Intraoperative Endodontic Applications of Cone-Beam Computed Tomography

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Abstract

Introduction: The use of cone-beam computed tomography (CBCT) in endodontics for diagnosis, treatment planning, and follow-up has been extensively reported in the literature. Compared with the traditional spiral computed tomography, high-resolution limited CBCT results in a fraction of the effective absorbed dose of radiation. However, it should be prescribed only after weighing the cost of radiation exposure with the benefit of the diagnostic information that can be obtained from the scan. Methods: The purpose of this article is to discuss the application and advantages of intraoperative CBCT in endodontics, while reducing radiation exposure during complex endodontic procedures. Results: In cases of increased difficulty or intraoperative complications such as complex anatomy, dystrophic calcifications, root resorptions, perforations, and root fractures, it is prudent to consider the use of CBCT with its inherent diagnostic value and limited radiation exposure. Conclusions: The benefits of the added diagnostic information provided by intraoperative CBCT images in select cases justify the risk associated with the limited level of radiation exposure. (J Endod 2013;39:548–557)

Key Words

CBCT, cone-beam computed tomography, diagnosis, intraoperative, root canal treatment

Since the first cone-beam volumetric tomography unit was approved for dental use in the United States in 2000 (1), numerous endodontic applications of this technology, along with cone-beam computed tomography (CBCT), have been described in the literature. Most of these applications are focused on preoperative assessment and treatment planning and include diagnosis and canal morphology (2–4), assessment of internal (2, 4, 5) and external root resorption (4, 6, 7), treatment planning and assessment of traumatic dental injuries (7, 8), assessment of root fractures (2, 9), presurgical anatomic assessment (2, 4), and treatment planning for tooth anomalies such as dens invaginatus (10, 11). Comparison studies have shown CBCT to be more accurate than conventional periapical radiographs in measurement of the length of root fillings (12) and diagnosing the presence of resorption lesions (13–15), periapical bone defects (16–20), root fractures (21–23), and perforations (24). These studies underscore the potential benefits of CBCT in diagnosis and treatment of endodontic problems.

In 2011, the American Association of Endodontists (AAE) and the American Academy of Oral and Maxillofacial Radiology (AAOMR) issued a joint position statement regarding the use of CBCT in endodontics (25). The statement emphasizes that the use of CBCT should be prescribed only after weighing the risks of radiation exposure with the benefit of the diagnostic information that can be obtained from the scan. Also, CBCT should never be routinely used in every case with every patient, and its prescription should only occur after a thorough clinical examination. In certain circumstances, however, use of limited field of view (FOV) CBCT may actually reduce the potential radiation exposure of the patient during the course of endodontic treatment. The statement notes that the “use of limited field of view CBCT systems can provide images of several teeth from approximately the same radiation dose as two periapical radiographs, and they may provide a dose savings over multiple traditional images in complex cases” (25). Situations occur during the course of endodontic treatment that may require additional diagnostic information to provide the best outcome for the patient. Use of CBCT in place of multiple periapical radiographs to obtain this needed information not only provides more accurate assessment but also reduces patient exposure to radiation.

One indication cited in the joint position statement of the AAE and AAOMR for the use of CBCT in endodontics was “intra- or post-operative assessment of endodontic treatment complications, such as overextended root canal obturation material, separated endodontic instruments, calcified canal identification, and localization of perforations” (25). Such intraoperative use of CBCT aids in avoidance of iatrogenic mishaps, which greatly influence the outcome of endodontic treatment. The overall prognosis of endodontically treated teeth has been shown to decrease because of perforations (26–29), presence of periapical radiolucency (29–31), and overfill or underfill of obturation materials (32, 33). Fracture resistance of endodontically treated teeth has also been shown to decrease when excessive tooth structure has been removed during endodontic treatment (34). Judicious use of intraoperative limited FOV CBCT images may prevent the occurrence of iatrogenic mishaps and reduce removal of healthy tooth structure when anatomy of the tooth is not fully apparent on standard periapical radiographs.

