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CONE BEAM COMPUTED TOMOGRAPHY IN ENDODONTICS– A REVIEW.

Dental Science

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ABSTRACT

Imaging is an essential part of endodontic practice, from diagnosis and treatment planning to outcome assessment. For decades, intraoral radiographs are widely used in the field of endodontics to detect the presence, location and size of periapical lesions. Although this imaging modality provides valuable information it has its own limitations in the form of anatomic superimposition, compression of three-dimensional (3D) structures in a two-dimensional (2D) image, geometric distortion etc. This may lead to compromised diagnostic information and outcome of the treatment. The introduction of cone beam computed tomography (CBCT) in dentistry provided us with a diagnostic tool that overcomes most of these limitation of conventional radiographic techniques. CBCT has great potential to become a valuable tool for the diagnosis and management of endodontic problems, as well as for assessing root fractures, the presence of periapical lesions, resorption, perforations, particular root canal anatomies and the nature of the alveolar bone topography around the teeth. This review aims to provide comprehensive information related to the principles of Cone beam computed tomography and its potential applications in the management of various endodontic conditions.

KEYWORDS

Cone Beam Computed Tomography, Endodontics, Anatomic variation, Periapical lesions, Root resorption.

INTRODUCTION:

Radiographs are an important part of endodontic therapy, starting from diagnosis to treatment and follow-up. Conventional radiography is the fundamental tool of endodontic practice and needed for the success of any endodontic treatment. It comprises the basis of all the stages of endodontic treatment starting from diagnosis, intraoperative procedure assessment, treatment planning, and evaluation of treatment outcome.However, images acquired using conventional intraoral radiographic techniques reveal information in two dimensions only (height and width). Valuable and relevant information in the third dimension (depth) is limited.[1]

Cone Beam Computed Tomography (CBCT) is an extra-oral imaging system specifically designed for three dimensional imaging of the oral and maxillofacial structures. Most of the limitations associated with conventional radiography like compression of a three dimensional object into a two dimensional image, image distortion, anatomic superimposition, are overcome with cone beam computed tomography (CBCT).[1] The aim of this paper is to review in detail the literature available regarding the role of cone beam computed tomography in endodontics with respect to its indications and applications.

Cone Beam Computed Tomography:

The first prototype CBCT scanner was developed in 1982 for angiographic applications at Mayo. In 1997, the department of Radiology of the Nihon University School of Dentistry developed a dental radiology unit using a new technology known as limited cone-beam computed tomography. In the year 2000, the first CBCT to be approved by the FDA for dental use in the US was Newtom from Verona (Italy).[2]

Numerous systems are currently commercially available at this time, thus providing a wide range of choices for the purchaser of CBCT systems.[3]Table 1.

Table 1. Selected CBCT imaging systems

Unit	Model(s)	Manufacturer/distributor
Accuitomo	3D Accuitomo—XYZ Slice View Tomographa, FPDa, 3D Accuitomo 170, Veraviewepocs 3D R100, Veraviewepoc 3D F40	J. Morita MFG Corp., Kyoto, Japan
Acteon	X-Mind Trium	Acteon North America, Mt Laurel, New Jersey, USA
Asahi Roentgen	Auge Solio, Aliloth, Alphard 3030 (PSR 9000 N), Alphard 2520	Asahi Roentgen Ind. Co. Ltd. Kyoto, Japan
Belmont	Bel-Cat, Bel-Cat PA, Bel-Cat CM	Takara Belmont Corporation, Somerset, New Jersey, USA
Carestream	CS 81003D, CS 9000, CS 9300,CS9500a	Carestream Dental, Atlanta, Georgia, USA

