International Journal Dental and Medical Sciences Research (IJDMSR)
ISSN: 2393-073X Volume 3, Issue 1 (Jan- 2019), PP 68-76
www.ijdmsr.com

Cone Beam Computed Tomography in Endodontics

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ABSTRACT: Cone Beam Computed Tomography (CBCT) is introduced for imaging of maxillofacial region, shift from 2D to 3D imaging. The 2 dimensional radiographic technique provide representation of the tissues, but are limited in differentiating superimposing structures. This drawback has been overcome by Cone Beam Computed Tomography (CBCT). When compared with conventional computed Tomography (CT) CBCT has lower radiation dose. CBCT produces a high contrast image with good resolution in a short period of time. CBCT system configurations are also available that provide small field of view images at low dose with sufficient spatial resolution. These characteristics make it highly relevant for applications in endodontic diagnosis, treatment guidance and post treatment evaluation detect the true nature of resorptive lesions, assess root canal anatomy and root fractures. Therefore the aim of this article is to provide information on CBCT and its potential applications in endodontic practice.

Keywords: Cone Beam Computed Tomography, Dental caries, Endodontics, field of view, Three dimensional imaging.

I. INTRODUCTION

Periapical imaging is mostly used for the diagnosing, therapeutic planning and for preoperative control and monitoring of bone healing. Low dose CBCT is widely used now because of three dimensional details of bone structure. Progression of healing is better visualized. Standardization of images facilitates lesion detection and visualization. Selection of FOV size is important.

Radiographic evaluation is essential for performing endodontic treatment procedures such as root canal surgeries, apicectomy, dentoalveolar trauma, Ellis fractures etc. Radiographic imaging are used in all stages in endodontics like preoperative, intraoperative and postoperative assessment[1].

Today, radiographic evaluation in endodontics is confined to conventional intraoral and panoramic radiography[2]. Radiographs in endodontics are used for the diagnosis of odontogenic pathoses, treatment of the pulp chamber and root canals of a compromised tooth[1]. The conventional radiography has limitationsas the three dimensional anatomy of that areais radiographed into a two dimensional image.

Conventional radiography has the disadvantage of magnification, distortion andsuperimposition[3]. Despite their history and widespread use, periapical radiography yields limited information for a number of reasons. Conventional radiography compresses three dimensional structures on to a two-dimensional image and also create geometric distortion and anatomical noise[1]. The radiograph can be seen only in mesiodistal plane, while buccolingual plane is very less appreciated. If more accurate imaging techniques are not used, anatomical complexities and diseases affecting the dental hard tissues, such as resorption and operative procedural errors may not be appreciated and hence the diagnostic quality of the radiograph is impaired. Intraoral periapical radiographs of a particular area or tooth need to be compared over time to assess the development or progression of a disease. The radiographs should be standardized with respect to all of the radiation exposure parameters, X-ray beam angle and the object to image receptor distance. Poorly-standardized radiographs may result in a misinterpretation of disease onset or progression[4]. Interpreting radiographs is also difficult when roots of teeth overlap and anatomical structures are present. Dental materials such as crowns, posts, and filling materials may also be difficult to interprete on the radiograph. Goldman et al. showed only 47% agreement between six examiners in evaluating healing of periapical lesions using 2D periapical radiographs[1].

Although for three dimensional oral imaging CT and CBCT is available, CT application in Endodontics is limited and also it has high radiation dose and it is costly.

Cone Beam ComputedTomography is a new application and hasbeen first introduced in 1996 for the clinical application of 3D imaging in endodontics. (William). It used rather than CT thatgenerates three-dimensional (3D) data at lower costand lower absorbed doses than conventional CT[3]. There are certain advantages of cbct:

- Very Compact equipment
- The axial, coronal and sagittal sections can be viewed simultaneously which are valuable because they are not seen in traditional 2D radiography[5]
- Higher resolution resulting in sharper images and better diagnosis.
- Produces a 3D images and provides geometrically accurate images
- Increased specificity for caries, periodontal and periapical lesions when compared to conventional CT and periapical radiographs.
- Small FOV – hence possible to have images of only the area of interest.
- Less exposure time and lower radiation dose when compared to medical CT.
- Patient comfort increases when compared to traditional intra oral radiographs as there is no placement of intra oral film or sensors.
- The patient is in a sitting position, and in not lying down as with medical CT further increasing the comfort and acceptance by the patients.
- Good soft tissue imaging when compared to the traditional 2D imaging[6]

This article describes CBCT and its importance as a diagnostic tool in clinical endodontic practice.

