolucent line difficult.

In case 4, it was impossible to make the x-ray beam pass through the fracture line *in vivo* because of the direction of fracture line; therefore, the fracture line did not appear on the conventional intraoral radiography.

A recent study compared the accuracy of CBCT scans made by five different systems in detecting VRFs *in vitro*; axial slices were the most accurate in detecting VRFs (13). In the present report, axial CBCT images clearly revealed the fractures in all four cases. These results suggest that CBCT is an excellent option for detecting VRFs in non-endodontically treated molars, thereby allowing better conclusive diagnoses. CBCT can also be useful in evaluating the localization of separated fragments to help make decisions regarding clinical treatment.

Despite its advantages, CBCT technology also presents some limitations, such as high radiation doses when compared to plain-film radiography (8). Endodontic assessment with CBCT should follow the 'as low as reasonably achievable' (ALARA) principle. Therefore, CBCT should only be considered when conventional radiographic techniques fail to provide useful information for diagnosing VRF (14). A study of cone-beam CT technology found that a smaller field of view (FOV) results in lower effective doses; a smaller FOV should be used for dental images, whereas a larger FOV should be restricted to cases in which a wider view is required (15). In the present study, the Sirona unit does not offer multiple FOVs.

Conflict of interest

The authors deny any conflicts of interest.

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