Intraoperative applications of CBCT include the following: location of calcified canals, evaluation of unexpected anatomic findings, evaluation of missed canals in endodontic retreatment, evaluation of root resorption and root fractures, and assessment of iatrogenic errors such as perforation, fractured instruments, and extruded obturation materials. The purpose of this article is to discuss the application and
advantages of intraoperative CBCT in endodontics, while reducing radiation exposure during complex endodontic procedures.

**Interpretation of Root Canal Anatomy**

**Case 1: Determination of Second Mesiobuccal Canal in Maxillary Second Molar**

A 41-year-old woman was referred for consultation and treatment of her maxillary right second molar. Clinical and radiographic examination was performed, and a diagnosis of pulp necrosis and symptomatic apical periodontitis was obtained. Initial radiographic examination was performed with RVG 6100 digital sensors (Carestream, Atlanta, GA) and included 2 periapical radiographs and a bite-wing radiograph. Periapical radiolucencies were evident around the palatal (P) and distobuccal (DB) root apices (Fig. 1A). On access, the mesiobuccal (MB), DB, and P canals were located by using a dental operating microscope (DOM), and working lengths were obtained. Mueller burs (Brasseler USA, Savannah, GA) and ProUltra Endo Tip #2 (Dentsply Tulsa, Tulsa OK) were then used to trace the MB groove in an attempt to localize the second MB (MB2) canal. Despite all clinical efforts, no MB2 was identified. The tooth was sealed by using Cavit (3M ESPE, Seefeld, Germany), rubber dam was removed, and the patient was scanned with limited FOV CBCT at 76 μm (Kodak 9000) (Fig. 1B and C). Careful examination of the CBCT study revealed that MB2 was not present. Periradicular radiolucencies were confirmed at the apices of MB, DB, and P canals. Nonsurgical root canal treatment was completed on #2 (Fig. 1D).

**Case 2: Taurodontism**

A 34-year-old man was referred for consultation and treatment of the maxillary right first molar. The patient’s chief complaint was discomfort in the maxillary right posterior quadrant with cold sensitivity during the past few weeks. Clinical and radiographic examination was performed, and a diagnosis of symptomatic irreversible pulpitis and symptomatic apical periodontitis was obtained. Initial radiographic examination was performed with RVG 6100 digital sensors (Carestream) and included 2 periapical radiographs and a bite-wing radiograph (Fig. 2A and B). The periapical radiograph revealed a deep furcation consistent with a taurodontism. On isolation and access, caries was removed, and the pulp chamber was exposed. A C-shaped root canal anatomy was initially diagnosed with 4 root canal orifices. However, patency was not achieved in all canals. At this point, the need for intraoperative CBCT was indicated to further evaluate the root canal morphology and possible intracanal and intercanal connections. The patient was informed, and consent was obtained. The tooth was then temporarily sealed by using Cavit, rubber dam was removed, and the patient was scanned with limited field of view CBCT at 76 μm (Kodak 9000) (Fig. 3). Analysis of the CBCT scan confirmed the anatomy of taurodontism (Fig. 3A) as well as the presence of maxillary mucositis in relationship with the maxillary right first molar (Fig. 3B and C). Axial cuts showed the presence of 4 canals (Fig. 3D) with fusion of the DB and P roots, creating the C-shape anatomy (Fig. 3D). With this information, the nonsurgical therapy was successfully completed (Fig. 4A), and a permanent core buildup was performed (Fig. 4B).
Case 3: Localization of Palatal Canal on a Maxillary Molar

