ISSN: 03875547
Volume 45, Issue 03, May, 2022

Cone beam computed tomography in Endodontic – a review of the literature

Salma Issa Daheem[1*], Hussein Al_Hwazi[1]

Literature Review Submitted to the Restorative & Esthetic Dentistry Department, College of Dentistry, University of Baghdad[1]

Corresponding Author: 1*

Keywords:
cone beam computed tomography, endodontic diagnosis, management of endodontic problems, radiography.

ABSTRACT

The objective of this paper is to (i) Review current literature on the endodontic applications of CBCT; (ii) Based on current evidence make recommendations for the use of CBCT in Endodontics; (iii) Highlight the areas in which more research is required. 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. This article provides a literature review and pictorial demonstration of CBCT as an imaging adjunct for endodontics. This can be ascribed to high radiation exposure, cost factor. Since it limits the radiation exposure and rapidly provides 3D reconstructed images which have been proven to be accurate in all aspects. This paper reviews the importance of three dimensional CBCT technology over conventional two dimensional imaging system along with its potential drawbacks. A systematic literature search was performed by using electronic databases, using PubMed database racecourse followed by extensive hand researched finally included All the articles eligible to be included in the review were in the English language and ranged from the year 2000 to the present. Also all the studies reviewed were based on the various uses of cone beam computed tomography in the field of endodontics. Studies demonstrate the advantages of CBCT over conventional imaging for almost all endodontic applications, with the exception of assessing the quality of root canal fillings. It is clear that the usefulness of the CBCT cannot be disputed. Of course, availability, dose and costs must be considered when prescribing CBCT imaging for the patient.

1. INTRODUCTION

Successful management of endodontic problems depends on diagnostic imaging techniques to provide the critical information about the teeth under examination, and their surrounding anatomy. Therefore, radiographic examination is a crucial component in management of endodontic problems. It comprises a basis for all aspects of endodontic treatment from diagnosis and treatment planning to outcome assessment], and adjacent anatomical structures. They are used for preoperative, intraoperative and postoperative assessment and follow-up. X-ray imaging serves at all stages of endodontics from diagnosis of odontogenic and nonodontogenic pathoses to treatment of the root canal system in a compromised tooth, biomechanical instrumentation, obturation, and healing assessment which provide useful information for the presence and location of periradicular lesions, root canal anatomy and the proximity of Cone beam computed tomography is a modification of the computed tomography (CT) concept, involving the single rotation of an X-ray source around the dental subject [1].

Types of CBCT Equipment.

CBCT systems can be categorized according to the orientation of the patient during image acquisition, the scan volume irradiated, or the clinical functionality. Patient Positioning. Depending on the system employed, maxillofacial CBCT can be performed with the patient in three possible positions: (1) sitting, (2) standing, and (3) supine. Equipment that requires the patient to be supine has a larger physical footprint and may not be readily accessible for patients with physical disabilities. Standing units may not be able to be adjusted to a height to accommodate wheelchair bound patients. Seated units are the most comfortable; how- ever fixed seats may not allow ready scanning of physically disabled or wheelchair bound patients. As scan times are often similar to or greater than those used with panoramic imaging, perhaps more important than patient orientation is the head restraint mechanism used. Scan Volume, the dimensions of the FOV, or scan volume, are primarily dependent on the detector size and shape, beam projection geometry, and the ability to collimate the beam. The shape of the FOV can be either a cylinder or spherical. Collimation of the primary X-ray beam limits x-radiation exposure to the region of interest (ROI). Field size limitation therefore ensures that an optimal FOV can be selected for each patient based on disease presentation and the region designated to be imaged. Based on available or selected scan [2].

Classification of cone beam computed tomography

According to field of view or scan volume, the classification of cone beam computed tomography is as follows:

1. Small volume/limited field or limited volume. This has a volume height of 5 mm.

Single arch. This has a field of view of 5–7 cm. [3]

2-Inter-arch has a field of view of 7–10 cm.

3-Maxillofacial CBCT has a field of view of 10–15 cm.

4-Cranio-facial CBCT has a field of view height of 15 cm.

Effective dose of cone beam computed tomography Radiation dose of CBCT is dependent on the following exposure parameters:

1. Nature of the X-ray beam (pulsatile or continuous).
2. Amount of rotation of the X-ray source and detector.
3. The type and amount of beam filtration.
4. kV, mA and voxel size.

Voxel size or the element by volume is generally a three-dimensional representation. Field of view com- praises of a number of voxels. In the CBCT equipment, the size of the voxel varies from 0.1 to 0.4 mm [4].