II. CONE BEAM COMPUTED TOMOGRAPHY (CBCT)

Components of CBCT includes 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. The X-ray source and detector rotate around a fixed fulcrum within the region of interest (ROI). During the exposure sequence hundreds of planar projection images are acquired of the field of view (FOV) in an arc of at least 180◦. In this single rotation, CBCT provides precise, immediate and accurate 3D radiographicimages.As CBCT expose the entire FOV, only one rotation of the gantry is required to acquire data for image reconstruction. CBCT's utilize a smaller, limited field of view along with a high spatial resolution in all planes[1].

Unlike regular X-rays, CBCT scans are able to differentiate between many types of structures and airspaces including bone, teeth, airway, paranasal sinuses. 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[7].

With the help of viewer software, the clinician is able to scroll through the entire volume and can simultaneously view axial, coronal and sagittal 2D sections[3].

Like conventional radiography, CBCT utilizes ionizing radiation. CBCT produces more radiation than conventional radiography but the difference is minute while it is several times lower than CT imaging. Not all CBCT units produce the same dose of radiation. The same CBCT unit may produce different amount of radiation depending on the field of view (focused or large), power settings, rotation around head (180°or 360°), etc. The effective dose of one CBCT unit has been reported to be equivalent to two or three standard periapical radiographic exposure[5].

CBCT is useful in the assessment and treatment of complex endodontic conditions such as:

- Detection of suspected additional canals and unusual root and canal anatomy based on radiographic examination.
- To assess the location and severity of root resorption. External and internal resorptions can be easily differentiated with CBCT.
- To study the root canal system anomalies and for determination of direction and angulation of root curvature
- To assess the dimensions of lesion or defect and its spatial relationship with vital structures before performing surgical endodontics
- CBCT also plays vital role in the detection and management of dento-alveolar traumatic injuries, assessment of endodontic treatment complications, such as overextended root canal fillings, separated instruments, presence of denticles and diffuses calcification, and detection of iatrogenic perforations[5].

Different types of cone beam equipments: The FOV is classified into two categories based on the machines. A limited CBCT (FOV ranges from 40-100 mm (8x8cm) is utilized for endodontic purposes while a full CBCT (FOV ranges from 100-200cm (12x12mm)) is useful for multiple implants, extensive pathologies, orthodontics[1,3]

III. ROLE OF CBCT IMAGING IN ENDODONTIC

Imaging serves as 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.

Preoperative

- Extent of the dental caries
- Periapical pathologies
- 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
- Pre-condensation radiograph is made to assure the proper fitting of the master cone[6].

Post operative

- To evaluate the root canal obturation and seal
- Tooth and periapical hard tissue changes after treatment
- Planning for surgical considerations[7]
- Cases where periradicular healing is incomplete[6]

IV. LIMITATIONS OF CBCT

Sometimes Cone beam computed tomography imaging affected by radiographic artifacts related tothe X-ray beam.When the CBCT X-ray beam encountersan object of very high density(egenamel or metallic restorations), lower energy photons in the beam are absorbed by the structure. so the mean energy of the X-ray beam increases. This is called 'beam hardening' and the phenomenon produces two types of artifact: distortion of metallic structures, called 'cupping artifact', and the appearance of streaks and dark bands between two dense structures.(Fig. 1)

These artifacts can reduce the diagnostic quality of the images[4].

