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CBCT IN ENDODONTICS: THE 3D GAME CHANGER

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ABSTRACT One of the most commonly encountered chief complaints include pain of endodontic origin. In addition to the clinical examination, the radiographic assessment of any underlying pathological condition acts as an essential tool for the preoperative assessment, treatment planning and the post operative analysis. Ever since the advent of CBCT, it has emerged as an indispensable tool for detecting complex conditions owing to its ability of generating accurate three-dimensional multiplanar images of the maxillofacial region. It overcomes the limitations of the conventional periapical and panoramic radiographs which offer a limited two-dimensional (2D) view of a three-dimensional (3D) anatomical area. Despite the software's highly advanced features that allow interesting manipulations of the brightness and contrast in addition to the real-time on-screen dimensional assessment with minimum distortion, it exposes the patient to a higher radiation dose and is susceptible to artifacts. Overall, CBCT has revolutionized the field of dentistry with its excellent diagnostic ability and technical advancements.

KEYWORDS : Cone Beam Computed Tomography, Conventional Radiography, Digital Imaging, Endodontic Diagnosis.

INTRODUCTION

In the field of Dentistry, particularly Endodontics, it is crucial to obtain a diagnostically correct image so as to facilitate the clinician in the preoperative risk assessment, treatment planning and the post operative therapeutic analysis thereafter. The imaging modalities make use of either the conventional intraoral and extraoral films or the more advanced digital receptors.

In 1972, a three-dimensional diagnostic imaging modality "Computerized Axial Transverse Scanning' or Computed Tomography (CT) was invented by Sir Godfrey Hounsfield. Tomography or "slice imaging" refers to capturing a 3D area of interest in thin slices and then synthesising them either manually or electronically.

CBCT provides high quality, 3D accurate images of the dentition with the adjacent osseous structures of the maxillofacial region. The highly advanced software with its inherent features permits interesting permutations and combinations of brightness and contrast. In addition, the measurement tools make the real-time on-screen dimensional assessment possible. Various image enhancement tools assist to further arm a clinician with adequate knowledge about the suspected underlying pathological derangements which may have gone unnoticed or superimposed in the conventional 2D imaging (Fig 1).

Limitations Of Conventional 2d Imaging

Firstly, the traditional imaging modalities only provide a two-dimensional (2D) representation of a three-dimensional (3D) anatomical area. Secondly, the superimposition of surrounding structures may camouflage the possible pathological condition. Thirdly, geometric errors may occur in case of the compromised condition of any component of the imaging chain process.[16]

Fig 1. Three-dimensionally advanced Orthophos S extraoral imaging modality. (Courtesy: Baba Jaswant Singh Dental College, Hospital and Research Institute, Ludhiana).

Cone Beam Computed Tomography

CBCT is considered to be the standard of care today. The x-ray source and digital detector are attached to a rotating gantry with a fixed fulcrum. A divergent cone shaped or pyramidal x-ray beam is projected through the anatomy of interest. The ionizing radiation passes through the desired field of view (FOV) such that several hundreds of planar images are obtained when the source and detector rotate in an arc of at least 180°.

The optimum resolution required for CBCT is usually task specific. Since the earliest sign of any periapical pathological derangement is periodontal space widening and discontinuity of the lamina dura, hence the desirable resolution in endodontics must not exceed the width of the periodontal space (200μm).[10]

Principles Of Cbct

The CBCT diagnostic imaging modality primarily functions on three basic principles such as the voxel size, the field of view (FOV) and the slice thickness/measurement accuracy.

Types Of Cbct Equipment

The CBCT apparatus may vary according to the scan volume irradiated, patient positioning and the clinical functionality.

Patient Positioning -

Maxillofacial CBCT can be performed with the patient in three possible positions: sitting, standing and supine.

Scan Volume -

The units can be designed as follows: (1) Small field of view (focused, limited field)—approximately 5 cm or less, (2) single arch—5 cm to 7 cm, (3) inter-arch—7 cm to 10 cm, (4) maxillofacial—10 cm to 15 cm, (5) craniofacial—greater than 15 cm.