Resolution

There are two types of image resolution - spatial resolution and contrast resolution. Spatial resolution is the ability to show fine details, such as demonstrating the periodontal ligament space or a narrow root canal. Most of the CBCT devices allow choice of this setting. Depending on the type of CBCT unit, lower resolution may be chosen resulting in reduced patient radiation dose. [5] are displayed in gray levels. Higher image resolution is obtained by higher radiation dosage which is definitely harmful to the patient. Hence, it is important to reduce the exposure parameters to avoid unnecessary exposure of the patient and the clinician to the harmful radiation. Hence, the clinicians who are operating the CBCT must have a thorough understanding of the operational settings and their effects on the quality of the image and radiation safety [6].

Radiation Dose Considerations

For a meaningful comparison of radiation risk, radiation exposures are converted to effective dose (E), measured in Sieverts (Sv). The Sv is a large unit;

There are a number of factors that will affect the radiation dose produced by a CBCT system: pulsed beam versus continuous beam; amount, type, and shape of the beam filtration; the number of basis images dependent partly on use of 360° or lesser rotations; and limitations on the size of the field of view. Factors such as beam quality and filtration are unique to a specific machine, while other factors, such as FOV, can sometimes be operator controlled. Typically, the smaller the field of view for a given system, the lower the radiation dose applied, [7]

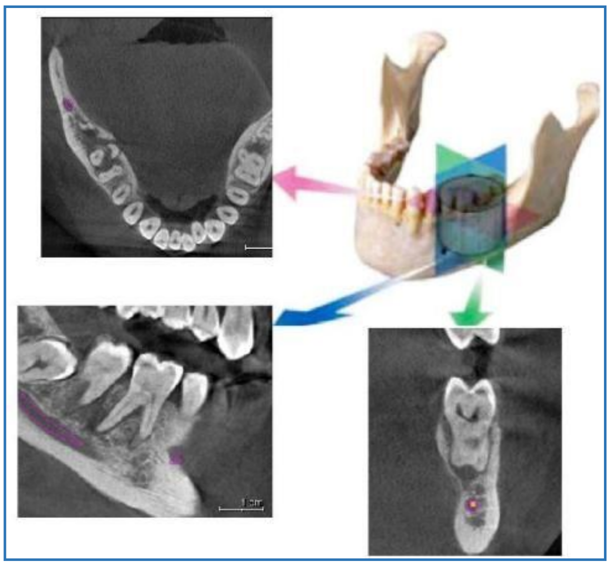

Figure 1 Standard Display modes of CBCT Volumetric data in the Axial, Sagittal and Coronal Plan

Limitations of CBCT

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. If any component of the imaging chain process is compromised, the resulting image may demonstrate expo sure or geometric errors and be suboptimal. 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 [8].

The presence of metallic restorations (e.g. amalgam restorations, metal posts and/or crowns, and implants) or even gutta-percha can cause significant radio- graphic artefact, sufficient to compromise details of root canal anatomy and relevant pathosis such as root resorption and root fractures. Metal artefact reduction algorithms (MAR) are becoming more common in operating and viewing software in order to overcome this disadvantage [9]. Beam hardening and photon starvation artefact are found, and analysis the adjacent ‘normal’ image to deduce what grey shades should be found in the boundary zones immediately adjacent to the artefact. These grey shades are then applied in the affected areas of the image where information is deficient, essentially smoothing the image and approximating the true detail. This is, how- ever, open to error, and resultant images may reduce accurate fine detail [10].

The main advantages of CBCT

1. reduced patient exposure to ionizing radiation and a superior image quality with regard to dental hard tissues and bone assessment]., the patient is often exposed to radiation for only a small portion of the overall scan time.
2. The X-ray source can be collimated so that the radiation is limited to the area of interest. This produces a specific volume of data (FOV) appropriate and relevant to the patient's needs. The smaller the FOV, the less radiation exposure to the patient [11]. As mentioned
3. The degree of rotation of the X-ray source around the patients head can also be altered. The higher degrees of rotation produce higher number of images.
4. The scan times attainable with CBCT are short and comparable with panoramic radiography. This is helpful in that the likelihood of patient movement during the scan is less. Furthermore, as previously stated, the CBCT hardware is much smaller and less expensive than CT machines. So, CBCT is well suited for application in dental practice perhaps the most important advantage of CBCT in endodontic is three dimensional demonstrations of the anatomic features. CBCT units reconstruct the projection data to produce images in three dimensions [12].
5. obturation, and its problems as under or overfilling
6. -broken instrument.
7. useful in planning per apical endodontic surgery and determine the location of sinus which can be easily differentiated and mental foramen and inferior dental nerve
8. -image accuracy.
9. Economical, comfortable and safe.