- Endodontic sealers have also been reported to produce artifacts that mimic fracture line[5].
- The spatial resolution of CBCT is approximately2 line pairs per mm and is inferior to conventional dental radiography, which has a spatial resolution of 15-20 line pairs per mm,so the image quality is hampered[4].
- The effective dose of CBCT is generally higher than that of conventional intraoralradiography[4].
- Limited contrast resolution in the CBCT technologies affect the diagnostic quality of the image.
- Increased radiation exposure compared to conventional intraoral radiographs
- Cost of CBCT is high, hence less affordability to the common population.
- Dentist must be computer savvy[6]
- Scan times are lengthy at 15-20 seconds and needs the patient to stay still[3].
- Patient movement during the scan can adversely affect the sharpness of the final image[4]

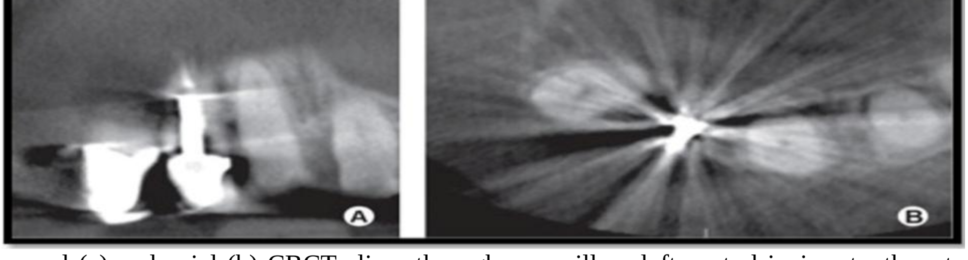

Figure 1: Coronal (a) and axial (b) CBCT slices through a maxillary left central incisor tooth restored with a post-retained crown. Beam hardening caused by the metallic post that has resulted in the appearance of streaks and bands, impairing the quality of the images.(Picture courtesy-Durack C, Patel S. Cone beam computed tomography in endodontics. Brazilian dental journal. 2012;23(3):179-91.)

V. APPLICATION OF CBCT IN ENDODONTICS

1. Assessment of tooth morphology

Knowledge of root canal anatomy and its variations is essential for clinicians for the success of effective root canal treatment (RCT) so that they can be accessed, cleaned, shaped, and obturated[1]

Most often intraoralperiapical radiographs may not show the presence of all canals within the root, especially in the buccolingual plane. Failure to identify and treat accessory canals can negatively influence treatment outcome .Such missed canals may be responsible for persistent infection and post treatment disease.
The prevalence of a second mesiobuccalcanal (MB2) in maxillary first molars has been reported to vary from 69% to 93%. Ascompared to conventional radiographs increased number of MB2 canal can be identified with CBCT .

CBCT imaging has also been reported to characterize the high prevalence of the distolingual canal, highlight anomalies in the root canal system of mandibular premolars, and assist in the determination of root curvature.

In a study that evaluated 608 permanent mandibular second molars using CBCT a higher prevalence of "C" shaped canals was noticed.[8] (Fig 2)

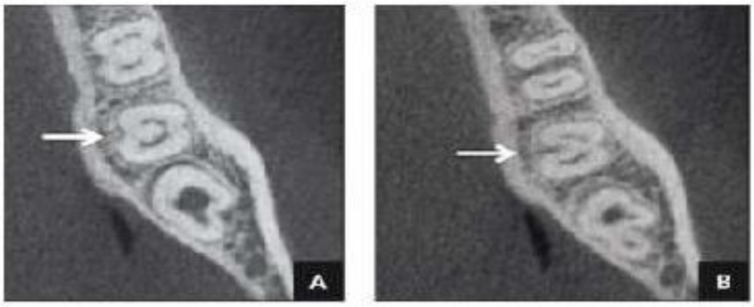

Figure 2: Images A and B showing the presence of C-shaped canals

CBCT is an effective tool for the detection of additional distolingual roots and C-shaped canals.[9] Undetermined canal morphology enhances the possibility of peri-operative mishaps such as ledge formation, canal transportation or even perforation , potentially compromising the outcome of the treatment . (Fig 3 and 4)

Figure 3: Root morphology in IOPA(showing mesiobuccal and distobuccal roots with 16)

