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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. Seventy 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.

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

I. INTRODUCTION

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/ conebeam computedtomography/cone beamCT’’combined with‘‘toothroot 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 70 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 (9–13), 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 . 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 mSv (SEDENTEXCT Project 2011)

	Effective dose (mSv)
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).

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 (3) . Fractured files and root canal filling materials also can cause artifacts to develop (3, 2). 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 , and this is mainly explained by the fact that older patients have more dental restorations (2,5).

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 . 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 (10).

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 (6,5). In several studies, CBCT imaging was superior in detecting the number of roots to PRs (10). 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 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)

CBCT reconstructions are somewhat important in assessing teeth with an unusual number of roots, dilacerated teeth, and dens in dente (11, 12). 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, 13).

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 . 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 . These clinical studies presume that the radiologic findings from CBCT scanning represent the ‘‘true’’ status of the periapical tissues . 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 maximize the diagnostic yield of the captured data, and the reconstructed slices are geometrically accurate because pixels of CBCT images are isotropic. Therefore, periapical lesions will not change size or disappear on reconstructed scans as can happen with intraoral radiography as a result of poor irradiation geometry (8). CBCT imaging was also better than PR in detecting apical lesions in teeth with symptomatic irreversible pulpitis (6).

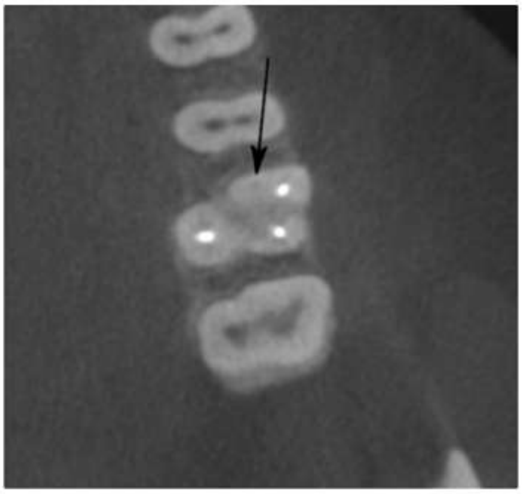

Figure 1. A CBCT axial scan of an upper molar with a missed second mesiobuccal canal.

CBCT scanning revealed lower healed and healing rates for primary root canal treatment compared with PRs when the outcome was assessed after a 1-year follow-up, particularly in molar roots . The 1-year retreatment follow-up showed that lesion volume reduced significantly in 57% of teeth , but in a recent follow-up study , no difference between PRs and CBCT imaging was found. In another recent study , bone density of periapical lesions was calculated in Hounsfield units before and 2 years after treatment, and CBCT imaging showed bone accumulation in periapical lesions. There is no agreement on the possibility of differentiating cysts from granulomas using CBCT imaging because the findings of studies that used

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histology as their ‘‘gold standards’’ are controversial .

Presurgical Assessment

CBCT imaging has been recommended for endodontic surgery treatment planning (1, 2, 3). 3D imaging allows us to clearly identify the anatomic relationship of the tooth involved in the surgery . In a study that compared anatomic landmarks using CBCT imaging and PRs before apical surgery, the distance from the lower molars to the mandibular canal could be measured only in 24 of the 64 radiographs analyzed (15). CBCT imaging may play an important role in microsurgery on the palatal root of maxillary molars; the distance between the cortical bone plate and the palatal apex can be measured, and the presence of the maxillary sinus between the roots can be assessed . Furthermore, a study reported that in 70% of the cases, CBCT imaging revealed clinically relevant information that was missed by PRs , and bone defects measured on PRs were approximately 10% smaller than on CBCT images (3).

Root Canal Treatment Quality Assessment

Void detection in root fillings was analyzed using different techniques including intraoral analogic radiographs, intraoral digital radiographs, and CBCT imaging. Voids larger than 300 mm were determined with all imaging techniques. For small void detection, all digital intraoral techniques performed better than intraoral analogic and CBCT images . In a 2-year follow-up study on 115 teeth, density and the apical extent of root fillings were outcome predictors detected by PRs, whereas CBCT imaging revealed the density of root fillings and the quality of coronal restoration as important factors . The precision of CBCT endodontic working length measurements varied between 0.41 and 0.51 mm if compared with the ‘‘gold standard’’ of electronic apex locators . All these studies underlined that CBCT imaging may be more useful as a diagnostic tool than for intraoperative or postoperative evaluation, with the exception of those cases that must be followed up because of their uncertain prognoses.(8)

Assessment of Endodontic Complication: Root Fracture, Resorption, or Perforation

If the root fragment has been not displaced, root fractures may be difficult to visualize through conventional intraoral radiography in the immediate post-trauma clinical situation (8). The fracture is seen as a radiolucent line between the fragments and as a discontinuity of the periodontal ligament shadow, but the surrounding tooth structure, particularly if the projection angle is not perpendicular to the fracture line, maymaskthefracture . There is no agreement on the accuracy of CBCT imaging in detecting vertical root fracture.

Horizontal root fractures are presumably easier to detect than longitudinal fractures, particularly those in the mesiodistal plane (9). The higher the spatial resolution was in the CBCT images, the higher the diagnostic accuracy was (9). However, the lower-resolution CBCT images were no more accurate than those of the PRs .Highdensity materials, such as root canal filling or metal post, may reduce the diagnostic ability of CBCT imaging (8). In another study , CBCT diagnostic ability was not influenced by the presence of posts or gutta-percha (Fig. 2). The accuracy of detections of vertical root fractures depends on the CBCT system used.