Multimodality -

Hybrid multimodal systems combine digital panoramic radiography with a relatively small-to medium FOV CBCT system.

Radiation Dose

Radiation exposures are usually converted to effective dose (E) and measured in Sieverts (Sv). Since sievert is a large unit, therefore for maxillofacial imaging milli-[10−3; mSv] or micro-[10−6; μSv] sieverts are used. The tissues specified by the International Commission on Radiological Protection (ICRP) for calculating the effective dose include skin, salivary glands, thyroid, esophagus, bone surface, bone marrow, brain and "remainder tissues". The effective doses for digital panoramic radiographs vary from 5.5 to 22.0 μSv, while digital cephalometric radiographs range from 2.2 to 3.4 μSv. Overall, a single CBCT radiation exposure is equivalent to 0.4 to 2.7 digital panoramic radiographs.[10]

According to Signorelli, L. et al, 2016[12] radiation exposure for digital panoramic radiographs is 21.87 μSv and lateral cephalogram is 5.03 μSv. Therefore, a single CBCT exposure accounts for up to 3 to 6 times a digital panoramic radiograph and 15 to 26 times a lateral cephalogram.

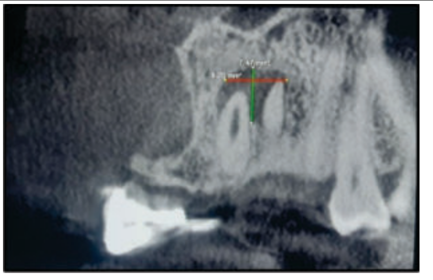
Cbct Applications In Endodontics

According to the AAE and AAOMR Joint Position Statement: Use of Cone Beam Computed Tomography in Endodontics 2015 Update,[14] CBCT has emerged as an advanced three-dimensional imaging modality of choice in certain complex clinical scenarios where the conventional radiography proves to be insufficient. The various indications which preclude the use of CBCT are depicted in Table 1.

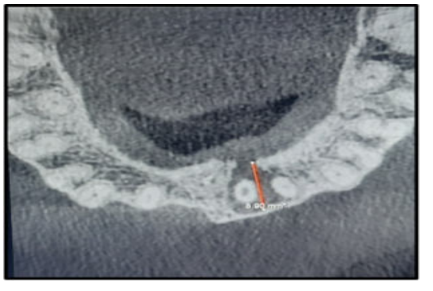
Table-1

Table 1. Various imaging tasks simplified using the Cone Beam Computed Tomography.

S. NO.	INDICATIONS FOR USE OF CBCT IN ENDODONTICS
1.	Differential diagnosis a. Lesions of endodontic origin b. Lesions of non-endodontic origin c. Diagnosis of endodontic treatment failures d. Vertical root fractures
2.	Evaluation of anatomy and complex morphology a. Anomalies b. Root canal system morphology
3.	Intraoperative or postoperative assessment of endodontic treatment complications a. Overextended root canal obturation material b. Separated endodontic instruments c. Calcified canal identification d. Localization of perforation
4.	Dentoalveolar trauma
5.	Internal and external root resorption
6.	Presurgical case planning
7.	Implant site assessment
8.	Assessment of endodontic treatment outcomes

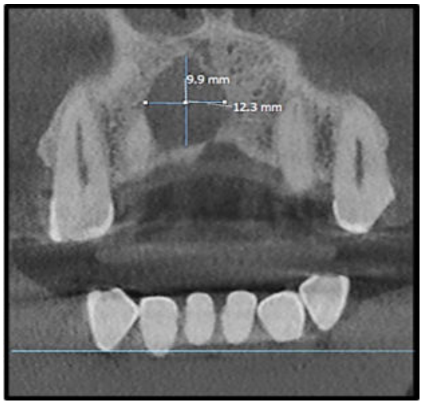


(a)

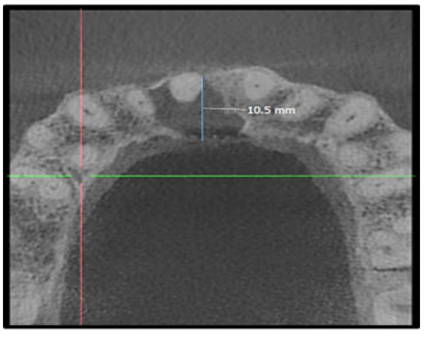


(b)

Fig 2. CBCT images (a) coronal view, showing the periapical radiolucency with respect to the maxillary right central and lateral incisor (b) axial view, showing erosion of cortical plate on the palatal aspect and thinning of the buccal cortical plate with respect to the maxillary right central and lateral incisors respectively.