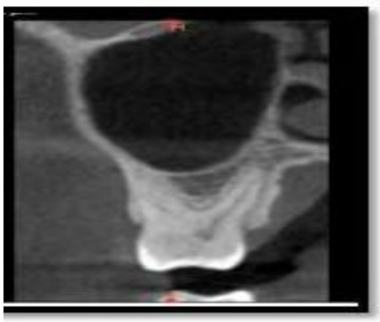

Figure 4: Root morphology on CBCT(showing palatal and buccal root with 16)

2. Detection of periapical pathology

The most common pathologic conditions affecting theteeth are the inflammatory lesions of the pulp and periapical areas.In this regard CBCT is significantly more accurate and sensitive than conventional radiography in the identification of apical periodontitis in humans .Periapical bone destruction associated with endodontic infection can beidentified using CBCT before the evidence of their existence becomes identifiable on conventional radiographs [10].

Estrela and colleagues proposed aperiapical index based on cone beam-computed tomography(CBCTPAI) for identification of AP similar results are reported by Low et al. whocompared the preoperative consensus assessment of theapical condition of 37 premolars and 37 molars in themaxilla (156 total roots) using periapical radiography andCBCT referred for possible apical surgery and found the latermethod to demonstrate significantly more lesions (34%)than conventional radiography. [11]

Early radiolucent changes are seen in the CBCT before they are visualized on conventional radiographs.[1]CBCT scans resulted in 62% more periapicalradioluscent areas being detected on individual roots of mandibular and maxillary teeth. Thus early detection of periapical lesions can make the outcome of treatment more successful.[3]Lesions in the cortical bone is detected radiographically when there is perforation of the bone cortex, erosion from the inner surface of the bone cortex, or extensive erosion or defects on the outer surface. It is known that periapical lesions in cancellous bone cannot be detected radiographically. However in CBCT bone defects of the cancellous bone and cortical bone can be revealed separately. The prevalence of apical periodontitis was found to be significantly higher when using CBCT, in comparison with periapicalradiographs.[1](Fig 5 and 6).

Figure 5: IOPA showing radicular cyst with 13 12 11

Figure 6: CBCT (axial section) showing radicular cyst with 13 12 11

3. Diagnosis of root fracture

According to Kavita R et al the prevalence of vertical root fracture has been reported to range from 10.9% to 12.9%, with highest incidence occurring in an age group of 40–60 years.

Identifying the presence of vertical root fractures (VRF) is often a challenge in endodontics. If the root fragment has been not displaced, root fractures may bedifficult to visualize through conventional intraoral radiography in theimmediate post-trauma clinical situation.

CBCT has found particular application for the diagnosis of root fractures.Twentycases with suspected vertical root fractures were subjected to radiographic imaging. They found that CBCT wassignificantly better than conventional radiographs in the diagnosis of vertical root fractures.

Hassan et al. 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. [1]

Horizontal root fractures are presumably easier to detect than longitudinal fractures, particularly those in the mesiodistalplane. The higher the spatial resolution was in the CBCT images, the higher the diagnostic accuracy .[7] (Fig 7 and 8)

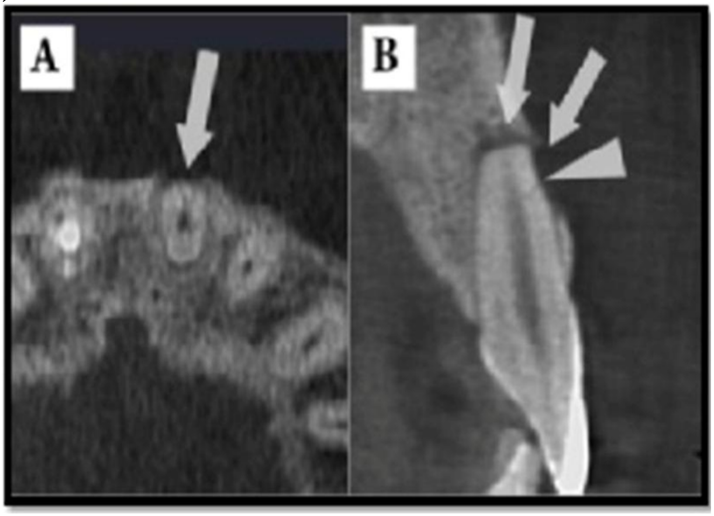

Figure 7: A) CBCT view shows a tiny horizontal root fracture on the buccal surface of the maxillary left central incisor, B) and periradicular lesion in the apical area (arrow) and adjacent to the fracture line (arrow head)

