Cone Beam Computed Tomography Updated Technology for Endodontic Diagnosis

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KEYWORDS

- Cone beam computed tomography • Radiographic diagnosis
- 3-dimensional radiology • Radiographic outcome assessment
- Root canal morphology • Endodontic diagnosis • Apical periodontitis

KEY POINTS

- Narrow field CBCT has many applications in Endodontics and reduces the negative effects of anatomic noise, geometric distortion and technique sensitivity observed on 2D images.
- Narrow field CBCT provides earlier detection of apical periodontitis than conventional 2D radiographs providing improved diagnostic value, treatment efficiency and outcome assessment.
- Narrow field CBCT provides excellent image resolution at reduced radiation exposure as compared to mid or large field of view CBCT.
- CBCT assists the practitioner to identify canal morphology, numbers of canals and relative positioning even in the presence of calcific metamorphosis and dystrophic calcifications.
- Identification and treatment of lateral canals is supported by viewing their specific location with the use of narrow field of view CBCT before or during endodontic therapy.

INTRODUCTION

According to the Merriam-Webster dictionary, the term “diagnosis” is defined as: “the art or act of identifying a disease from its signs and symptoms.” In the field of endodontics, dentists review a multitude of signs and symptoms to formulate their diagnosis. These include, but are not limited to: sensitivity to heat, sensitivity to cold, percussion, palpation, bite, swelling, caries, periodontal disease, presence of sinus tracts, and unstimulated pain. In addition to these symptoms, tests are used to identify variations from normal such as electric pulp tests,¹ laser Doppler,² and radiographs³ (first used in 1896 by Otto Walkhoff). In the early 1960s Seltzer and Bender⁴,⁵ identified several discrepancies using 2-dimensional (2D) radiographs for observing...
apical periodontitis (AP). These included: (a) a delayed appearance of radiographic evidence of AP until 40% cortical plate demineralization developed and (b) a lack of correlation between the size of the histologic defect and AP image.

In addition, according to Durack and Patel, 2D radiographs are of limited value due to the compression of 3-dimensional (3D) structures, geometric distortion, anatomic noise, and temporal perspectives.4–6

Radiographs are used to identify the changes inside visually opaque objects. Although interpretations of these images are only part of the diagnostic process, the dental community places great emphasis on this information. In the early 1970s, Brynolf studied the benefit of using radiographs from multiple angles to increase their diagnostic value. She found that using 3 images improved diagnosis significantly.7 Later that decade, grave concerns developed. Many articles published supported the idea that reading dental radiographs was too subjective.8–10 To this concern, Orstavik and colleagues12 developed a guide to standardize apical observations called the Periapical Index. Despite these efforts, 2D radiographs were still limited in diagnostic value due to the factors previously listed.4–6

Computer-assisted tomographic imaging or cone beam computed tomography (CBCT), a technology borrowed from medicine, previously focused on the need for better surgical guidance during implant placement.14 The principle of ALARA21 (As Low As Reasonably Achievable) as related to radiation exposure and the lack of resolution initially limited CBCT use in endodontics.15 A new area of research emerged, and old paradigms were shifting.17 These advances solved many of the listed 2D limitations.6,13 Specific applications of this technology developed and the Endodontic community embraced them.18–20

The current narrow field of view CBCT provides a 3D, low-radiation/high-resolution solution to many endodontic diagnostic and treatment problems.11 This article will display specific case scenarios and supporting literature for the application of CBCT technology.

ROOTS: ANATOMIC NOISE HIDES ANATOMY

Case #1: Maxillary Left First Bicuspid—Diagnosis: Pulpal Necrosis/Symptomatic Apical Periodontitis

Identification of root structure, curvature, and location are hampered in 2D radiographs by anatomic noise (Fig. 1).6 In this case, CBCT (Figs. 2 and 3) assisted with

Fig. 1. Preoperative 2D periapical x-ray, arrow pointing to hidden radicular anatomy “Anatomic Noise”.

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the preoperative identification of the presence, location, shape, and lengths of 3 separate distinct roots. Note the accurate orientation, size, and location of apical periodontitis clearly observed on sagittal (see Fig. 2) and coronal views (see Fig. 3).\textsuperscript{16} Treatment is clearly supported by preoperative knowledge of root anatomy.

**CANALS: HIDDEN CANAL MORPHOLOGY**

**Case #2: Mandibular Left First Molar, Diagnosis: Irreversible Pulpitis/Symptomatic Periodontitis**

Preoperative identification of the number, location, and length of canals is facilitated with a CBCT scan (Figs. 4–7). Successful endodontic treatment depends on treating all canals (see Fig. 7).\textsuperscript{22} In tooth #19, a midmesial canal is observed on the preoperative axial scan (see Fig. 5) and verified clinically (see Fig. 6).
Fig. 4. Preoperative 2D view periapical x-ray.

Fig. 5. 3D CBCT axial view 3 mesial canals (arrows).