(a)



(b)

Fig 3. CBCT images (a) coronal view, showing the periapical radiolucency with respect to the maxillary right central incisor (b) axial view, showing erosion of cortical plate on the palatal aspect with respect to the maxillary right central incisor.

1. Differential Diagnosis

1 a. Lesions of Endodontic Origin

Prior to the advent of 3D imaging, the 2D conventional radiography provided limited information regarding the location and extent of the lesion. Also, the superimposition of the adjacent structures such as the zygomatic process and buccal bone visually obstructed the maxillary molar root apices. However, CBCT allows a clinician to view the anatomy of interest three dimensionally along the axial, coronal and sagittal planes in 0.1mm sections. Besides permitting the 3D real time dimensional assessment, CBCT is highly effective in detecting the erosion or thinning of the cortical plate around the radiolucent lesion (Fig 2 and 3). Overall CBCT has been found to detect more periapical lesions in maxillary molars and premolars as compared to PA radiography.[1]

1 b. Lesions of Non-Endodontic Origin

Several non-endodontic lesions such as central giant cell granulomas, periapical cemento-osseous dysplasia, simple bone cysts, odontogenic cysts, malignancies and neuropathic pain may present as a challenging diagnostic task. The 3D radiographic imaging provides adequate information regarding the size, location, spatial relationship of the suspected lesion with the adjacent structures (e.g., nerve fibres, vascular bundle).[1]

1 c. Diagnosis of Endodontic Treatment Failures

CBCT helps in diagnosing retreatment cases with suspicious missed canals, accessory canals, ambiguous anatomy, underfilled and overfilled root canals etc. with greater efficiency.

1 d. Vertical Root Fractures (VRFs)

They are witnessed in 8.8 % to 13.4 % post endodontic cases. They usually run along the buccolingual direction, hence are difficult to diagnose. Conventional periapical radiographs report successful diagnosis in 66 % cases as opposed to 86 % by CBCT.[5] CBCT scans have been found to be more accurate in detecting 0.2-mm VRFs (70%) and 0.4-mm VRFs (90%) as compared with digital radiographs (43.3% and 60%, respectively) and the overall accuracy of CBCT in detecting VRF's has been observed to be higher in comparison to conventional periapical and digital radiographs.[9]

2. Evaluation Of Anatomy And Complex Morphology

2 a. Dental Anomalies

Several anomalies such as the c-shaped canal configuration, calcifications, bifurcations, accessory canals etc. pose a diagnostic challenge with the 2D conventional radiography. However, CBCT with its nominal voxel resolution power as high as 0.076 mm has tremendously improved their visualization and identification.[16]

2 b. Root Canal System Morphology

Three dimensional reconstructed multiplanar images generated by CBCT help to precisely locate the canal orifices and identify the canal morphology. The results obtained with CBCT have been found to be comparable to those achieved with canal staining and clearing techniques.[16]

3. Intraoperative Or Postoperative Assessment Of Endodontic Treatment Complications

3 a. Materials Extending beyond the Root Canal

Overfilling or overextension of the root canal may cause injury to some important vital structures lying in the immediate vicinity of the root apices such as the inferior alveolar neurovascular bundle (IAN) or maxillary sinus. Endodontic treatment accounts for about 10 % of the reported nerve injuries. These may be attributed to various factors such as - periapical infections, local anaesthetic administration, over-instrumentation, use of intracanal medicaments or irrigants, mechanical compression and endodontic surgery. CBCT reconstructs an accurate and distortion free three-dimensional image so as to assist in risk assessment and potential chances of nerve injury.[2]

