Contemporary Management of Horizontal Root Fractures to the Permanent Dentition: Diagnosis—Radiologic Assessment to Include Cone-Beam Computed Tomography

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Abstract
Historically, obtaining several periapical radiographs has been recommended to diagnose horizontal root fractures. Assessing the 3-dimensional orientation of a fracture is correlated to treatment and outcome. However, conventional radiography yields only limited information for accurate diagnosis. Cone-beam computed tomography (CBCT) is a relatively new and useful technology, which provides an auxiliary imaging modality to supplement conventional radiography for evaluating horizontal root fractures. Despite the increasing application of this technology as well as a growing body of evidence supporting its value in diagnosing horizontal root fractures, there are no specific guidelines for its use. This article aimed to provide such preliminary guidelines for cases of suspected horizontal root fracture as a result of trauma. From a database search, it was concluded that CBCT is most useful in cases in which conventional radiography yields inconclusive results or shows a fracture in the middle third of a root. In such cases, CBCT may rule out false negatives, i.e., a suspected root fracture not visualized with conventional radiography. For a root fracture in the middle third, CBCT may rule out or confirm an oblique course of fracture involving the cervical third in the labiobuccal dimension. Although there are considerable advantages when CBCT is included in the assessment of horizontal root fracture and its possible sequelae, more experimental and clinical studies are warranted to determine the exact impact on outcomes. (Endod 2013;39:S20–S25)

Key Words
CBCT, diagnosis, horizontal root fracture

Horizontal root fracture (HRF) implies a severe injury to cementum, dentin, and pulp as a result of trauma to teeth and periodontium. The overall incidence of HRF is low and has been reported to range from 0.5%–7% when compared with other forms of dental impact injuries (1, 2). HRFs occur mainly in central (68%) and lateral (27%) maxillary incisors; in contrast, only 5% of root fractures are found in mandibular incisors (3). HRF presents a challenging entity to properly diagnose; the limitations of conventional radiography for diagnosis are well known and are documented in the dental literature (4–8).

With the advent of cone-beam computed tomography (CBCT) in recent years, a new tool is available to accurately diagnose HRF regarding the presence or absence as well as the exact location, extent, and direction of the fracture line. Several recent case reports illustrate the potential of CBCT in diagnosing HRFs (9–15); in addition, 2 recent systematic studies have highlighted its relevance for prognosis and treatment planning (3, 16).

Most recent trauma guidelines suggest that in addition to conventional radiography, CBCT scans may be considered for the diagnosis of HRF (Table 1). However, concerns have been raised because of higher levels of radiation, higher cost to the patient, and the need for sufficient training to properly evaluate the entire data set (17–19).

Although the use of CBCT for the diagnosis of HRF has been suggested by the American Association of Endodontists and the American Association of Oral and Maxillofacial Radiologists (20) as well as the International Association of Dental Traumatology (6), specific considerations, indications, and contraindications for use have not yet been documented. Hence, this article aims to provide preliminary guidelines for the use of CBCT in trauma cases.

Review
The authors initially queried PubMed by using the terms [horizontal root fracture AND CBCT] and included all relevant articles. Other articles were found by searching these search terms individually as well as from related articles offered by the PubMed Web site as a result of each search query. Articles concerning vertical root fractures were not included in this article. All included articles were peer-reviewed. Case studies and systematic reviews were included as well as 1 animal study.

