REVIEW ARTICLE

Cone-beam Computed Tomography and Endodontic Practice – A Review

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ABSTRACT

Cone-beam computed tomography (CBCT) is a contemporary, radiological imaging system designed specifically for use on the maxillofacial skeleton. The system overcomes many of the limitations of conventional radiography by producing undistorted, three-dimensional images of the area under examination. These properties make this form of imaging, particularly suitable for use in endodontics. The clinician can obtain an enhanced appreciation of the anatomy being assessed, leading to an improvement in the detection of endodontic disease and resulting in more effective treatment planning. In addition, CBCT operates with a significantly lower effective radiation dose when compared with conventional CT.

Keywords: Cone-beam computed tomography, Conventional radiography, Endodontic practice, Root canal morphology, Root fracture.

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INTRODUCTION

One of the earliest three-dimensional (3D) modalities to be introduced in medical imaging was the computed tomography (CT) system. However, the associated limitations of CT unit were a cost factor, lengthy scanning procedure, and high radiation dose to the patient. Each image slice of the CT machine required a separate scanning and reconstruction. These shortcomings were addressed by the introduction of a novel technique, the cone-beam CT (CBCT). The first version of CBCT machine was developed for angiography, in 1982, by Richard Robb at the Mayo Clinic. The technology was later refined over the next two decades and around 1988, CBCT unit was developed that could be used specifically for dentomaxillofacial imaging. In the early 1990s, manufacturers launched improved office-based CBCT scanners that offered the advantages of CT scanning with far fewer disadvantages. In this image modality, the X-ray beam is in the shape of a cone, which rotates around the patients head, capturing a spherical or cylindrical volume of data, called a field of view;[1] a composite image is composed of 3D pixels, called voxels. Voxels rendered from CBCT are isotropic, which means they are equal in length, height, and depth and can, therefore, be viewed from every possible angle with precise geometrical accuracy that has been confirmed in several studies.[2]

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ADVANTAGES OF CBCT IN ENDODONTICS

Perhaps, the most important advantage of CBCT in endodontics is that it demonstrates anatomic features in 3D that intraoral, panoramic, and cephalometric images cannot. CBCT units reconstruct the projection data to provide interrelational images in three orthogonal planes (axial, sagittal, and coronal). In addition, because reconstruction of CBCT data is performed natively using a personal computer, data can be reoriented in their true spatial relationships. Due to the isotropic nature of the constructed volume elements ("voxels") constituting the volumetric dataset, image data can be sectioned non-orthogonally. Most software provides for various non-axial two-dimensional images in multiplanar reformation (MPR).[3] Such MPR modes include oblique, curved planar reformation (providing "simulated" distortion free panoramic images), and serial transplanar reformation (providing cross-sections), which can be used to highlight specific anatomic regions for diverse diagnostic tasks. Enhancements including zoom magnification, window/level adjustments, and text or arrow annotation can be applied. Cursor-driven measurement algorithms provide the clinician with an interactive capability for real-time dimensional assessment. On-screen measurements are free from distortion and magnification.[4] Because acquisition occurs innately as high-resolution 3D volumetric data and can be displayed as interactive images, CBCT technology provides the clinician with an unparalleled visualization of the often complex relationships and boundaries between teeth and their associated pathology and anatomic features

within the alveolus and jaws such as the maxillary sinus and mandibular canal and foramen.

LIMITATIONS OF CBCT IN ENDODONTICS

Despite the provision of the third dimension, the spatial resolution of CBCT images (0.4 mm–0.076 mm or equivalent to 1.25–6.5 line pairs per mm^{-1} [$lp.mm^{-1}$]) is inferior to conventional film-based (approx. 20 $lp.mm^{-1}$) or digital (ranging from 8 to 20 $lp.mm^{-1}$) intraoral radiography. However, the ability of this technology to demonstrate geometrically accurate images in all 3D and the elimination of anatomic noise facilitates the assessment of a number of features important in endodontic diagnosis, treatment, and long-term management.[5] The CBCT projection geometry results in the whole volume within the FOV being irradiated with every basis image projection. Scattered radiation is produced omnidirectionally and is recorded by pixels on the CBCT detector but does not reflect actual attenuation of the object within a specific path of the X-ray beam. Additional recorded X-ray non-linear attenuation is noise. This can be eliminated somewhat by algorithms such as wavelet transformation of filtered back-projection data; however, due to the use of an area detector, some of this non-linear attenuation is recorded and contributes to image degradation when not adequately attended to by noise reduction algorithms. Remaining noise contributes to the graininess of the image which can be more pronounced in images in systems using a large FOV, especially where low signal due to restricted radiation exposure is the case.[6]