A 51-year-old woman was referred for consultation and treatment of the maxillary right first molar. On the basis of a comprehensive clinical and radiographic examination, the tooth was diagnosed with pulp necrosis and symptomatic apical periodontitis. Periapical radiographs showed widening of the periodontal ligament space and loss of lamina dura, with diffuse periradicular radiolucency around the DB root (Fig. 5A). On isolation and access, the MB1 and DB were located by using a DOM. No MB2 was identified clinically under the operating microscope. The P canal presented with dystrophic calcifications, and patency was not achieved. The tooth was temporarily sealed by using Cavit, rubber dam was removed, and the patient was scanned with limited FOV CBCT at 76 μm (Kodak 9000) (Fig. 5B–D). Analysis of the CBCT scan revealed the exact location and orientation of the P canal, which was calcified up to 5 mm from the radiographic apex. The presence of periradicular radiolucencies was observed on the MB, DB, and P roots. No MB2 was identified on the coronal and axial cuts. By using the information obtained on the CBCT scan, corrective clinical measures were taken to locate the P canal by using ultrasonic instruments. All root canals were cleaned, disinfected, and filled without complications (Fig. 5E).

Establishing the Clinical Boundaries of Therapy

Case 4: Evaluation of the Extent of Calcification of Buccal Canal in a Maxillary First Premolar

A 64-year-old woman was referred to the predoctoral endodontics clinic for root canal therapy on the maxillary left first premolar. After

Figure 3. (A) Sagittal CBCT image of maxillary right first molar demonstrating extent of pulp chamber extension and depth of furcation. (B and C) Sagittal image with extent of mucositis in the sinus measured. (D and E) Axial images demonstrating C-shaped anatomy and presence of 4 canal systems.

Figure 4. (A and B) Postoperative periapical radiographs demonstrating completion of nonsurgical root canal therapy and core buildup placement on maxillary right first molar.
clinical tests were performed and periapical radiographs were taken (Fig. 6A), a diagnosis of pulp necrosis with normal apical tissues was given. Upon access and caries removal, the P canal was located, but the dental student was unable to locate the buccal canal, and the case was referred to the graduate endodontic clinic. An intraoperative limited FOV CBCT scan at 76 μm (Kodak 9000) was taken and analyzed (Fig. 6B and C). The axial and coronal cuts revealed the location of the buccal root, but no evidence of a patent canal was noted along the length of the buccal root. The decision was made to treat the lingual canal only and leave the buccal root intact, thereby avoiding unnecessary removal of tooth structure and/or perforation. Nonsurgical root canal treatment was completed on the lingual root of the maxillary left first premolar (Fig. 6D).

### Root Resorption

#### Case 5: Diagnosis of External Inflammatory Root Resorption and Extent of Crown Root Fracture

A 61-year-old woman was referred for consultation and treatment of the maxillary right first molar. Her dental history included
orthognathic surgery 43 years prior and endodontic access of the maxillary right first molar 2 months prior. Clinical examination revealed no response to thermal tests, with tenderness to palpation, percussion, and biting. During the periodontal examination a localized 5-mm pocket was probed on the mesial aspect of the maxillary right first molar. All other probing depths were less than 3 mm. There was no evidence of sinus tracts or soft tissue swelling. Preoperative radiographs were taken with digital sensors (Kodak RVG 6100) and included 2 periapical and 1 bite-wing radiographs (Fig. 7D). Loss of lamina dura and widened periodontal ligament space were noted on the MB and DB roots, with a diffuse periradicular radiolucency of 3 mm in diameter around the distal root. The P and DB roots were shortened and had the radiographic appearance of external inflammatory root resorption. The maxillary right first molar was diagnosed as previously initiated therapy and asymptomatic apical periodontitis. On access, 4 canal orifices were identified (MB1, MB2, DB, and P) by using a DOM. An intracoronal crack was also noted that extended down the mesial and distal aspects of pulp chamber. (Fig. 7E). The files in the mesial canals appeared 2–3 mm short of the radiographic apex, and the file in the P canal appeared 3–4 mm short of the radiographic apex. The amalgam restoration was removed, and it appeared that the cracks did not extend beyond the level of the canal orifice, although the 5-mm mesial periodontal pocket indicated possible crack propagation. Patency of all canals was confirmed with an electronic apex locator, and a periapical odontal pocket indicated possible crack propagation. Patency of all canals was confirmed with an electronic apex locator, and a periapical odontal pocket indicated possible crack propagation. Patency of all canals was confirmed with an electronic apex locator, and a periapical odontal pocket indicated possible crack propagation.