Fig. 6. Axial view 3 mesial canals.
CALCIFICATIONS

Case #3: Maxillary Left Central Incisor Diagnosis—Pulpal Necrosis/Symptomatic Apical Periodontitis

Canal obliteration may represent dystrophic calcifications (DC, calcification of degenerating or necrotic tissue pulp stones\(^{23}\)) or calcific metamorphosis (CM, A process of mineralization after trauma\(^{24}\)) (Figs. 8–11). The mechanism for dentin deposition in CM has been debated by the profession and is still unclear.\(^{25,26}\) It has been suggested that the severity of the injury may be related to the rate of deposition.\(^{27}\) The predominance

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Fig. 7. Postoperative 2D periapical x-ray 3 mesial canals.

Fig. 8. Preoperative 2D periapical x-ray, arrow points to calcified root canal.
of literature suggests that despite the appearance of CM on a 2D radiograph, a narrow pulp canal space persists (see Figs. 9 and 10). With the development of CBCT, pretreatment identification and location of this narrow pulp space can facilitate minimally invasive treatment.
LATERAL CANALS
Case #4: Maxillary Left Central Incisor Diagnosis—Pulpal Necrosis/Symptomatic Apical Periodontitis

Treatment of lateral canals requires pretreatment knowledge of their presence and location (Figs. 12–15).\textsuperscript{31} 2D radiology does not provide adequate information to

Fig. 11. Postoperative 2D periapical x-ray minimally invasive treatment.

Fig. 12. Preoperative 2D periapical x-ray.
Fig. 13. Preoperative 3D CBCT coronal view, arrow pointing to lateral canal exiting into lateral radicular defect.

Fig. 14. 3D CBCT sagittal view provides accurate measurement from apex to lateral canal (distance between arrows).
predictably locate and treat this entity.\textsuperscript{32,33} Successful endodontic treatment depends on the adequate debridement of bacteria from all spaces.\textsuperscript{31} CBCT technology assists the practitioner with identifying the specific location of lateral canals (see Figs. 13 and 14). Overcoming the obstacle of identifying and locating lateral canals enhances the ability to treat these difficult cases (see Fig. 15).\textsuperscript{34}

\textbf{BONE MORPHOLOGY IDENTIFIABLE ON CBCT}

\textit{Fenestration Case #5}

Identification of a fenestration can assist in planning apical surgery (Figs. 16–18).\textsuperscript{35} CBCT offers the opportunity to accurately evaluate an area of apical periodontitis

\textbf{Fig. 15.} Postoperative 2D periapical x-ray, gutta-percha cone in lateral canal.

\textbf{Fig. 16.} 3D CBCT preoperative sagittal view—isolating buccal plate demonstrating fenestration (arrow pointing to fenestration of Buccal Bone).
for size, volume, and location before surgery. Some studies find no value in apical grafting, while others advocate that the need for grafting is based on the volume of the space to be grafted. These studies suggest that larger lesions may not heal successfully from apical surgery without grafting, due to a lack of clot stability. CBCT can be used to determine the volume of the apical periodontitis lesion. Future research may be able to identify the specific volumetric limits for clot stability and graft usage as opposed to the linear measurement currently used.

**Dehiscence Case #6**

Maxillary left second bicuspid—diagnosis: previously treated root canal/symptomatic apical periodontitis. In case #6 (Figs. 19–22), despite a careful and comprehensive examination and periodontal probing, a vertical root fracture was clinically undetectable. The etiology for endodontic failure was ultimately identified with the use of a CBCT. Isolating the buccal plate defect on a coronal plane view assisted to identify the boney dehiscence (see Fig. 21). In this case, the vertical fracture was verified during the surgical exposure (see Fig. 22). Vertical fractures and cracks may not be visible on 3D

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**Fig. 17.** 3D CBCT preoperative reconstructed view buccal plate demonstrating fenestration (arrow pointing to fenestration of buccal bone).

**Fig. 18.** Apical operative view, demonstrating fenestration observed after flap reflection (arrow pointing to fenestration of buccal bone).
Fig. 19. Preoperative 2D periapical x-ray #13.

Fig. 20. 3D CBCT axial view (arrow pointing to buccal bone defect over vertical fracture).

Fig. 21. 3D CBCT sagittal view (arrows pointing to buccal bone dehiscence). The fracture may not be visible on CBCT; look for the adjacent bone loss (arrows).
images. The Nyquest Theorem identifies the limitation of an image’s ability to identify a crack or fracture defect to equal twice the voxel size used to scan the object.39

IDENTIFYING CYSTS

A radicular cyst is a common odontogenic lesion of inflammatory origin. The ability to distinguish a cyst from a granuloma has been studied over the years.40–45 Various studies have suggested that the presence of an opaque lamina provides evidence of a cyst. A study by Ricucci and colleagues46 refutes this theory. In support, one only needs to return to the findings of Seltzer, Bender, Bhaskar47 and more recently by Lalonde,40 to see that cysts, granulomas, and abscess all have a similar appearance on 2D radiographs. Conflicting studies have been published debating CBCT’s effectiveness to distinguish cysts from granulomas.48 In the following examples, one observes the lumen of the cyst42 as detected on CBCT (Figs. 23 and 24) but not visible

Fig. 22. Surgical exposure of fracture and dehiscence (arrows). The fracture may not be visible on CBCT; look for the adjacent bone loss (arrows).