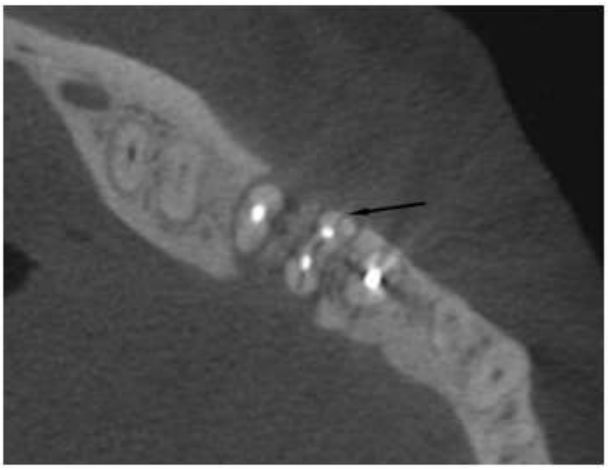

Figure 2. A CBCT axial scan of a vertical root fracture in the lower molar mesial root.

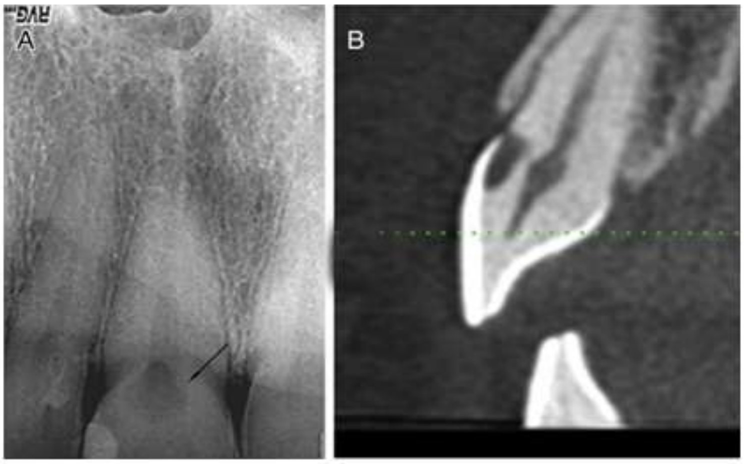

Figure 3. (A) Typical periapical radiography of external resorption. (B) A CBCT scan showing external resorption.

Resorptive defects may spread within the root in all directions, and their sizes and the positions of radiolucency may not be detected on the radiograph (Fig. 3A and B) . Although intraoral radiography was reasonably accurate in diagnosing internal and external cervical root resorption, CBCT scans resulted in enhanced diagnosis of the presence and type of root resorption , especially in the apical third .

This is also reflected by the sensitivity and specificity of the results. Intraoral radiography was slightly more accurate in diagnosing external cervical root resorption than internal root resorption, which may be caused by the fact that the scans' irregular margins may be specific for this type of resorptive lesion (5).

Correctly diagnosing complications such as perforation can be challenging as well (10). Accurate preoperative identification of a root perforation is important for treatment planning and prognosis. Radiographic detection is challenging on the labial and lingual root surface because the image of the perforation is superimposed on that of the root. Preoperative radiographs from 2 different horizontal angles can facilitate the identification of a labiolingually misdirected post. However, the greatest limitation of conventional radiography is the inability to fully describe the 3D anatomy of teeth and their related structures (Fig. 4A and B). CBCT imaging showed the tendency to more accurately identify fractured files, cast post deviations, and perforations compared with radiographs . These results corroborate the fact that CBCT imaging is a more accurate tool than PRs for the assessment and management of complex endodontic problems (2). Smaller voxel size is preferred for the diagnosis of simulated external root resorption (9,10), whereas similar results were found for the detection of simulated internal resorption and perforations (11, 12).

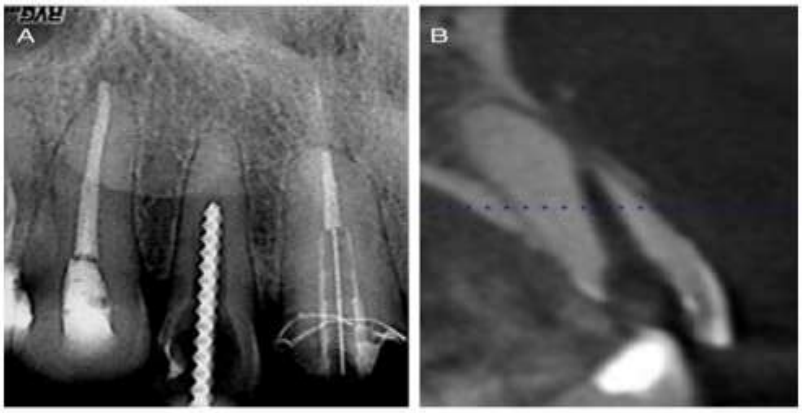

Figure 4. Typical periapical radiography of root perforation in an upper front tooth. (A) An image with K-file until perforation. (B) A CBCT scan of the same tooth root perforation.

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II. CONCLUSIONS

Radiologic examination is an essential part of the diagnosis and management of endodontic treatments. At this time, intraoral radiography is the imaging technique of choice for the management of endodontic disease, but CBCT imaging appears to provide a superior validityandreliabilityinthedetection of periapical lesions.The superior accuracy of CBCT imaging may result in the early detection of periapical lesions and may help to determine their exact locations and extents. 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 and better resolutions become available. However, endodontic cases should be judged individually, and CBCT imaging should be considered for situations in which information from conventional imaging systems may not yield adequate amounts of information to allow for the appropriate management of endodontic problems.

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