Case Report/Clinical Techniques

Separated Instruments

Case 6: Determining the Location of a Separate Instrument to Enable Bypass and Removal

A 38-year-old man presented for evaluation and treatment of his mandibular right first molar. Dental history revealed a previous attempt to perform a root canal retreatment 1 week prior. The endodontist accessed the tooth and attempted to loosen the separated instrument in the MB canal by using ultrasonics tips and files without positive outcome. At this point, the endodontist sealed the access with Cavit (Fig. 8A) and referred the case to a different endodontist. On initial consultation, the patient was symptomatic and frustrated with the fact that the instrument was not removed. A CBCT scan was prescribed to (1) determine possible spaces for ultrasonic activation without risks of stripping or perforation, (2) evaluate the location of the mental foramen to determine the feasibility of apical surgery in case the file was deemed unretrievable, and (3) diagnose the size and location of the apical resorption. Analysis of the scan revealed a clear space between the instrument and the lingual wall of the MB canal (Fig. 8A–D). Incidentally, a clear intracanal root resorption, presumably inflammatory, was also observed. With this information available, the second endodontist

**Figure 7.** (A and B) Intraoperative photographs depicting crack lines (arrows) on mesial and distal aspects of pulp chamber. (C) Postoperative photograph demonstrating composite resin core buildup and orthodontic band cemented in place. (D) Preoperative periapical radiograph demonstrating resorption of DB and P roots and radiolucent lesions around DB and MB roots. (E) Intraoperative periapical radiograph demonstrating patency files in all canals. The files in the mesial and palatal canals are several millimeters short of the radiographic apices. (F) Postoperative radiograph demonstrating completed endodontic treatment. (G and H) Intraoperative CBCT scan demonstrating extent of P root resorption (arrows) and (I) apical foramen of MB canals exiting short of anatomic apex (arrows). (J) No evidence of crestal bone loss caused by fractures.
accessed the tooth and bypassed and removed the instrument. Once this obstruction was removed, all efforts were aimed at debriding and disinfecting the resorptive defect at the apical third to achieve disinfection of this niche. Failure to do so would have likely affected the outcome of the root canal retreatment, despite the successful removal of the separated instrument. The nonsurgical root canal retreatment was then successfully completed (Fig. 8E), and the patient returned asymptomatic at the 3-month follow-up, with radiographic evidence of healing in process (Fig. 8F).

**Vertical Root Fracture**

**Case 7: Differential Diagnosis of Vertical Root Fracture**

A 67-year-old woman presented for examination and endodontic treatment of her maxillary right second premolar. The patient was complaining of dull pain in the maxillary right posterior quadrant that started 2 weeks prior. Patient reported having endodontic therapy on the maxillary right second premolar more than 20 years ago. Clinical examination revealed no response to thermal tests, with tenderness to palpation, percussion, and biting. Periodontal examination was within normal limits, with no probing depths of more than 3 mm. There was no evidence of sinus tracts or soft tissue swelling. Preoperative periapical radiographs were taken with RVG 6100 digital sensors (Fig. 9A and B). Loss of lamina dura and widened periodontal ligament space were noted with diffuse periradicular radiolucency. Accordingly, the maxillary right second premolar was diagnosed as previously treated with symptomatic apical periodontitis. The existing full crown restoration was passively lifted, and the silver cones were removed by using ultrasonic and Hedstrom files. Working length was obtained, and canals were irrigated. Under the DOM, a possible fracture on the palatal aspect of the buccal root was noted. The canal was stained with methylene blue, but no definitive diagnosis was possible. The tooth was temporarily sealed by using Cavit, rubber dam was removed, and the patient was scanned with limited FOV CBCT at 76 µm (Kodak 9000) (Fig. 9C and D). Analysis of the study confirmed the presence of a root fracture on the buccal root of the maxillary right second premolar. The patient was referred for extraction and rehabilitation.