Outcome of HRF
The prognosis of teeth involved in HRF varies according to the literature (1, 21). A 2008 study by Cvek et al (22) showed that 20% of teeth with root fractures (109 of 534) did not show healing but rather pulpal necrosis. Andreasen et al (1) observed that 60% of the teeth with root fractures exhibited external root resorption. Orhan et al (2) reported that the time elapsed between trauma and treatment, stage of root development, and signs and symptoms of mobility and pain may influence the type of healing. They also indicated that communication of the fracture line with the oral cavity results in pulpal necrosis. Moreover, Orhan et al (2) reported that healing usually occurs when the fracture avoids the cervical third of the root, although pathologic changes can occur several years after the injury, requiring long-term follow-up of patients. Fractures in the middle third of the root are considered most common (23), whereas those located in the cervical third appear to have the worst prognosis (24).
Earlier studies, however, did not find a direct correlation between pulpal necrosis and the level of the fracture (25). Moreover, when seen along a buccolingual line, HRF often follows an oblique line (Fig. 1) (1), which in turn may directly relate to prognosis. Indeed, fractures confined to the apical or middle third with lesser diastasis, younger age of the patient, and lack of mobility of the coronal fragment subsequent to injury tend to lead to a better prognosis and more favorable results (16, 21).

Clinical and Radiographic Examination of HRF

The diagnostic procedures in a case of a suspected HRF include a comprehensive clinical evaluation that includes assessment of mobility, presence or absence of tenderness and pain to palpation of the soft tissues, percussion of the affected teeth, and pulp vitality and sensitivity tests (6). Common clinical signs of HRF include bleeding into the sulcus, mobility of the coronal fragment, and history of impact trauma to the alveolus or teeth. When signs and symptoms suggestive of HRF are present, intraoral radiography is typically prescribed by clinicians (Fig. 2).

Table 1 summarizes the recommendations by several organizations for the radiographic diagnosis of traumatic dental injuries. Multiple periapical radiographs are recommended and, more recently, consideration of CBCT (6), because it was believed that visualization of the presence and location of root fracture allows the clinician to better choose the appropriate course of treatment.

Unfortunately, conventional radiography has limitations for the diagnosis of HRF (Figs. 2 and 3). If the x-ray beam does not pass directly through the fracture line, the fracture often cannot be shown on the radiographs (2). Minimal fracture fragment displacement, structure superimposition, soft tissue swelling, and the presence of foreign objects can complicate the appearance of tooth fracture in conventional radiographs (11). Bornstein et al (16) noted that root fractures are often missed in routine daily practice; in fact, it had been shown earlier that expert examiners found an additional 21 occult fractures that were not detected by the treating dentist at the time of injury (26).

Others have discussed similar limitations of radiographs in cases of HRF. For example, Iibuko et al (27) noted limitations of periapical radiographs in accurately detecting fractures. Inherent disadvantages of conventional radiographic methods include magnification, distortion, and anatomic superimposition of 2-dimensional images.

<table>
<thead>
<tr>
<th>Source</th>
<th>Year (reference)</th>
<th>Recommendation</th>
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<tbody>
<tr>
<td>AAE Trauma Guidelines</td>
<td>2004 (31)</td>
<td>Take 4 radiographs (1–4). Radiographs taken at different angulations are useful. Sensitivity test: (1) occlusal, (2) periapical central angle, (3) periapical mesial eccentric, and (4) periapical distal eccentric</td>
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<tr>
<td>AAPD Trauma Guidelines</td>
<td>2010 (32)</td>
<td>Radiographic findings may reveal 1 or more radiolucent lines that separate the tooth fragments in horizontal fractures. Multiple radiographic exposures at different angulations may be required for diagnosis.</td>
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<tr>
<td>IADT Guidelines</td>
<td>2007 (7)</td>
<td>As a routine, several projections and angles are recommended: 90° horizontal angle, with central beam through the tooth in question, occlusal view, and a periapical radiograph with lateral angulations from the mesial or distal aspect of the tooth in question. For more detailed information see current textbooks (1).</td>
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<tr>
<td>IADT Guidelines</td>
<td>2012 (6)</td>
<td>Several projections and angulations are routinely recommended, but the clinician should decide which radiographs are required for the individual. The following are suggested: A periapical radiograph with a 90° horizontal angle with central beam through the tooth in question, occlusal view, and a periapical radiograph with lateral angulations from the mesial or distal aspect of the tooth in question. Emerging imaging modalities such as CBCT provide enhanced visualization of traumatic dental injuries, particularly root fractures and lateral luxations, monitoring of healing, and complications. Availability is limited, and its use is not currently considered routine; however, specific information is available in the scientific literature.</td>
</tr>
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Coohenca et al (5) also described poor sensitivity of conventional intraoral radiography in the detection of small displacements of fragment as well as alveolar fractures. Limitations are due to projection geometry, superimposition of anatomic structures, and processing errors. Moreover, small fissures or incomplete fractures without
Figure 2. In a 13-year-old patient a root fracture can be seen in the middle root canal third (A and B). The sagittal CBCT slice clearly shows the presence of a single fracture (C).