CRANEX	3Dx, 3D, and 3D for Endo, Scanora 3D	SOREDEX, Tuusula, Finland
Galileos	Comforta, Compacta, ComfortPLUS, Orthophos XG 3D, Orthophos SL 3D	Sirona Dental Inc., Charlotte, North Carolina, USA
Gendex	GXCB-500a, GXCB-500HD, GXPD-800, GXPD-700 with 3D CBCT	Gendex Dental Systems, Hatfield, Pennsylvania, USA
Hitachi	CB MercuRaya/CB Thronea	Hitachi Medical Systems, Tokyo, Japan
i-CAT	Classica, Next Generation (Model 17–19, Platinum), i-CAT FLX, i-CAT FLX MV	Imaging Sciences International, Hatfield, Pennsylvania, USA
I-MAX	I-MAX Touch 3D	Owandy Corporation, Paris, France
KaVo	3D eXam, 3D eXam+	KaVo Dental Corp., Biberach, Germany
Newtom	3Ga, VGa, 5G, VGi, VGi Fex Giano	QR, Inc. Verona, Italy (a Cefla company)
OP 300	OP 300, OP 300 Maxio 3D	Instrumentarium Corporation, Milwaukee, Wisconsin USA
Biolase	DaVinci Imaging D3D	Biolase Irvine, California USA
Panoramic Corp.	Encompass Eagle 3D	Panoramic Corporation, Fort Wayne, Indiana USA
PreXion (Fine Cube)	PreXion3D Elite, PreXion 3D Eclipse	Yoshida Dental Mfg. Co. Ltd., Tokyo, Japan/ Distributed by TeraRecon Inc., San Mateo, California USA
Promax	3D, 3Ds, 3D Plus, 3D Mid, 3D Max	Planmeca OY, Helsinki, Finland
Ray	RayScan 3D Alpha	LED Dental, Atlanta, Georgia, USA
MyRay	SkyView 3D Panoramic imagera, Hyperion X5, Hyperion X9	My-Ray Dental Imaging, Imola, Italy
Suni	3D, 3D HD	Suni Medical Imaging, Inc. San Jose, California, USA
VaTech	Picasso Series (Trio/Pro/Master)a, PaX-i3D, PaX-Flex 3D, PaX-Uni 3D, PaX-Duo 3D, Pax-Zenith 3D, PaX-Reve 3D	Vatech, Giheung-gu, Korea

Principle of Cone Beam Computed Tomography:
The CBCT imaging employs the principle of tomo synthesis. In a single scan, the X-ray source and a reciprocating X-ray sensor rotate around the patient's head and acquires multiple scans of the region of the interest. The acquired scans subsequently undergo a primary reconstruction mathematically, which replicate the patient's anatomy into a single, 3D volume that comprises volume elements (VOXELS). Voxel dimensions are dependent on the pixel size on the area detector. In CBCT Voxel is as small as 0.1–0.4 mm for each of the cube face, and therefore, the image has moderately high resolution.[4]

Indication for CBCT[5]

- To investigate any jaw pathology such as cysts, tumors and fibro-osseous lesions;
- Investigation of the paranasal sinuses and bony components of the TMJ.
- Assessment of pre and post-implant surgery; Assessment of orthodontic cases including dental and skeletal base relationship and orthognathic surgeries;
- Assessment of wisdom teeth, in particular, their relationship to the inferior dental canal and the antrum of Highmore.
- Evaluation of facial trauma;
- Endodontics -hopeless teeth can be saved by discovering untreated root canals;
- In addition, sleep disorders can also be diagnosed. Earlier to CBCT, it could only be assessed with a full cranial hospital CT scan.

Limitation of CBCT[6]

- Low contrast range (dependent on the type of X-ray detector)
- Limited detector size causes limited field of view and limited scanned volume
- Limited inner soft tissue information
- Increased noise from scatter radiation and concomitant loss of contrast resolution
- Movement artefacts affecting the whole dataset
- Truncation artifacts (caused by the fact that projections acquired with region of interest selection do not contain the entire object)
- Can not be used for estimation of Hounsfield units (HU).

Applications of CBCT in Endodontic Practice:
Application in Preoperative Assessment (Root Canal Anatomy and Morphology) :The success of endodontic treatment depends on the identification of all root canals so that they can be accessed, cleaned, shaped, and obturated. The prevalence of a second mesiobuccal canal (MB2) in maxillary first molars has been reported to vary from 69% to 93% depending on the study method employed.[7]

Matherne et al.(2008) compared the ability of three board-certified endodontists to detect the number of root canals on intraoral digital (both charged-couple device and photostimulable phosphor) plate images with CBCT in 72 extracted teeth (3 equal groups of maxillary molars, mandibular premolars, and mandibular incisors). They found that on average the observers failed to detect at least one root canal in 40% of teeth using intraoral radiographs.[8] Figure 1

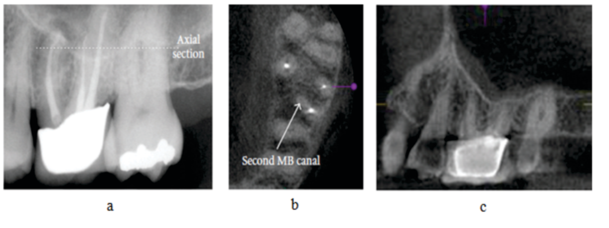

Fig.1.(a). Note the overlap of the interproximal contacts between the molars indicating a geometric distortion in the horizontal plane. CBCT imaging ((b) 0.076mm axial and (c) 0.076 Parasagittal clearly demonstrates an additional canal that was not previously treated.

Application in the assessment of Pulp chamber parameters: It has been shown that CBCT imaging can be used to measure pulp chamber parameters and volumetric changes.[9]By identifying CBCT coronal view landmarks (e.g. cusp tip, central fossa, pulp chamber roof, furcation, etc).