**Case 8: Differential Diagnosis of Additional Canals or Vertical Root Fracture**

A 64-year-old woman presented for examination and endodontic treatment of her maxillary right second premolar. Comprehensive clinical and radiographic examination was performed, and the tooth was diagnosed as previously treated with symptomatic apical periodontitis (Fig. 10A and B). No deep periodontal pockets were diagnosed. On access, the root canal filling was removed, and a lingual projection was observed; the possibility of a second canal or root was discussed with the patient. The tooth was temporarily sealed by using Cavit, rubber dam was removed, and the patient was scanned with limited FOV CBCT at 76 µm (Kodak 9000) (Fig. 10C–E). Careful interpretation of the CBCT images revealed the presence of a vertical bone loss along the lingual aspect of the root (Fig. 10C) and a root fracture on the lingual side of the maxillary right second premolar (Fig. 10D). The endodontic procedure was not completed, and the patient was referred for extraction and rehabilitation.
Management of Iatrogenic Root Perforation

Case 9: Location of Mesiolingual Perforation and MB Root Canal in a Mandibular Second Molar

A 73-year-old woman was referred for consultation and endodontic treatment of the mandibular right second molar. Clinical and radiographic examination was performed, and the tooth was given a pulpal and periradicular diagnosis of symptomatic irreversible pulpitis and symptomatic apical periodontitis (Fig. 11A). There was no evidence of sinus tracts or soft tissue swelling, and all periodontal probing depths were less than 3 mm. Endodontic treatment was initiated, and occlusal access was performed. The distal canal and 1 mesial canal were located. A lingual perforation occurred while searching for the second mesial canal, and a periapical radiograph was immediately taken to confirm the perforation (Fig. 11B). A small amount of mineral trioxide aggregate (MTA) (Pro Root; Dentsply, Tulsa Dental, Johnson City, TN) was placed over the perforation to seal it and prevent further contamination. The access was temporarily sealed, and an intraoperative CBCT scan (Kodak 9000) was taken to evaluate the location of the perforation as well as the location of the second mesial canal (Fig. 11C–F). By using the intraoperative CBCT images, the location and relationship of the perforation with the crestal bone were determined, and the precise location of the MB canal was identified. Taking into consideration the location of the perforation, the MTA seal was removed, and the perforation was repaired with Geristore (Denmat, Santa Maria, CA). The root canal was then completed without further complications (Fig. 11G).

Discussion

Accurate diagnostic imaging is an essential part of endodontic evaluation and treatment. Conventional two-dimensional radiographs are still the most widely accepted and used imaging modality in endodontics. This is despite the fact that classic and current literature has highlighted the limitations of conventional radiographs (16, 35–37). These limitations arise primarily because of the inherent projection of a three-dimensional anatomy into a two-dimensional view, which leads to geometric distortion and, consequently, misinterpretation and/or misdiagnosis. It has been shown that CBCT is not subjected to the same limitations because of the production of accurate three-dimensional images (16). Current literature has demonstrated that preoperative CBCT images precisely reproduce maxillofacial tissues (2–4), elucidate the presence of periapical lesions more accurately than conventional radiographs (16–20), and display the location and extension of perforations (24), traumatic injuries (8), and resorptive defects (7, 14–16). Despite the myriad advantages that CBCT offers compared with conventional radiographs, its use for preoperative endodontic examination should carefully be considered on the basis of the as low as reasonably achievable protocol concerning radiation levels to expose patients to the least amount of radiation possible, while still gaining the most useful information for proper diagnosis.