Disadvantage;

1. scatter
2. motion artifact due to increased scan time,
3. poor contrast resolution, thus soft tissue cannot be reviewed

Application Of CBCT On Endodontic

1-Preoperative Assessment, (Tooth Morphology)

1-. The success of endodontic treament depends on the identification of all root canals so that they can be accessed, cleaned, shaped, and obturated [13]. 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. This variability occurs in the buccolingual plane where superimposition of anatomic structures impedes detection of small structural density changes. Conventional radiographic techniques, at best, can only detect up to 55% of these configuration [14]. CBCT was found to be a very reliable and non-invasive method to view root canal anatomy in all the spatial planes (Axial, coronal and sagittal) and eliminates the risk of image distortion and anatomic noise. [15], CBCT was found to correctly identify all the root canals in almost 99.71% of the cases. It could correctly identify the presence of second MB2 canal in all cases in maxillary molars which were commonly missed out by periapical radiographs. It was found by various studies that the CBCT detection rates increased from 60% to 93.3% with increasing resolution suggesting that if CBCT has to be used,

The success of endodontic treatment depends on identification, cleaning, shaping and obturation of all accessible areas of root canal system. As a result, failure to distinguish and treat all canals can negatively affect treatment outcome.

To accurately assess the degree of curvatures associated with the roots of teeth, CBCT is a reliable tool, and the preoperative availability of this information reduces the chances of occurring the aberrations outlined above. Furthermore, when endodontic treatment for teeth with anatomical and morphological anomalies such as dens invaginatus and tooth fusion, is required, CBCT has been shown to be a useful assessment and treatment planning [16].

Root fracture

RF are difficult to diagnose accurately using conventional radiography while they are less common than fractures of the crown and account for only 7% of dental injuries [17]. Detecting the presence of vertical root fractures (VRF) is an often dilemma in endodontic. Clinical and radiographic sign of the presence of root fracture does not always present itself until the fracture has been occurred for some time. While a deep, isolated, thin periodontal pocket is suggestive of VRF, however, even clinical signs of longstanding VRF maybe little more than a draining buccal sinus, other type of fracture are horizontal root fractures (HRF), generally have an oblique orientation when they occur in the apical and middle thirds of the root and can only be identified with periapical radiogragh, when the X-ray beam passes within 15–20° of the orientation of the fracture line. As such, these injuries may be missed with PR, but they are reliably identified with CBCT. By altering CBCT exposure parameters, the radiation dose may be reduced by up to 80% with little impact on the diagnostic yield in the detection of HRF [18].

Crown fractures

[19] Cone beam computed tomography may provide a more objective assessment of the thickness of the dentine overlying the pulp.

Crown root fractures

[20], [21]., Cone beam computed tomography permits a more accurate visualization of the course of the often oblique nature of these fractures and the relationship of the fracture to the pulp, periodontium and crystal bone, thus facilitating manage

Diagnosis of Root Resorption and Perforations

Conventional periapical radiographs provide limited clinical information with respect to the three dimensional defect such as root resorption. It is unable to reveal the exact location and nature of the resorptive defect or thickening of remaining root canal dentine particularly in the bucco-lingual direction. There is further image distortion and superimposition of various anatomic structures resulting in limited diagnostic information. 3D CBCT reconstructed images are useful in the diagnosis of the size of the defect as well as its proximity to the root canals [22]. The CBCT voxels being isotropic ensures that the images produced are completely accurate geometrically and free from distortion, thus accurately differentiating between external and internal type of root resorption. Additionally, they are also useful in identifying the portal of entry of the periapical lesions to differentiate invasive cervical resorption from internal root resorption. CBCT imaging also allows for better visualisation of the perforation site in various sections and angulations without any geometric distortion of images [23].

Assessment of periapical periodontitis

Periapical radiography (PR) is the accepted reference standard for the radiological detection of AP. However, anatomical noise may hide early stages of AP-related. This can lead to difficulty in the diagnosis of early signs of endodontic disease, especially in cases where clinical signs and symptoms indicate pulp necrosis or irreversible pulpitis [24].

Figure 2. A) Cross-sectional CBCT view showing the extrusion of sealer after root canal therapy (RCT) of the left maxillary first molar. This image also represents the anatomical relation of roots and maxillary sinus; B) Note the extrusion of the sealer through the periapical lesion into the maxillary sinus. C) Anatomical relation of roots and buccal/palatal cortical plates D) Three-dimensional reconstruction

Localization of canals

Pre-operative knowledge of the tooth anatomy can preempt endodontic complexities and improve treatment outcome. Anatomic challenges may hinder endodontic success. Maxillary first molar usually has three roots and four canals. An in vivo study was done where maxillary first and second molars were sectioned and the number of canals was determined only to find that there was 80% correlation between CBCT and other type [25]. The presence of a fourth canal in 67.14% of the teeth. He concluded that the reliability of CBCT imaging to detect the additional canals in the maxillary molar increased with magnification

Calcified canals

According to [26] intra-operative CBCT can be useful for the assessment of the depth of the calcification to guide the clinician for locating and assessing the patent part of the canals. In addition, when a complete calcification is detected, CBCT can be used to study the apical pathos is to avoid perforation of a completely calcified canal. It can be used in cases with complex tooth anatomy within the realms of dose considerations.