Root length and curvature:Information regarding root canal length and curvature is essential to facilitate root canal instrumentation to the appropriate length and to minimize treatment aberrations.

Estrela et al.(2008) presented a simple and reliable method for assessing the severity of the radius of curvature of root canals using CBCT, based on three mathematical points.[10]Park et al.(2013) employed sophisticated mathematical modelling software and CBCT scans to calculate points of maximum curvature, or points of maximum abruptness of curvature.[9]

Application CBCT in the evaluation of Dental Periapical Pathosis: The most common pathologic conditions that involve teeth are the inflammatory lesions of the pulp and periapical areas. Estrela et al.(2008)compared the accuracy of CBCT, panoramic and periapical radiographs from a consecutive sample of 888 imaging exams of patients with endodontic infection (1,508 teeth) in the detection of apical periodontitis (AP). While a gold standard was not available, they found the detected prevalence of AP to be significantly higher with CBCT.[10] Low et al.(2008) who compared the preoperative consensus assessment of the apical condition of 37 premolars and 37 molars in the maxilla (156 total roots) using periapical radiography and CBCT referred for possible apical surgery and found the later method to demonstrate significantly more lesions (34%) than conventional radiography.[11] Figure 2.

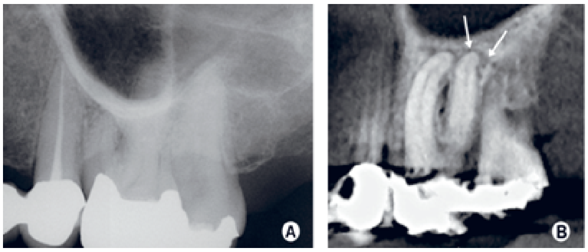

Figure 2. (a) Periapical radiograph of a symptomatic maxillary left first molar tooth. There is no evidence of a periapical radiolucency associated with the roots of this tooth. (b) Sagittal CBCT slice through the same tooth demonstrating the periapical bone destruction(white arrows) not evident on the periapical radiograph.

Application in Dental root fractures: Traumatic injuries to a tooth can vary in severity from a simple enamel infraction to a complete ex-articulation of tooth (avulsion).Among these injuries, tooth fracture (crown fractures, crown-root fractures and root fractures) are considered to be the third most common cause of tooth loss.[12]

A study conducted by Kamburoglu et al.(2009) who compared the diagnostic accuracy of 3 oral and maxillofacial radiologists in detecting simulated horizontal root fractures on conventional radiographic (analog film, PSP and CCD-based digital) images and CBCT of 36 teeth. They found that the sensitivity of CBCT (0.92) was significantly greater than analog film (0.74), PSP (0.71), and CCD (0.68) images.[13]

Hassan et al.(2009) compared the accuracy of 4 observers in detecting ex vivo vertical root fractures (VRFs) on CBCT and periapical images and assessed the influence of root canal filling on fracture visibility. They found an overall higher accuracy for CBCT (0.86) scans than periapical radiographs (0.66) for detecting VRF which was slightly reduced by the presence of opaque obturation material.[14]Figure.3

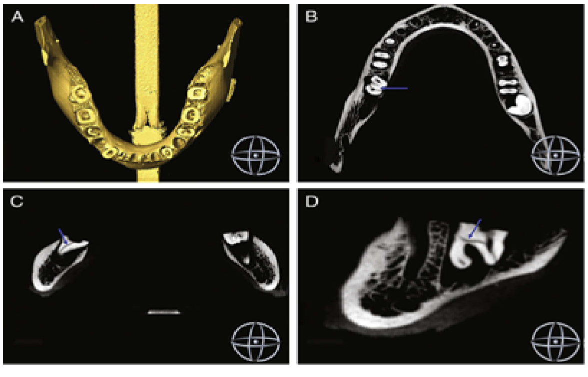

Fig 3. I-CAT CBCT reconstructions. (A) Three-dimensional surface reconstruction of the mandible. Fracture line is visible on 2D slices (arrow). (B) Axial, (C) coronal, and (D) sagittal.

Diagnosis, Assessment and Management of Root Resorption:Root resorption results in the loss of dentin, cementum, or bone by the action of clastic cells.[15] Root resorption may be classified into external or internal root resorption, based on the location of the lesion. External root resorption affects the outer surface of the root and internal resorption affects the walls of the root canal.