3 b. Fractured Instruments

CBCT provides adequate information regarding the canal curvature, shape and the amount of intra-radicular dentin present. It is highly beneficial in fragment localization in cases where the instrument lies beyond the canal curvature such that it cannot be appropriately visualized by the dental operating microscope. For example, if a separated instrument lies towards the lingual aspect of a ribbon-shaped canal, then bypassing the obstruction from the buccal aspect may be attempted. Overall, a three-dimensional assessment helps in formulating a retrieval or bypass strategy.[1]

3 c. Calcified Canals

Though magnification and illumination are crucial elements in treating calcified canals, the use of CBCT proves to be an indispensable tool. The increased sensitivity and specificity of CBCT in addition to the inherent software-based measurement tools provide a safer and more predictable approach for locating calcified canals. Also, the multiplanar image reconstruction post insertion of radiopaque markers such as obturating materials or instruments also facilitate canal localisation.[4]

3 d. Perforations

Iatrogenic errors such as root perforations may be caused either during post space preparation, strip perforations, fractured instrument retrieval attempts or localizing calcified canals.

Shemesh et al, 2011[11] compared the diagnostic ability of three-dimensional CBCT scans with two-dimensional periapical radiographs (PR) obtained at two different angulations to locate strip perforations after biomechanical preparation with gutta percha and sealer compacted through lateral condensation. Both imaging methods showed similar specificity, however, CBCT showed significantly higher sensitivity. Single and two-angulated PRs detected 40% and 63 % of the perforations respectively, suggesting the two-angled PRs to be superior. Overall, no significant difference was appreciated between the PRs and CBCT in the detection of root perforations.

4. Dentoalveolar Trauma

CBCT is highly efficient in visualizing traumatic injuries to the orofacial complex in all three orthogonal planes (axial, sagittal and coronal) to facilitate the clinician in decision making.

A study comparing the influence of CBCT as an adjunctive diagnostic tool for endodontic treatment planning of immature traumatic teeth with suspected necrosis of the pulp observed that in 49 % cases chosen for wait and watch treatment plan "before" CBCT were converted to a more aggressive approach of endodontic orthograde treatment or extraction "after" CBCT.[8]

5. Internal And External Root Resorption

CBCT provides detailed description regarding the exact location and extent of the resorptive defect unlike the conventional imaging. PA radiographs detected 68.8 % IRR as opposed to 100 % sensitivity of CBCT scans. In case of ERR, conventional radiography could not detect lesions smaller than 0.3 mm in depth and 0.6 mm in diameter.[1]

CBCT is superior to digital periapical radiography for detecting internal and external inflammatory resorptive defects after traumatic injuries and could also be considered for the differential diagnosis of resorptive defects in endodontically treated teeth.[7]

6. Presurgical Visualization

CBCT permits 3D reconstruction of the area of interest, hence allowing the clinician to know the proximity of the entire defective lesion to the adjacent anatomical landmarks prior to the surgical exploration. The relationship of the root apices of the maxillary and mandibular posterior teeth with the maxillary sinus, mental foramen, mandibular canal and the incisive canal aid substantially in presurgical treatment planning.[13]

7. Implant Site Assessment

AAOMR states that the PA radiographs may be supplemented with the panoramic radiographs for the preoperative assessment. While small FOV CBCT may be used as an adjunctive diagnostic tool in accordance with the ALARA principle to minimize radiation exposure.

CBCT allows assessment of the bone volume, alveolar ridge topography, bone density, linear measurements, jaw boundaries, fabrication of surgical guides and proximity of adjacent vital structures to the potential implant site. It allows virtual implant planning and analysis of multiple treatment options until the final treatment plan is concocted.