To date, the intraoperative use of limited FOV CBCT has not been reported in the literature, despite the fact that it is not unusual to encounter internal root canal anatomy that was not completely revealed by traditional preoperative radiographs. The cases outlined in this article exemplified clinical situations that might benefit from further imaging information to provide the best clinical care. Furthermore, they underscore the value of taking intraoperative CBCT images to facilitate safe and effective endodontic treatment and to contribute to decision-making in cases in which it may be prudent to set the boundaries and evaluate the benefit/risk ratio that will be in the best interest of the patient’s care. A good example of this clinical situation would be the...
presence and clinical patency of MB2 canals in maxillary molars. As endodontists we should always strive to treat all canals, despite the fact that this often involves removal of additional tooth structure. However, if the canal is not negotiable, the unnecessary removal of tooth structure will increase the susceptibility to fracture (34) and the risk of root perforation.

When canals are identified but are subjected to calcification, intraoperative CBCT has been shown to be a powerful tool for assessing the extent of calcification, thereby contributing to determining the proper sequence of the treatment. As illustrated in the present article, CBCT images permitted the visualization of the depth of calcifications and guided the clinician to the correct location, angle, and depth to access

Figure 10. (A and B) Preoperative periapical radiographs of maxillary right second premolar showing previous nonsurgical endodontic treatment. (C–E) Intraoperative coronal, axial, and sagittal images after gutta-percha removal confirming presence of root fracture (arrow in D) and associated bone loss on palatal aspect of the root (arrow in C).

Figure 11. (A) Preoperative periapical radiograph of mandibular right second molar. (B) Intraoperative periapical radiograph with file in perforation site. (C–F) Intraoperative coronal, axial, and sagittal images identifying location of perforation (arrows in C, D, and F) and MB canal (arrow in E). MTA placed over the perforation is visible in coronal and axial views. (G) Postoperative periapical radiograph after completion of endodontic treatment and perforation repair.
the patent portion of the canals. On the basis of accurate measurement of the length and width of canal walls and distance from important anatomic structures provided by the CBCT scan, the canals were found and properly treated. On the other hand, when complete calcifications were detected, the intraoperative CBCT scan provided the critical information that led to the decision of preserving dental structures, particularly when apical pathosis is not present and the risks of attempting to expose a completely calcified canal are unjustifiable.

Vertical root fractures can be one of the most challenging diagnostic situations in endodontics. The cases illustrated in the present article have demonstrated the advantage of using CBCT intraoperatively after removal of obturation materials to diagnose root fractures. In cases in which preoperative scans are taken, artifacts created by the root canal filling materials would have made definitive diagnosis of these conditions challenging. Vertical root fractures are also rarely visualized on traditional preoperative periapical radiographs.

Precise identification of the location of a perforation can help dictate the type of repair material used. In the case presented in this article, the location of the perforation was identified at the height of the crestal bone by using intraoperative CBCT images. The intraoperative periapical radiograph with the file in the perforation site was not able to provide this information. A bondable repair material (Geristore) was chosen for final repair to prevent washout, which might have occurred with MTA. Also, placement of a small amount of MTA over the perforation before intraoperative CBCT enabled exact location of the perforation site. Accurate location of the perforation was critical in determining management in this case.

From the clinical point of view, the case series presented follows the AAE/AOMR recommendations of using CBCT for the assessment of endodontic complications such as those previously mentioned. By relying on the intraoperative CBCT images, it was possible to elucidate tooth morphology, determine the boundaries and risks for attempting root canal treatment in cases of calcified canals, and use them as a guide for localization and understanding of complex endodontic anatomy. In addition, the intraoperative CBCT scan was an important tool for detecting periapical pathosis, resorptive defects, extension of crack propagation, root perforation, and vertical root fractures in cases in which the diagnosis or treatment was compromised by the limitations of radiographs.

In conclusion, the patient always has the right to an informed decision, especially when other diagnostic means are inconclusive. In cases of increased difficulty or intraoperative complications, it is prudent to consider the use of limited FOV CBCT with its inherent accurate diagnostic value and limited radiation exposure. In essence, the benefits of the added diagnostic information provided by intraoperative CBCT in select cases justify the risk associated with the limited level of radiation exposure.

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