The clinical diagnosis of root resorption relies on the radiographic demonstration of the process. Clinical studies comparing the diagnostic accuracy of CBCT and conventional radiography in the detection of root resorption are limited. Kamburoğlu et al.(2011) assessed examiner ability to identify and differentiate between simulated external cervical resorption and simulated internal root resorption at the cervical region of the root canal, using CBCT and conventional, periapical radiography. Cone beam computed tomography performed statistically better than intraoral periapical radiography in the detection and localization of the simulated resorption cavities.[16] (Figure 4). Furthermore, some *ex vivo* studies have also demonstrated that, compared to periapical radiography, CBCT is a significantly more effective method of determining the exact site of simulated resorptive cavities on the external surfaces of roots.[17,18]

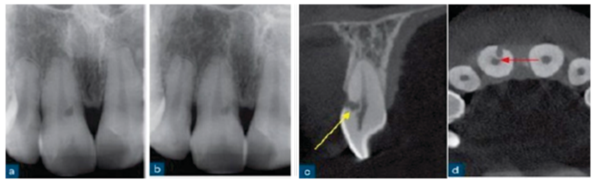

Figure 4. External cervical resorption(ECR). (a and b) Parallax radiographs of the maxillary left central incisor reveal a radiolucency in the coronal third of the root canal.(c) Reconstructed sagittal and (d) axial CBCT slices confirm the presence and true extent of the ECR lesion.

Application of Cone Beam Computed Tomography in non-surgical and surgical re-treatment:
Non-Surgical Endodontic Re-treatment: The management of failed root canal treatment is dependent on the mode of failure, which may be multi-factorial. Treatment options commonly include non-surgical endodontic re-treatment, surgical re treatment, extraction, and no treatment. An effective treatment plan can only be devised when firstly, the diagnosis, and secondly the reason behind treatment failure have been determined.

Two-dimensional methods reproduce the three-dimensional anatomy as a 2D image. Crucially, essential information of the three-dimensional anatomy of the tooth/teeth and adjacent structures is obscured and which may lead to compromised diagnostic information and outcome of the treatment.

Limited FOV CBCT is useful in identifying untreated canals and root perforations, assessing complex anatomy such as fins or fused roots, evaluating instrumentation and obturation quality, and visualizing bone loss patterns that are consistent with apical periodontitis, marginal periodontitis, furcation involvement, or root fractures.[19]

Surgical Endodontic Re-treatment: Surgical endodontic re-treatment is indicated when persistent periapical periodontitis does not heal after root canal treatment and non-surgical endodontic re-treatment is either not possible due to the presence of irretrievable or impassable fractured instruments, ledges or blockages, or has already been attempted but failed as a result of an extra-radicular infection.

CBCT has been recommended for the planning of surgical endodontic re-treatment. CBCT allows the anatomical relationship of the root apices to important neighboring anatomical structures, such as the inferior dental canal, mental foramen, and maxillary sinus, to be clearly identified in any plane the clinician wishes to view.

Low et al (2008) compared the findings of periapical radiographs with those of CBCT in root-treated maxillary posterior teeth, that were being assessed for periapical surgery. In this study, 34% of periapical lesions detected by CBCT were not detected with periapical radiographs.[20] Furthermore, Kurt et al (2014) performed surgical endodontic re-treatment on 40 maxillary first molars. Two groups of patients were included; one had a preoperative CBCT scan and the other was evaluated only with periapical radiographs. The CBCT group had fewer sinus perforations during surgery and the procedure was more efficient to carry out.[21]

Application of CBCT in Postoperative Assessment:
Monitoring the healing of apical lesions is an important aspect of postoperative assessment in endodontic. There is limited data in the literature pertaining to the outcome of endodontic treatment using CBCT as the assessment tool, but that which exists suggests that the outcome of treatment may not be as favorable as it appears when conventional radiographs are used to assess outcome.

In a clinical study comparing the outcome of endodontic treatment in humans, Liang et al. reported the success rates to be 87% when the cases were assessed using periapical radiographs and 74% when CBCT was used.[22]

Paula-Silva et al. compared CBCT and conventional periapical radiographs to assess the outcome of endodontic treatment in dogs. Six months after treatment, the success rate was deemed to be 79% when the teeth were assessed with conventional radiographs, while the success rate was 35% when CBCT was used to assess outcome.[23]

CONCLUSION:

This review paper highlights the potential uses of CBCT in the assessment and management of endodontic problems. Radiographs are an important part of endodontictherapy, especially for diagnosis, treatment, and follow-up. Conventional radiology is the fundamental tool of endodontic practice and needed for the successful management of any endodontic treatment. However, images acquired using conventional intraoral radiographic techniques reveal information in two dimensions only. Valuable and relevant information in the third dimension is limited. Cone beam computed tomography is a three-dimensional imaging technique that overcomes many of the limitations of conventional radiography and is a beneficial adjunct to the endodontist's armamentarium. 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. 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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Conflicts of Interest

There are no conflicts of interest.

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