The Importance of Cone-beam Computed Tomography in the Management of Endodontic Problems: A Review of the Literature

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Abstract

Introduction: To obtain essential information in clinical endodontics, cone-beam computed tomographic (CBCT) imaging can be used in all phases of treatment including diagnosis, treatment planning, during the treatment phase, and through post-treatment assessment and follow-up. The purpose of this article was to review the use of CBCT imaging in the diagnosis, treatment planning, and assessing the outcome of endodontic complications. **Methods:** Literature was selected through a search of PubMed electronic databases for the following keywords: tooth root injuries, tooth root radiography, tooth root perforation, tomography, cone-beam computed tomography, endodontic complications, tooth root internal/external resorption, root fractures, and broken instruments. The research was restricted to articles published in English. One hundred twelve articles met the inclusion criteria and were included in this review. **Results:** Currently, intraoral radiography is the imaging technique of choice for the management of endodontic disease, but CBCT imaging appears to have a superior validity and reliability in the management of endodontic diagnosis and complications. **Conclusions:** Endodontic cases should be judged individually, and CBCT imaging should be considered in situations in which information from conventional imaging systems may not yield an adequate amount of information to allow the appropriate management of endodontic problems. CBCT imaging has the potential to become the first choice for endodontic treatment planning and outcome assessment, especially when new scanners with lower radiation doses will be available. *(J Endod 2014;40:1895–1901)*

Key Words

Cone-beam computed tomography, dental radiography, endodontics, root canal therapy, x-ray diagnosis

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0099-2399/$ - see front matter

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http://dx.doi.org/10.1016/j.joen.2014.05.009

Radiographic examination represents an essential part of the contemporary management of endodontic problems, from diagnosis and treatment planning to outcome evaluation. Intraoral and panoramic radiographic assessments have inherent limitations in the fact that 3-dimensional (3D) anatomy is compressed in a 2-dimensional (2D) image; superimposition of anatomic structures may result in geometric distortion of the area and anatomic noise that can hide the region of interest. Cone-beam computed tomographic (CBCT) imaging may overcome these problems by producing 3D images of teeth and surrounding tissues (1, 2).

This article aims to review CBCT features and report how the technology can be applied to improve diagnosis and treatment planning and assess the outcome of endodontic treatment. A search on PubMed electronic database of the existing literature was performed. The keywords used were "CBCT/cone-beam computed tomography/cone beam computed tomography/cone beam CT" combined with "tooth root injuries," "tooth root radiography," "tooth root perforation," "tooth root internal/external resorption," "tooth/root resorption," "complication," "dental pulp cavity injuries," "dental pulp perforation," "tooth/root fractures," "vertical root fractures," or "broken instruments/periapical." The research was limited to dental publications and articles written in English from January 1995–January 2014. Six hundred forty-four "*in vivo*" and "*in vitro*" studies were included. An additional manual search in the *Journal of Endodontics*, *International Endodontic Journal*, *and Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology* helped to find 21 more literature sources. Duplicate articles were removed, and a total of 403 literature sources were analyzed in detail. Two hundred fifty-four articles were excluded after a further detailed screening because they were case reports or papers related to orthodontics, periodontology, and oral surgery. A total of 148 full-text articles were further analyzed, and 112 were selected for this review.

CBCT Imaging

CBCT captures a 3D volume of data in a single scan, and the raw data from each rotation are reconstructed to produce tomographic images (3, 4). The size of the field of view (FOV) can be variable (2). CBCT devices were divided into 4 subcategories (5): dentoalveolar (FOV <8 cm), maxillomandibular (FOV 8–15 cm), skeletal (FOV 15–21 cm), and head and neck (FOV >21 cm).

Radiation Dose

The effective dose of CBCT scanners may vary, but it can be the same as that of a panoramic dental x-ray and considerably less than that of a medical computed tomographic scan (Table 1) (2, 5–8). The radiation dose can be reduced using a smaller FOV, less projections (180°), and a bigger voxel size (9, 10). Some studies have shown that the number of projections has no effect on image quality (11–13), but others have reported that FOV and the number of projections have a significant influence on root canal visibility (14, 15).

Images acquired with big voxel sizes and then reconstructed at smaller voxel sizes may obtain similar qualities with reduced radiation doses (16). If no difference in diagnostic accuracy is found between CBCT images taken with different resolution settings,

TABLE 1. The Range of Effective Dose from Conventional Dental Imaging Techniques and Dental Cone-beam Computed Tomographic Imaging in μSv (SEDENTEXCT Project 2011)

	Effective dose (μSv)
Intraoral radiograph	<1.5
Panoramic radiograph	2.7–24.3
Cephalometric radiograph	<6
MSCT maxillomandibular	280–1,410
Dental CBCT unit type	
Dentoalveolar (small and medium FOV)	11–674
Craniofacial (large FOV)	30–1,073

CBCT, cone-beam computed tomographic; FOV, field of view; MSCT, multi-slice computer tomography.

those resulting in reduced doses should be selected (9). Small-volume scanners deliver lower radiation doses and may be suggested for the endodontic imaging of only 1 tooth or 2 neighboring teeth because the FOV is similar in size to conventional periapical radiographs (PRs). The radiation dose of the small-volume CBCT scanner is similar to 2–7 standard PRs, whereas the radiation dose of a large-volume scanner is similar to that of a full-mouth series of PRs. However, radiation dose is machine specific and can vary greatly (1, 6, 9).