APPLICATIONS OF CBCT IN ENDODONTIC PRACTICE

CBCT overcomes the limitations of conventional radiography. Therefore, the potential benefits of this imaging system in endodontics, where the anatomy being assessed is complex, are vast. These advantages, combined with the reduced cost and size of CBCT hardware and scans when compared with conventional CT, have seen an increased uptake in this form of imaging in dental practices in recent years. With CBCT becoming an ever more accessible component of the endodontists armamentarium, it is important to be aware of the applications of this form of imaging method in managing endodontic problems.[7]

DETECTION OF APICAL PERIODONTITIS

CBCT is significantly more sensitive than conventional radiography in the detection of apical periodontitis in humans. Periapical bone destruction associated with endodontic infection can be identified using CBCT before evidence of the existence of these lesions presents itself on conventional radiographs.

ASSESSMENT OF ROOT CANAL MORPHOLOGY AND ITS VARIATIONS

Recognition of the variations in the root canal anatomy is important for the success of endodontic diagnosis and treatment. Periapical radiographs may reveal only up to 50% information about all the canals within the root, especially in the buccolingual plane. Such missed canals are responsible for reinfection and failure of the endodontic treatment. Most commonly missed canal causing reinfection and necessitating retreatment is the second mesiobuccal canal (MB2) present in maxillary first molars. The prevalence of MB2 canal can vary from 69 to 93%. CBCT can help in identifying MB2 canal with much more precision as compared to a conventional radiograph.[8] CBCT imaging can also be used to detect additional distolingual canals, "C"-shaped canal, and in the assessment of canal curvature. It has been shown that CBCT reports a higher incidence of distolingual canal (33%) as compared to conventional radiography (21%).[9]

ASSESSMENT OF INTRAOPERATIVE IATROGENIC ERRORS

Intraoperative assessment such as unexpected anatomic findings, location of calcified and missed canals in endodontic retreatment, curvature of roots before using rotary instrumentation, and iatrogenic errors such as fractured instruments, overextended obturation materials, and perforations can be effectively performed with limited FOV CBCT scans which greatly influences the outcome of endodontic treatment.[10]

ASSESSMENT OF POTENTIAL SURGICAL SITES

CBCT has been highlighted as an extremely useful tool in the planning of surgical endodontic treatment. The spatial relationship of the specific root(s) undergoing the surgical procedure (and the associated bony destruction) can be accurately related to adjacent anatomical structures such as the maxillary sinuses, the inferior dental nerve canal, and the mental foramen.[11] By arming themselves with this information, clinicians can assess the appropriateness of individual cases for treatment. Identifying and excluding unsuitable cases can reduce surgical morbidity. In cases deemed appropriate for treatment, accurate pre-operative measurements that are relevant to the surgical procedure (e.g., root length and angulation, thickness of the cortical plate, and root end to mental foramen distance) can be made and applied to the surgical site during treatment, thereby enhancing case management and reducing the potential for iatrogenic damage.[12]

ASSESSMENT AND MANAGEMENT OF DENTAL TRAUMA

The benefits of CBCT in the assessment and management of dentoalveolar trauma have been highlighted in literature. The exact nature and extent of the injuries to the teeth and the alveolar bone can be assessed accurately by eliminating anatomical noise and image compression, thereby allowing appropriate treatment to be confidently implemented. The degree and direction of displacement associated with luxation injuries can be evaluated easily using CBCT. Furthermore, CBCT has been shown to be far more sensitive than multiple periapical radiographs in the detection of horizontal root fractures.[12]

DIAGNOSIS OF VERTICAL ROOT FRACTURES (VRFs)

Ex vivo studies have demonstrated that CBCT is more sensitive than conventional radiography in the detection of vertical fractures in roots. However, care should be taken when assessing root-filled teeth for VRF using CBCT as scatter produced by the root filling or other high-density intraradicular material may incorrectly suggest the presence of a fracture.[13-15]

ASSESSMENT OF THE OUTCOME OF ENDODONTIC TREATMENT

The ability of CBCT to detect the bony destruction associated with apical periodontitis before the damage is evident on conventional radiographs is an encouraging discovery. The outcome of endodontic treatment can be expected to be better when it is executed before the development of conventional radiographic signs of the disease.[16]

CONCLUSION

CBCT is a highly promising technology that will in all likelihood be used increasingly in dentistry and in the field of endodontics, in particular, as the technology and quality of research in the area improves. Nevertheless, the effective radiation dose to patients when using CBCT is higher than in conventional intraoral radiography and any benefit to the patient of CBCT scans should outweigh any potential risks of the procedure, to be justified. The radiation should be as low as reasonably achievable. The decision to prescribe CBCT scans in the management of endodontic problems must be made on a case-by-case basis and only when sufficient diagnostic information is not attainable from other diagnostic tests, be they clinical or radiographic.

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