CBCT scans must be considered in cases of suspicion of periapical pathosis, inflammatory lesions, tumors, cysts, inspection of maxillary sinus and temporomandibular joint (TMJ).[1]

8. Outcomes Assessment Endodontic Treatment

A clinical study evaluating the diagnostic efficiency of digital periapical radiography at central view (DP), DP combined with 10° mesially and distally angled views (DPS) and CBCT in detecting apical periodontitis utilizing histological findings as the reference concluded that the sensitivity for DP, DPS and CBCT were 0.27, 0.38 and 0.89 respectively, thereby proving CBCT to be a superior imaging modality.[6]

Advantages Of Cbct

- High-resolution images with maximum spatial resolution upto 0.076 mm can be obtained.
- Reconstructed projection data depicting true spatial relationships in all three planes (axial, sagittal and coronal) is possible.
- Enhancements like zoom magnification, text or arrow annotations and window/level adjustments are available.
- Real-time dimensional assessment is possible due to cursor-driven measurement algorithms.
- On-screen measurements obtained are free from geometric errors.

Limitations Of Cbct

- There is inferior spatial resolution (0.4 mm to 0.076 mm or equivalent to 1.25 to 6.5line pairs per mm−1 [lp.mm−1]) as compared to conventional film-based (approx. 20 lp.mm−1) or digital (ranging from 8–20 lp.mm−1) intraoral radiography.
- Image noise occurs due to scattered radiation.
- Pronounced "heel effect" may be observed due to varying intensity of x-rays emitted by the anode.
- Some artifacts can hamper the CBCT interpretation such as:
- Cupping artifacts, streaks and dark bands may result due to the beam hardening effect.
- Patient-related artifacts such as un-sharpness of the reconstructed image may occur due to the patient's movement during radiation exposure.
- Scanner-related artifacts may result in circular or ring-shaped defects.
- Cone beam–related artifacts may result due to partial volume averaging, under sampling and cone-beam effect.
- The soft tissue contrast which is provided is also inadequate.
- Higher radiation exposure occurs in certain situations.[15]

Way Forward

Newer CBCT units shall be installed with new, high-performance flat-panel detectors and software algorithms, which will primarily focus on enhancing the noise-power spectrum and noise-equivalent quanta.

Ongoing research in the field of CBCT includes several areas of exploration. Firstly, there is a focus on image perception and quality assessment, aiming to improve the diagnostic decision-making process for dentists. Secondly, advanced reconstruction techniques are being developed, utilizing sophisticated algorithms to reduce imaging artifacts. Thirdly, investigations to reduce image artifacts caused by the presence of metallic devices like screws and implants are under progress. Furthermore, image registration is being studied to align tissues for image-guided surgery and outcomes assessment. Image-guided procedures are also being developed, providing real-time surgical navigation. Lastly, segmentation techniques are being refined to enable better differentiation between normal and diseased tissues, allowing for accurate volumetric measurements.[3]

The future of CBCT holds great potential, with advancements in hardware and software, as well as ongoing research in various areas. These developments will further enhance the capabilities of CBCT systems and contribute to improved dental imaging and diagnostic practices.

CONCLUSION

CBCT helps to visualize the anatomy of interest in all 3 orthogonal planes (axial, sagittal and coronal). It also permits 3D reconstruction thereby eliminating the need for any invasive surgical exploratory procedure. Owing to its higher resolution, it is able to detect even the earliest manifestations of any underlying pathological condition. However, this 3D advanced imaging modality may be used as an adjunct rather than a substitute for the 2D imaging for diagnosing diverse clinical conditions.

REFERENCES:

1. Berman, L. H., & Hargreaves, K. M. (2020). *Cohen's Pathways of the Pulp: Cohen's Pathways of the Pulp - E-Book*. Elsevier Health Sciences.
2. Chong, B. S., Gohil, K., Pawar, R. R., & Makdissi, J. (2016). Anatomical relationship between mental foramen, mandibular teeth and risk of nerve injury with endodontic treatment. *Clinical Oral Investigations*, *21*(1), 381–387. https://doi.org/10.1007/s00784-016-1801-8
3. Cotti, E., & Schirru, E. (2022). Present status and future directions: Imaging techniques for the detection of periapical lesions. *International Endodontic Journal*, *55*(S4), 1085–1099. https://doi.org/10.1111/iej.13828
4. Floratos, S., & Miltiadous, M. A. (2017). Intraoperative Use of CBCT for Identification and Localization of Calcified Canals: A Clinical Technique. *Case Reports in Dentistry*. https://doi.org/10.1155/2017/1265701
5. Hassan, B. a. R., Metska, M. E., Özok, A., Van Der Stelt, P., & Wesselink, P. R. (2009). Detection of Vertical Root Fractures in Endodontically Treated Teeth by a Cone Beam Computed Tomography Scan. *Journal of Endodontics*, *35*(5), 719–722. https://doi.org/10.1016/j.joen.2009.01.022
6. Kanagasingam, S., Lim, C., Yong, C. P., Mannocci, F., & Patel, S. K. (2016). Diagnostic accuracy of periapical radiography and cone beam computed tomography in detecting apical periodontitis using histopathological findings as a reference standard. *International Endodontic Journal*, *50*(5), 417–426. https://doi.org/10.1111/iej.12650
7. Lima, T., De Oliveira Gamba, T., Zaia, A. A., & De Jesus Soares, A. (2016). Evaluation of cone beam computed tomography and periapical radiography in the diagnosis of root resorption. *Australian Dental Journal*, *61*(4), 425–431. https://doi.org/10.1111/adj.12407
8. De Almeida, F. Q., Hassan, D. M., Abdulrahman, G. Y., Brundin, M., & Vestman, N. R. (2021). CBCT influences endodontic therapeutic decision-making in immature traumatized teeth with suspected pulp necrosis: a before-after study. *Dentomaxillofacial Radiology*, *50*(8). https://doi.org/10.1259/dmfr.20200594
9. Özer, S. Y. (2010). Detection of Vertical Root Fractures of Different Thicknesses in Endodontically Enlarged Teeth by Cone Beam Computed Tomography

versus Digital Radiography. *Journal of Endodontics*, *36*(7), 1245–1249. https://doi.org/10.1016/j.joen.2010.03.021

10. Scarfe, W. C., Levin, M. L., Gane, D., & Farman, A. G. (2009). Use of Cone Beam Computed Tomography in Endodontics. *International Journal of Dentistry*, *2009*, 1–20. https://doi.org/10.1155/2009/634567
11. Shemesh, H., Cristescu, R. C., Wesselink, P. R., & Wu, M. (2011). The Use of Cone-beam Computed Tomography and Digital Periapical Radiographs to Diagnose Root Perforations. *Journal of Endodontics*, *37*(4), 513–516. https://doi.org/10.1016/j.joen.2010.12.003
12. Signorelli, L., Patcas, R., Peltomäki, T., & Schätzle, M. (2016). Radiation dose of cone-beam computed tomography compared to conventional radiographs in orthodontics. *Journal of Orofacial Orthopedics / Fortschritte Der Kieferorthopädie*, 77(1), 9–15. https://doi.org/10.1007/s00056-015-0002-4
13. Silva, J. G., De Alencar, A. H. G., Da Rocha, S. S., Lopes, L. G., & Estrela, C. (2012). Three-dimensional image contribution for evaluation of operative procedural errors in endodontic therapy and dental implants. *Brazilian Dental Journal*, *23*(2), 127–134. https://doi.org/10.1590/s0103-6440201 2000 200007
14. Fayad, M. E., Nair, M. S., Levin, M. L., Benavides, E., Rubinstein, R. A., Barghan, S., Hirschberg, C. S., & Ruprecht, A. (2015b). AAE and AAOMR Joint Position Statement. *Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology*, *120*(4), 508–512. https://doi.org/10.1016/j.oooo.2015.07.033
15. Venkatesh, E., & Elluru, S. V. (2017). CONE BEAM COMPUTED TOMOGRAPHY: BASICS AND APPLICATIONS IN DENTISTRY. *Journal of Istanbul University Faculty of Dentistry*, *51*(0). https://doi.org/10. 17096/ jiufd.00289
16. Mallya, S., & Lam, E. (2018). *White and Pharoah's Oral Radiology: Principles and Interpretation*. Mosby.