Radiation risk is age dependent, and beyond 80 years old, the risk becomes negligible because the latent period between x-ray exposure and the clinical presentation of tumors will probably exceed the life span of a patient. In contrast, tissues of young people are more radiosensitive, and their prospective life spans are likely to exceed the latent period. At all ages, risks for females are slightly higher than for males (8).

Limitations of CBCT Imaging

One significant problem affecting the image quality and diagnostic accuracy of CBCT images is the scatter and beam hardening caused by high-density neighboring structures and materials. Crowns, bridges, implants, fillings, and intracanal posts can mimic endodontic complications or hide the existing ones (17–20). Image quality is influenced by several technical factors including device, FOV, voxel size, number of projections, tube voltage, and current (1, 21). Fractured files and root canal filling materials also can cause artifacts to develop (3, 22, 23). Patient age has an influence on the image quality of CBCT imaging, and a positive correlation may be found between age and the amount of resulting artifacts. The detection of anatomic structures, such as the mental foramen, nasal floor, and mandibular canal, seems to be reduced with increasing age (20), and this is mainly explained by the fact that older patients have more dental restorations (24, 25).

Application of CBCT Imaging in the Management of Endodontic Problems

Clinical endodontics requires essential information from radiographic images in 3 phases of the treatment: diagnosis and treatment planning, during the treatment, and in the post-treatment assessment and follow-up (26–28). CBCT imaging has been used in endodontics to study root canal anatomy and the prevalence of apical periodontitis to evaluate root canal preparation and filling and for retreatment, surgical endodontics, and experimental studies (29–32).

Assessment of Root Canal Anatomy

Because of the 2D nature of conventional radiography, it does not consistently reveal the actual number of canals present in teeth (6, 33–35). In several studies, CBCT imaging was superior in detecting the number of roots to PRs (29, 36). The major drawbacks of these studies were that the teeth were not sectioned to confirm the number of root canals (2, 9, 10). A recent study (30) compared CBCT data of 9 molars with histologic sections and found strong to very strong correlations of the data (6, 9). The reliability of CBCT imaging to detect the second mesiobuccal canal in the maxillary molar increased with higher resolution (6, 28, 33, 37).

CBCT reconstructions are somewhat important in assessing teeth with an unusual number of roots, dilacerated teeth, and dens in dente (11, 12, 31, 38, 39). Root morphology (ie, the number of root canals and whether they merge or not) can be visualized 3-dimensionally (Fig. 1). However, the use of CBCT scanning is not indicated to be a standard method for the evaluation of root canal anatomy. Limited-volume CBCT imaging can be used in select cases in which conventional intraoral radiographs provide equivocal or inadequate information (8, 16).

Detection of Apical Periodontitis

CBCT scanning is a tomogram and eliminates anatomic noise, thus enabling the detection of radiolucent endodontic lesions before the buccal or lingual plate is demineralized (40–42). Apical periodontitis (AP) is correctly identified with conventional radiographic methods when the disease is in an advanced stage according to the periapical index (40% demineralization). When lesions are small, CBCT imaging shows better diagnostic results (36, 43–50). These clinical studies presume that the radiologic findings from CBCT scanning represent the "true" status of the periapical tissues (51–55). In a study that proclaimed histopathological findings as the "gold standard" for images, CBCT scans were more sensitive in detecting AP compared with PRs, which missed AP more frequently when it was present (56).

Lesions associated with apices near the sinus floor had a high probability to be missed with PR (57–59). CBCT data also revealed additional relevant information about root canal morphology and neighboring anatomic structures, the relationship of a periapical lesion with a root, and the thickness of the cortical and cancellous bone plates, which cannot be readily obtained from conventional radiological views. Furthermore, CBCT software may be used to

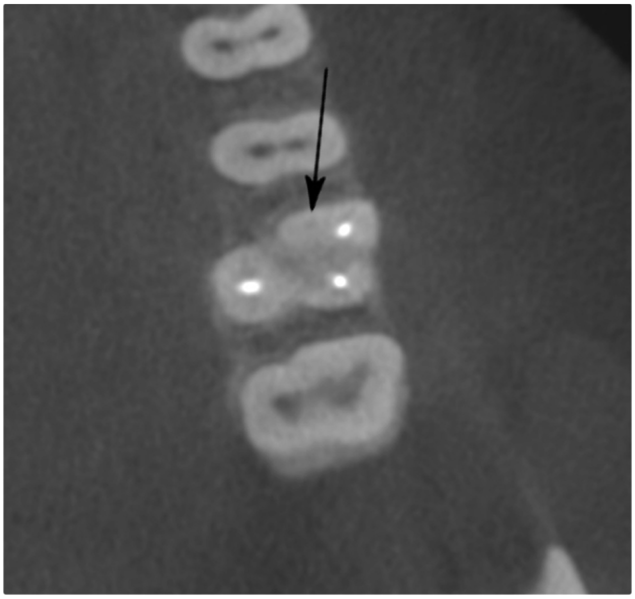

Figure 1. A CBCT axial scan of an upper molar with a missed second mesiobuccal canal.

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