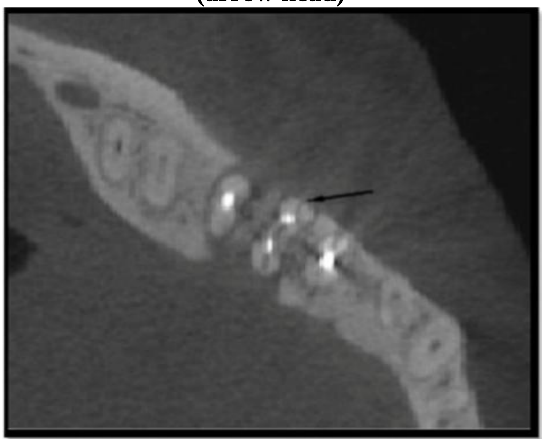

Figure 8: A CBCT axial scan of a vertical root fracture in the lower molar mesial root.

4. Assessment of Resorption and Perforation -

Rootresorption is defined as the loss of dental hard tissues as a result of osteoclastic activities. It can be aphysiological or a pathological phenomenon.Resorptive defects may spread within the root in all directions, andtheir sizes and the positions of radiolucency may not be detected on the radiograph.[12]

The sensitivity of conventional radiography is significantlypoorer than CBCT in the detection of external root resorption in its early stages and significant hard tissuedamage may have potentially occurred to the affected tooth before the resorption becomes evident onconventional radiographs.

CBCT has been shown to help and determine the treatment complexity as well said 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 .

CBCT has been implicated as a reliable and valid method of detecting external inflammatory root resorption and performs significantly better than intraoral PA radiography .CBCT helps in locating the lesion, reveals if theresorptive lesion has perforated the root canal or has perforated into the adjacent periodontium. .[3] External resorption, which presents with irregular radiolucency and intact root canal whereas internal resorption has clearly defined borders with no canal radiographically visible in the defect .

Conventional radiographs do not provide a true and full representation of the lesion, especially in the buccal-lingual direction. They are unable to identify the true extent, location or the portal of entry of a resorptivelesion . Internal root resorption (IRR) within the root canal itself is rare, usually asymptomatic, slowly progressing, and presents as a incidental finding on intraoral radiographic examination.

It is very common that internal and external inflammatory root resorption are confused and misdiagnosed therefore accurate assessment is essential as these conditions represent totally different pathological processes, with different etiological factors and treatment protocols CBCT has been used successfully to confirm the presence of IRR(internal root resorption) and differentiate it from ERR(external root resorption).

Root canal perforation can occur as a procedural error that results in communication between the root canal wallsand the periodontal space; it is capable of affecting the prognosis of endodontic retreatment . Timely detection of perforations will aid in selecting the proper therapy, thus minimizing bone loss, and in predictingthe outcome and analyzing failures.

Radiographic detection is challenging on the labial and lingual rootsurface, 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 helpto identify fractured files, cast post deviations and perforations.(Fig 9)

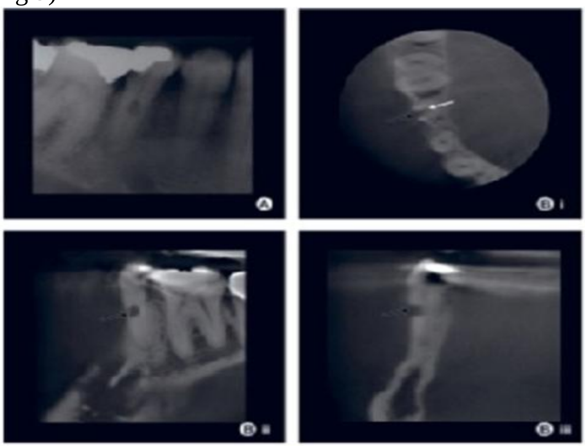

Figure 9. (a) Periapical radiograph of a mandibular second premolar tooth, which was affected by root resorption. It is unclearfrom the radiograph whether the root resorption is internal or external.(b) Axial(i),coronal (ii) and sagittal(iii)CBCT slices showed that the resorption originated on the external surface of the root (black arrows) and has perforated the root canal wall. The root canal shows no signs of internal resorption (white arrow)