CBCT and canal curvature

[27], [28] assessed the curvature of the root canals with the aid of CBCT. CBCT is a reliable method to assess the radius of curvature which can reduce the aberrations and chances of instrument fracture.

Complex root anatomy

A malformation caused due to the unfolding of the enamel organ into the dental papilla during the stages of tooth development. According to [29], CBCT can be useful in assessment of teeth with complex tooth anatomy. Studies by some authors, justifies the use of cone beam computed tomography for teeth with complex aberrations in cases where periapical radiography does not reveal the information required for the management and treatment of such teeth.

The Role of CBCT and MTA obturation

To evaluate the role of CBCT and MTA obturation in management of a permanent anterior tooth with open apex and periapical lesion. After CBCT evaluation of maxillary left central incisor with openapex and periapical lesion, it was endodontically treated with MTA obturation. The patient was recalled regularly for 6 months. CBCT was found to be a useful tool for the diagnosis and post-operative evaluation of this case. The MTA used for obturation in two visit endodontic treatment resulted in successful outcome, both clinically and radiographically due to the high osteogentic potential of MTA, it leads to a more predictable closure of the open root apex and periapical healing due to the induction of a cemented-like hard tissue [30].

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2. Discussion

There are many studies that are related to CBCT and mostly they have a diagnostic or descriptive aspect. These studies target understanding the application of CBCT, regarding its accuracy and diagnostic properties e.g. radiation exposure, quality, dose etc. Little evidence shown regarding the activity of CBCT in treatment. The CBCT devices usually have different designs and results differ for system to system. Lots of studies had different results in relation to the system compared.

Cone beam computed tomography examination improves the identification, location and appreciation of teeth with anomalous anatomy, for example dens invaginatus. More recently, CBCT has been used in conjunction with specialized software (3DEndo®, Dentsply Sirona, Bal- laigues, Switzerland) to evaluate the complexity of root canals prior to treatment [33].

[4]. was found the CBCT, to be more desirable for the evaluation of root canal anatomy, working lengths and also reducing the clinician's stress levels than PR. A recent three-dimensional classification of various dental anomalies based on CBCT investigations has been devised. [33].

[34] Determined the impact of CBCT imaging on decision-making amongst general dental practitioners and endodontists after failed root canal treatment. The examiners altered their treatment plan after viewing the CBCT in 49.8% of the cases. After viewing the CBCT scans, examiners' selection of the option to extract teeth from 11.67% to 20%. research has demonstrated a significant and predictable benefit to using CBCT examinations in identifying additional roots of mandibular molars [35].

[36], reported that endodontists failed to identify at least one canal in up to 41% of cases when evaluated with PR when CBCT was used as the standard.

[36], reported that only 8% of MB2 canals were identified using PR, whilst with CBCT, MB2 canals were identified in 54% of cases. However, CBCT imaging comes at the expense of increased radiation dose; therefore, CBCT should only be reserved for cases where there is potential benefit from a three-dimensional assessment. It is essential that patient radiation exposure is kept as low as reasonably practicable. The benefits of a CBCT investigation must outweigh any potential risks. Therefore, each scan must be optimized to reduce

patient exposure by adjusting the CBCT settings, thus allowing each examination to be personalized to the individual patient and the diagnostic needs, rather than just using manufacturer's default settings.

[38] aimed to evaluate the dimension of the periapical lesions, the relationship of the mandibular roots to the inferior alveolar canal and buccal bone dimension with CBCT and periapical radio- graphs before attempting apical surgery. lesions diagnosed with CBCT were detected. The dimension of the buccal bone could be ascertained as well thereby stressing on the importance of CBCT assessment in the mandibular quadrant before surgery. However, when normal periodical radiography is not in a position to demonstrate accurately the root canal morphology and the clinician is not in a position to formulate his/her treatment plan which would consequentially influence the outcome of the treatment, only then a limited volume, high-resolution CBCT should be attempt that when the progression of bone destruction occurs, periapical lesions can easily be diagnosed with PR [37].

3. Conclusion

Conventional intraoral radiography provides clinicians with an accessible, cost effective, high-resolution imaging modality that continues to be of value in endodontic therapy. There are, however, specific situations, both pre- and postoperatively, where the understanding of spatial relationships afforded by CBCT facilitates diagnosis and influences treatment. The usefulness of CBCT imaging can no longer be disputed—CBCT is a useful task specific imaging modality and an important technology in comprehensive endodontic evaluation.

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