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Cone Beam Computed Tomography The 3D Imaging Modality In Endodontics: A Review

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Abstract: *Imaging plays an important role in diagnosis and treatment planning in Endodontics. Two-dimensional (2D) projection radiography has been in use for more than half a century for diagnosis in the maxillofacial region. In the last decades, the introduction of three dimensional imaging characterized by Cone beam Computed Tomography has created a revolution in maxillofacial imaging - facilitating the transition of dental imaging from 2D to 3D. Cone-beam computed tomography (CBCT) has gained considerable acclaim worldwide in recent years as a viable 3D imaging modality. It produces images with smaller field of view,low radiation exposure, improved spatial resolution and user friendly software programs which has tremendous impact on endodontics from diagnosis to treatment and follow up. This article reviews CBCT and its role in endodontics.*

Keywords: *3D, Cone beam computed tomography, Diagnosis, Endodontics, Imaging*

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I. Introduction

Cone Beam Computed Tomography (CBCT) is a diagnostic imaging modality that provides high-quality, accurate three-dimensional (3D) representations of the osseous elements of the maxillofacial skeleton[1]. A technique that enables three-dimensional reconstruction, but using a cone beam to decrease the dose to the patient when compared conventional computerized tomography[2]. CBCT systems are available that provide small field of view images at low dose with sufficient spatial resolution for applications in endodontic diagnosis, treatment guidance, and post treatment evaluation. Endodontics is an image-guided treatment and, until recently, has been restricted to in-office periapical (PA) and panoramic radiographic assessments. The introduction of maxillofacial CBCT in 1996 provided the first clinically practical technology demonstrating application of 3D imaging for endodontic considerations[3] . Improved spatial resolutions and more user-friendly software programs have opened the door for more clinicians than ever before to use this technology. This article describes CBCT and its importance as a diagnostic tool in clinical endodontic practice.

II. Role of imaging in endodontics

Throughout the decades, imaging services have served a fundamental role in all stages of the endodontic treatment process. Endodontic treatments today rely on effective imaging techniques to assess tooth anatomy as well as surrounding structures and tissues during treatment planning[4].

Preoperative

- To analyze dental and alveolar hard tissue morphology
- Pathological alterations
- Morphology of tooth, including location and number of root canals, pulp chamber size, calcifications, root structure ,directions and curvatures
- Iatrogenic defects
- Crown and root fractures

Intraoperative

- To determine proper working length of root canal system
- Tooth and bone changes

Post operative

- To evaluate the root canal obturation and seal
- Tooth and periapical hard tissue changes after treatment
- Planning for surgical considerations[5].

III. Comparision Of 2d And 3d Imaging

CBCT uses a cone-shaped beam and digital processing to reconstruct a virtually distortion-free 3D image of the patient's craniofacial hard tissue anatomy in a single pass [5]. Intraoral radiography is based on the transmission, attenuation, and recording of X-rays on an analog film or digital receptor, and requires optimized geometric configuration of the X-ray generator, tooth, and sensor to provide an accurate projection of the tooth. The image produced is a two-dimensional (2D) representation of a three-dimensional (3D) object.3D characteristics such as complex dental anatomy and surrounding structures can make interpretation of 2D "shadows" difficult and can contribute to non healing of endodontic cases [6]. 3D CBCT imaging offers a tremendous advantage compared to earlier 2D scans. Unlike regular X-rays, CBCT scans are able to differentiate between many types of structures and airspaces including bone, teeth, airway, paranasal sinuses, and sometimes soft tissue while avoiding diagnostic limitations inherent in 2D images, including superimposition of structures, non uniform magnification and distortion and no depth information. Other advantages of CBCT scanning over 2D technology include the ability to visualize the patient as he or she truly exists and the ability to view the anatomy from a variety of slice thicknesses and viewing angles, including curved and planar reformations[1,5].