6. Pre-surgical Assessment-

CBCT's three-dimensional imaging helps in visualising anatomical relationship of the roots and root apices to surrounding anatomical structures in any plane.In addition, the thickness of the cortical plate, the cancellous bone pattern, fenestrations, the shape of the maxilla and mandible as well as the inclination of the roots of teeth planned for periapical surgery should be able to be determined before starting surgery. CBCT play an important role in planning for periapical microsurgery on the palatal roots of maxillary first molars .

The distance between the cortical plate and the palatal root apex could be measured, and the presence or absence of the maxillary sinus between the roots could be assessed. By selecting relevant views and slices of data, the thickness of the cortical plate, the cancellous bone pattern, fenestrations, as well as the inclination of the roots of teeth planned for surgery, can be accurately determined preoperatively. [1]

In a study that compared anatomic landmarks usingCBCT imaging and intraoral periapical radiographs before apical surgery, the distance from thelower molars to the mandibular canal could be measured only in 24 of the 64 periapicalradiographs analyzed.

The use of CBCT imaging may be indicated for selecting cases when planning endodontic surgery, but the decision should be based on potential complicating factors, such as the proximity of important anatomic structures. Thus CBCT can help immensely in planning for endodontic surgeries.[3]

7. 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.

Fernández et al, evaluated the outcome of endodontic treatments as assessed byconventional and digital Periapical radiographs and CBCT during a 5-year follow-up period. It was found thatCBCT as more sensitive than periapicalradiographs for the visualization of periapical lesions in a long-term evaluation. Inaddition, it was found that the root canal curvature, failure to disinfect gutta-percha, the presence of missedcanals and inadequate definitive coronal restoration at follow-up were prognostic factors that negativelyinfluenced the outcome of treatment.[7]

8. Developmental anomalies -

Developmental anomalies should be carefully observed and considered during the diagnosis and treatment planning of teeth with anomalies in order to enhance the chances of success.The use of cone beam computed tomography (CBCT) is very helpful in endodontic diagnosis of complex developmental anomalies.
Dental anomalies include dens invaginatus, short roots, microdontia,taurodontism, gemination,
supernumerary teeth ,dentinogenesisimperfecta, agenesis, and malformations resulting from trauma. Theradiographic 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. Root canal treatment of teeth with complex root canal anatomy such as dens invaginatus, fused root, talon's cusp, etc, can be problematic because infected pulpal tissues may be in inaccessible areas of the canal system.[5]
Jaya R (2013) stated in case report of dilated invaginatedodontomewith talon cusp in a permanent maxillary central incisor which was diagnosed by cone beam computed tomography and concluded that CBCT was useful in the interpretation of this complex tooth anomaly in multiple slices along the three axes. The reconstructed 3D CBCT images of the involved tooth revealed a complex structure comprising a ring-like formation of the root. The CBCT axial images revealed the pulp space to be compressed and discontinuous within the ring. As the CBCT revealed a very complex root canal anatomy not amenable to successful cleaning and shaping, the choice of surgical or non-surgical endodontics was ruled out and the tooth was extracted. In order toenhance the chances of success rate anatomic variations should be carefully observed and considered during thediagnosis and treatment planning of teeth with anomalies .CBCT provides detailed information that canallow visualization ofthe root morphology, resulting in better treatment planning and postoperativeassessments.[7]

VI. CONCLUSION

For the diagnosis and management of endodontic disease, radiological examination is a key tool. Routinely it is done by two-dimensional intra-oralradiography which has various limitations. Such limitations overcome by using CBCT and it helps in diagnosis and thus improves theoutcome of endodontic treatment.

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