Figure 3. In a 36-year-old patient, a root fracture can be seen in the middle third of the left central maxillary incisor on the occlusal radiograph (A). On the periapical radiograph of the same patient, a root fracture is visible in the cervical third of the right central maxillary incisor (B). (C) The sagittal CBCT slice shows the cervical location of the root fracture in the right central maxillary incisor (C). Also the left central maxillary incisor shows a root fracture on the sagittal CBCT slice (D). (From Bornstein MM, Wölner-Hanssen AB, Sendi P, et al. Comparison of intraoral radiography and limited cone beam computed tomography for the assessment of root-fractured permanent teeth. Dent Traumatol 2009;25:571–7.)
separation of the segments are sometimes not detectable by using conventional radiographs, whereas later the interposition of periodontal ligament may make these fractures detectable (27).

There is a significant risk of misdiagnosing the location of a root fracture on an anterior tooth by using intraoral radiography because of the possibility of an oblique course of the fracture line in the sagittal plane (Fig. 1) (3, 16). What appears to be a fracture confined in the middle third on a conventional film seen in the frontal plane can often show involvement of the coronal third when viewed from the sagittal plane (labiopalatine or labiolingual plane) by using a different radiographic imaging modality. It is reported in dental literature that fractures most often occur in the middle third of the root (3). However, Bornstein et al (16) argued that although most fractures are found in the middle root third on the basis of conventional films, this should be reconsidered. Indeed, according to their study, 30 teeth (68.2%) had a fracture located in the cervical third on the palatal aspect of the root (16).

Notably, HRFs in the cervical part of the root are considered to have the poorest prognosis (24). The risk of misdiagnosis of the location and course of the fracture line by using intraoral radiography could lead to improper treatment planning and unfavorable outcomes. Because of the limitations of intraoral radiography, CBCT was suggested as an imaging modality for the diagnosis of HRF. CBCT has been shown in an animal study to be superior to conventional radiography and multidetector helical CT (MDHCT) at slice thicknesses of 0.63 mm and 1.25 mm (27). In that study, 7 beagle dogs had 28 maxillary anterior teeth extracted, of which 13 received artificially induced HRFs. Six oral and maxillofacial radiologists who were blinded as to procedure, methods, and the condition of the roots of the teeth observed the images. The sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy of recognizing the presence of a fracture line were determined for each radiographic imaging modality. The diagnostic accuracy of CBCT was the highest among the radiographic modalities; the second was MDHCT (slice thickness, 0.63 mm), and MDHCT (slice thickness, 1.25 mm) was similar to conventional radiography. The authors concluded that CBCT should be considered as the most reliable imaging modality of choice for the diagnosis of HRF (27).

Figure 4. Flow chart illustrating diagnostic steps that should be undertaken when suspecting infra-alveolar fractures. Note the case-specific recommendation for CBCT use, which is in line with current recommendations to limit radiography while maximizing diagnostic yield. PA, periapical radiograph; RCT, root canal therapy.
CBCT Dosage Considerations

It has been argued that using CBCT exposes patients to higher radiation dosages compared with intraoral radiography, although CBCT uses far less radiation than conventional CT (28).

CBCT units can be classified according to the imaged volume or field of view (FOV), as large FOV (6-inch to 12-inch or 15–30.5 cm) or limited FOV systems (1.6-inch to 3.1-inch or 4–8 cm) (11). Limited FOV systems image a small area of the face, deliver less radiation, and produce a higher-resolution image (11).