IV. Cone Beam Computed Tomography

In fields of dentistry where 3D imaging is necessary, CBCT is considered by some to be the standard of care [1]. CBCT is accomplished by using a rotating gantry to which an X-ray source and detector are fixed. A divergent pyramidal- or cone-shaped source of ionizing radiation is directed through the middle of the area of interest onto an area X-ray detector on the opposite side of the patient [7]. The X-ray source and detector rotate around a fixed fulcrum within the region of interest (ROI). While rotating, the x-ray source emits radiation in a continuous or pulsed mode allowing projection radiographs or "basis images". These are similar to lateral cephalometric radiographic images, each slightly offset from one another. This series of basis projection images is referred to as the projection data. Software programs incorporating sophisticated algorithms including back-filtered projection are applied to these image data to generate a 3D volumetric data set, which can be used to provide primary reconstruction images in 3 orthogonal planes (axial, sagittal and coronal)[8]. CBCT is a complementary modality for specific applications rather than a replacement for 2D imaging modalities[1]. CBCT causes fundamental changes in diagnosis and management of endodontic problems. The clinician can easily apply a simple software to evaluate the areas of interest in any plane[9].

V. Types of CBCT equipment

Cone beam computed tomography systems are most commonly classified according to the dimensions of their Field of view(FOV) or scan volume. The following categorization has been proposed **[10].**

Small volume (also referred to as focused, small field, limited field or limited volume) systems have a maximum scan volume height of 5 cm. Single arch CBCT scans have a FOV height of 5-7 cm within one arch; inter-arch CBCT scans have a FOV with a height of 7-10 cm; maxillofacial CBCT scans have a FOV height ranging from 10-15 cm; and craniofacial CBCT have a FOV height in excess of 15 cm. For most endodontic applications, limited or focused FOV CBCT is preferred.

Less popular methods of classifying CBCT systems are based on the patient position during the scan (supine, sitting or standing) and the functionality of the systems; some systems are multimodal and have a digital panoramic tomograph (DPT) function[11].

VI. Radiation dosage

Effective dose of CBCT is almost similar to that of panoramic radiographs and equivalent to a few periapical radiograph[12] .One of the advantages of CBCT over computed tomography is the lower effective radiation dose[13].The dose depends on the region of the jaw to be scanned, size of Field of view(FOV), exposure time, the energy/potential(kV) and the tube current. Radiation dose can be reduced using smaller FOV, fewer projections(180 degree)and a bigger voxel size[14,15]. For endodontic applications ,the FOV should be limited to the region of interest, the FOV should encompass the tooth under investigation and the surrounding structures. This is the way to reduce radiation dose[16].

VII. Limitations of CBCT

CBCT has the problem of scattering and beam hardening artifacts caused by high density structure [17] which diminishes the contrast and limits the imaging of soft tissues. Therefore, CBCT is primarily indicated for imaging hard tissues. CBCT has lengthy scan times (15-20 sec) and they need the person to stay completely firmed [18].

Clinical Applications In Endodontics

2.1 Detection of Apical Periodontitis

Apical Periodontitis can be detected at an early stage using CBCT when compared to conventional radiographs. It appears that conventional radiography results in an under-estimation of the incidence of apical periodontitis [19, 20]. Two studies have been undertaken to investigate whether CBCT-detected lesions are true lesions. de Paula-Silva et al.[21]examined the periapical area of 83 treated or untreated roots in dogs' teeth. Each root in which a periapical lesion was present on the CBCT images but absent on the Periapical radiographs was histologically determined to have periapical inflammation [21]. These findings confirm that CBCT scans are more sensitive in detecting apical periodontitis than Periapical radiographs[13]. In addition, CBCT can demonstrate bone defects of the cancellous bone and cortical bone separately. As a result, the identification of apical periodontitis was substantially higher with CBCT than with periapical radiography [22].