Fig. 23. 3D CBCT coronal view of apical periodontitis #5 with cystic lumen (arrow pointing to black cystic lumen within gray apical defect).
on preoperative 2D image (Fig. 26). The question remains, however; if the lumen is not visible, is it a granuloma? Further research is needed to clarify this issue.

Case #7 Diagnosis: incisive canal cyst (Fig. 25).

Case #8 Maxillary right first bicuspid—diagnosis: pulpal necrosis/asymptomatic apical periodontitis radicular cyst (see Figs. 23, 24 and 26).

Fig. 24. 3D CBCT sagittal view of apical periodontitis #5 with cystic lumen (arrow pointing to black cystic lumen within gray apical defect).


Fig. 26. Preoperative 2D image of apical periodontitis #5.
Endodontic Recall

Endodontic healing has traditionally been verified clinically and radiographically. The AAE 2005 definitions are described in Box 1.

<table>
<thead>
<tr>
<th>Box 1</th>
<th>Definitions of endodontic outcomes</th>
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<tr>
<td>Healed—functional, asymptomatic teeth with no or minimal radiographic periradicular pathosis</td>
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<tr>
<td>Nonhealed—nonfunctional, symptomatic teeth with or without radiographic periradicular pathosis</td>
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<tr>
<td>Healing—teeth with radiographic periradicular pathosis, which are asymptomatic and functional, or teeth with or without radiographic periradicular pathosis, which are symptomatic but whose intended function is not altered</td>
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<tr>
<td>Functional—a treated tooth or root that is serving its intended purpose in the dentition</td>
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The outcome of endodontically treated teeth is heavily weighted on the observation of radiographic healing. The low predictive value of 2D radiography limits its usefulness for evaluation of repair. 3D imaging expands the function of the recall examination to include all periradicular tissues (cortical and medullary bone). The subsequent examples apply current CBCT technology to discover the true status of all periradicular tissues. 2D radiographs may indicate buccal or lingual plate healing but can mask the periradicular status. As noted by Orstavik, healing may take 1 to 4 years.

Case #9: Healing—Diagnosis: Previously Treated Root Canal/Asymptomatic Apical Periodontitis

Nonsurgical retreatment was completed in 2 visits with Ca(OH)2 used as intravisit medicament (Figs. 27 and 28). Patient returned for a 1-year routine recall (Fig. 29), asymptomatic. 2D radiographic examination revealed healed apex, while the 3D radiograph (Fig. 30) exhibited possible reduction is size of asymptomatic apical periodontitis when compared with 3D preoperative images (see Fig. 28).

Fig. 27. Pre-operative 2D periapical x-ray.
Case #10: Healed—Diagnosis: Previous Root Canal Treatment (Missed Mesiobuccal)/Symptomatic Apical Periodontitis

Nonsurgical retreatment was completed in 2 visits (Figs. 31 and 32), with Ca(OH)2 used as intravisit medicament. The patient returned 3 years after retreatment with...
continuous evidence of apical periodontitis on 2D radiograph. Surgical intervention (apicoectomy) was performed. One year and 18 months later, 2D (Figs. 33 and 34) and 3D screen shots exhibited healing of periradicular tissues.
Traumatic injuries to the dentition result in 1 of 3 outcomes. First, teeth may regain vital responses to tests due to revascularization. Second, teeth may remain nonresponsive to vitality tests due to aseptic necrosis (without apical periodontitis), or third, teeth may become infected and develop acute or chronic apical periodontitis (Figs. 35–37). CBCT can help the clinician make an earlier diagnosis. Generally necrotic changes are evident within 3 months of the trauma. Early intervention of endodontic treatment based on clinical and radiographic evidence can help avoid tooth loss due to resorption.

Fig. 34. 3D CBCT coronal view; note healed buccal plate and medullary bone (arrows).

Fig. 35. 3D CBCT coronal view—fracture of anterior maxilla observed superior to canine and lateral incisor (arrows).
A 45-year-old woman was hit in the face by a bus mirror and sustained a maxillary fracture, avulsions and luxations of multiple teeth (see Figs. 35–37). The CBCT was used to identify components of the maxillary fracture’s location and morphology, ridge defect height and width, and imaging of the temporomandibular joints.56,57

CONCLUSIONS

The previous examples identify the value of CBCT for Endodontics. Narrow field of view CBCT facilitates diagnosis, treatment and outcome assessment while adhering to ALARA principles. Additional applications for this technology can be...
expected within the Endodontic field as a result of the explosion of research in the imaging field.

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