The International Commission on Radiological Protections has introduced different tissue-weighting factors to measure absorbed doses (19). It was recently reported that CBCT resulted in absorbed radiation doses that are comparable to other dental surveys (28). A study by Bornstein et al (16) that used the NewTom QR-DVT 9000 (Quantitative Radiology S.R.L., Verona, Italy) found a 4 × 4 cm FOV to deliver 20.02 μSv of radiation. Ludlow et al (29) measured effective doses for a panoramic radiograph taken with various digital systems to vary between 5.1 and 24.3 μSv; this was less compared with the large FOV Newtom CBCT. Effective dosages with current small FOV CBCT units are typically in the range of single conventional radiographs, estimated at 7.3 μSv (30). However, Orhan et al (2) reported that larger FOV CBCT scanners may have up to 7 times the radiation risk of panoramic examination, depending on the area examined, the degree of collimation, and the acquisition software version.

Taken together, these data clearly suggest that limited FOV CBCT should be selected as imaging modality when a tomographic method is indicated.

Concluding Remarks and Recommendations

Before using CBCT for HRF diagnosis, it should be considered that children are at greater risk than adults from a given dose of radiation both because they are inherently more radiosensitive and because they have more remaining years of life during which a radiation-induced cancer could develop (18). Hatcher (19) stated that CBCT should be used to answer specific clinical questions that often require input from the radiology technologist and reviewing radiologists. A careful consideration for use of CBCT should clearly define what information might be gained by CBCT that could not be provided by a method of radiography that causes less damage. As always, the principle of as low as reasonably achievable must be followed (17, 20).

An approach (Fig. 4) to the indications and contraindications of limited FOV CBCT for diagnosis of HRF must consider the strengths and limitations of intraoral radiography. The usefulness of CBCT may be questioned in cases in which a single periapical film has definitively shown a fracture in the apical or coronal third of a root. However, clinical outcomes depend on the exact location of the fracture, extent of displacement, and potential connection of the fracture to the oral cavity (1). Therefore, in a case with an uncertain assessment from conventional radiographs, CBCT should be considered. For example, when using intraoral radiography, a fracture is observed in the coronal third; CBCT may not be needed when extraction is likely the course of treatment regardless of the CBCT findings. On the other hand, a high strategic value of the tooth in question may warrant more involved dentistry, including a CBCT scan.

When intraoral radiography shows a fracture in the middle third or the absence of fracture in a case when root fracture is suspected, CBCT is arguably indicated. In the case of the former, CBCT is useful because it can reveal the course of the fracture in the sagittal plane. For a favorable fracture plane, one avoiding the coronal third, Internal Association for Dental Traumatology guidelines recommend to clean the area around the tooth, reposition, take a periapical radiograph to confirm position, splint the tooth for 4 weeks, and monitor for pulpal necrosis for 1 year. In a case of an unfavorable fracture plane involving the coronal third, a clinician would likely extract. In the case of inconclusive findings by using conventional intraoral radiography, limited FOV CBCT is indicated because of the increased accuracy and sensitivity of CBCT over other imaging modalities. Similarly, a larger fracture diastasis likely has inferior prognosis (21), and the fracture gap is typically detectable within the resolution of the CBCT unit (27).

Another potential indication for the use of CBCT is for a more detailed evaluation of the injured tooth during the monitoring phase when intraoral radiography shows signs of external resorption. There is general agreement that CBCT provides valuable information allowing the exact localization, direction, and extent of root resorption as well as a differential diagnosis for perforations and communications with the periodontal ligament space (12). Limited FOV CBCT imaging seems to be generally advantageous in the diagnosis, assessment of prognosis, treatment planning, and treatment follow-up of HRF cases. Although there is considerable enthusiasm regarding the advantages of CBCT for diagnosis of HRF and its possible sequelae, more experimental and clinical studies are warranted to determine the exact impact on outcomes.

Acknowledgments

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References