2.2 Evaluation of Root Canal Anatomy And Complex Morphology

The success of endodontic treatment depends on identification,cleaning, shaping and obturation of all accessible areas of root canal system [23,24]. Knowledge of root canal anatomy and variations is essential for clinicians to facilitate effective root canal treatment [12].As a result, failure to distinguish and treat all canals can affect treatment outcome [25]. The prevalence of a second mesiobuccal canal (MB2)in maxillary first molars has been reported to be 69% to 93% depending on the study method. Most often radiographs may not show the presence of all canals within the root, especially in the buccolingual plane[12]. Increased number of MB2 canal can be identified with CBCT when compared to conventional radiographs [9]. In a study that evaluated 608 permanent mandibular second molars using CBCT a higher prevalence of "C" shaped canals was noticed [26,27]. CBCT is an effective tool for the detection of additional distolingual roots and C-shaped canals [28]. In addition CBCT is a reliable tool to assess the degree of curvatures associated with the roots of teeth [9].

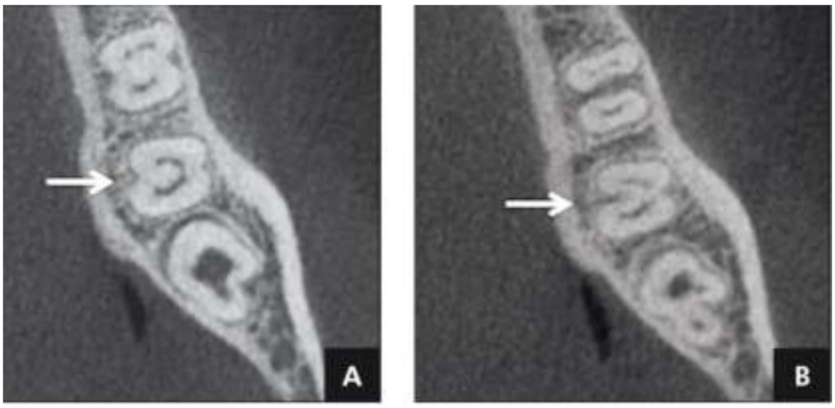

Fig 1: Images A and B showing the presence of C-shaped canal

2.3 Assessment of the Outcome of Root Canal Treatment

The most important area in which CBCT can be applied in endodontics is in determining the outcome of treatment. Earlier identification of periapical radiolucent changes using CBCT may result in earlier diagnosis and more effective management of periapical disease[13].de Paula-Silva et al.[29]evaluated periapical repair after root canal treatment in dogs' teeth using CBCT and Periapical radiographs Six months after treatment, a favourable outcome was detected in 79% of teeth assessed with periapical radiographs in comparison to 35% when CBCT was used[29]. Fernández et al.[30] evaluated the outcome of endodontic treatments as assessed by conventional and digital Periapical radiographs and CBCT during a 5-year follow-up period. It was found that CBCT as more sensitive than PRs for the visualization of periapical lesions in a long-term evaluation[30]. In addition, it was found that the root canal curvature, failure to disinfect gutta-percha, the presence of missed canals and inadequate definitive coronal restoration at follow-up were prognostic factors that negatively influenced the outcome of treatment[13].

2.4 Assessment in Endodontic Surgical Planning

CBCT plays an extremely useful role in planning of surgical endodontic treatment [31, 32]. The spatial relationship of the specific root 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, and nasal cavity can be assessed[33,34]. The true size, location and extent of the periapical lesion can also be appreciated [12]. The cancellous bone pattern, fenestrations, as well as the inclination of the roots of teeth planned for surgery can be accurately determined preoperatively [35].

2.5 Assessment of Dentoalveolar Trauma

Traumatic dental injuries present a challenge to clinicians worldwide. Correct diagnosis, treatment planning and follow-up of the injury are essential and must be achieved through detailed history taking and clinical and radiographic assessment[36]. Horizontal root fractures, resorptive defects (internal, external and invasive cervical) and alveolar fractures are readily observed and differentiated on CBCT images, whereas their diagnoses on periapical radiographs are often quite difficult[3].

Fig2: A) Periapical radiograph of a maxillary left central incisor tooth restored with an ill-fitting crown retained by a cast post and core. There is no evidence of a root fracture on the radiograph. (B) Sagittal CBCT slice showing a horizontal root fracture[35].

2.6 Assessment of Resorption, Perforation And Vertical Root Fracture

After dental luxation and avulsion injuries, root resorption is a common complication [37]. Root resorption is defined as the loss of dental hard tissues as a result of osteoclastic activities. It can be a physiological or a pathological phenomenon[13].The sensitivity of conventional radiography is significantly poorer than CBCT in the detection of external root resorption in its early stages [3] and significant hard tissue damage may have potentially occurred to the affected tooth before the resorption becomes evident on conventional radiographs[9]. CBCT has been shown to help and determine the treatment complexity as well as aid the clinician in offering an accurate prognosis on the basis of the extent of the resorptive lesion. As a result, both treatment and treatment outcomes are likely to become more predictable[12] .

Root canal perforation is a procedural error that results in communication between the root canal walls and the periodontal space; it is capable of affecting the prognosis of endodontic retreatment [38]. Timely detection of perforations will aid in selecting the proper therapy, thus minimizing bone loss, and in predicting the outcome and analysing failures[39].Radiographic detection is challenging on the labial and lingual root surface, because the image of the perforation is superimposed on that of the root. When adequate information cannot be obtained through clinical examination and using traditional 2D techniques, CBCT imaging may help to identify fractured files, cast post deviations and perforations.[40].

Identifying the presence of vertical root fractures (VRF) is often a challenge in endodontics[35].Twenty cases with suspected vertical root fractures were subjected to radiographic imaging. They found that CBCT was significantly better than conventional radiographs in the diagnosis of vertical root fractures. However, fine vertical cracks appear to not be revealed on CBCT images at current CBCT resolutions. However, the resultant vertical bone loss in one or more of the CBCT slices may be observed[3].

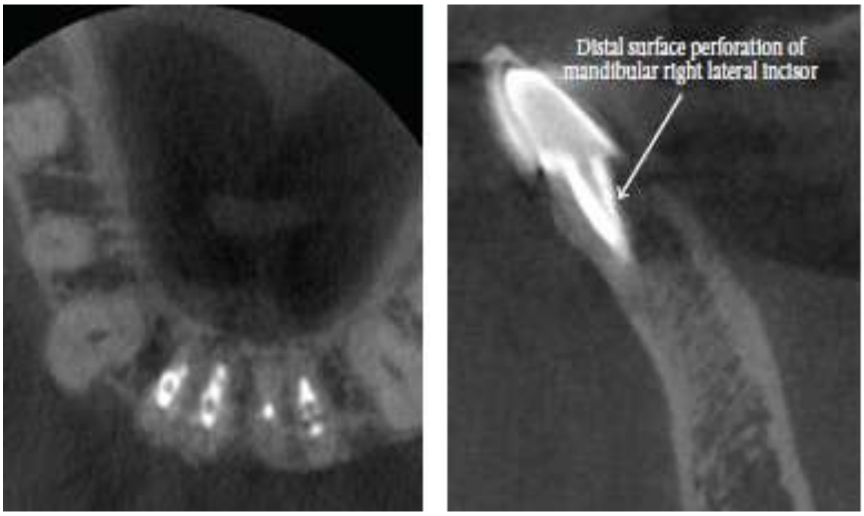

Fig 3: CBCT images ((a) axial, (b) sittal) demonstrate a mid-root post perforation[1].

2.7 Dental anomalies

Dental anomalies include dens invaginatus, short roots, microdontia taurodontism, gemination, supernumerary teeth dentinogenesis imperfecta, agenesis, and malformations resulting from trauma. The radiographic features of these anomalies have been studied extensively and are well represented in the literature, showing that deviations from normal anatomy can cause difficulties in diagnosis and treatment. In order to enhance the chances of success rate anatomic variations should be carefully observed and considered during the diagnosis and treatment planning of teeth with anomalies [12]. CBCT provides detailed information that can allow visualization of the root morphology, resulting in better treatment planning and postoperative assessments[41].

III. Conclusion

CBCT the three dimensional imaging technique overcomes the limitations of conventional radiographs and panoramic radiographs.It is a useful diagnostic imaging modality and beneficial adjunct to endodontists armamentarium.A cautious and rational approach should be considered when using this imaging technology in Endodontics.

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