Cone Beam Computed Tomography: A new horizon in clinical endodontics

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Abstract

Successful management of endodontic problems depend on diagnostic imaging techniques to provide the critical information about the teeth under examination, and their surrounding hard and soft tissues. The introduction of cone-beam computed tomography (CBCT) specifically dedicated for imaging the maxillofacial region heralds a true paradigm shift from 2D to 3D approach to data acquisition and image reconstruction. The system overcomes many of the limitations of conventional radiography by producing undistorted, three-dimensional images of the area under examination. It is capable of providing sub-millimetre resolution in images of high diagnostic quality, with short scanning times (10–70 seconds) and radiation dosages reportedly up to 15 times lower than those of conventional CT scans. These systems produce images with small field of view at low radiation doses with adequate spatial resolution that are suitable for many applications in endodontics from diagnosis to treatment and follow-up. This article provides an overview of specific application of various CBCT display modes to clinical endodontic practice.

Keywords: Apical periodontitis, Cone-Beam Computed Tomography, Computed Tomography scan, Endodontics, Field of view, Periapical radiograph, Root resorption, three dimensional Imaging, Vertical root fracture.

Introduction

Imaging techniques play a very important role in diagnosis, treatment planning and post-operative monitoring in endodontics. Since its inception, conventional radiography has remained the foundation of imaging in endodontics.(1) Two dimensional (2D) conventional radiographs serve at all stages of endodontic treatment. They are used for preoperative, intra-operative, postoperative assessment and follow-up. Pre-operative stage imaging is required to assess the dental and alveolar hard tissue morphology and pathologic alterations to assist correct diagnosis. At intra operative stage working length determination and "master cone" selection radiography is essential. Post-operatively final confirmation of outcome of treatment is evaluated on radiographs.(1,2,3) Kells first reported the use of lead wire in root canal space on a "radiogram" in 1899.(3) Despite several applications in endodontics, there are still many shortcomings that can be named for conventional imaging techniques.(1) On the other hand the high radiation dose, cost, availability, poor resolution and difficulty in interpretation have resulted in limited use of Computed Tomography (CT) imaging in endodontics.(4)

Limitations of conventional 2D imaging techniques(5,6)

- The amount of information gained from conventional film and digitally captured intraoral and panoramic imaging is limited by the fact that they are two dimensional (2D) representation of a three dimensional (3D) object. The objects are visualized in the mesial-distal and apical- coronal plane; however the bucco-lingual plane is not possible to assess.
- Anatomical structures surrounding the teeth may superimpose causing anatomical noise, leading to difficulty in interpreting periapical radiographs.
- 2-D radiographs show less severe bone destruction than is actually present.
- Soft tissue to hard-tissue relationships are not revealed.

So, in case of diagnostic dilemma and treatment planning of special cases, advanced 3-D imaging modalities, revealing additional information is desirable.

The revolutionary introduction of Cone Beam Computed Tomography (CBCT) in all fields of dentistry is unprecedented as it has created a true paradigm shift from a conventional 2D approach to a 3D understanding.(7) Two main innovations have driven development of the imaging system. The first is the change from analog to digital imaging. Second, advances in imaging theory and volume-acquisition data have allowed for increasingly detailed 3-D imaging. Powerful low-cost computers, less expensive cone-beam x-ray tubes, and the development of high-quality flat-panel detectors have increased the affordability and quality of the imaging systems and made CBCT imaging in the dental office a reality.(8) The role of CBCT imaging techniques has been expanded from diagnosis to image guided operative and surgical dental procedures.(9) Unlike medical CT, which captures the image in slices, CBCT data are captured in a 3-D pixel unit called voxel. As these voxels are isotropic, the object is accurately measured in different directions.(10) This enables the rendering of geometrically undistorted images of the maxillo-facial skeletal structure and allows viewing at different angles. CBCT has been applied for oral and maxillofacial surgery, implantology, endodontics, orthodontics, periodontics and temporomandibular disorders (TMD).[11,12]

CBCT systems provide small field of view images at low radiation dose with sufficient spatial resolution for applications in endodontic diagnosis, treatment guidance and post treatment evaluation.

This article tends to review the fundamentals of CBCT and also its applications in contemporary endodontic practice

Cone Beam Computed Tomography (CBCT)

CBCT is a contemporary, three-dimensional, diagnostic imaging system designed specifically for use on the maxillofacial skeleton.[5] In the late 1990s, two independent Italian and Japanese groups developed a new tomographic scanner known as "CBCT" or "digital volume tomography (DVT)" specifically for maxillofacial and dental uses.[13] The Food and Drug Administration (FDA) approved the first CBCT unit for dental use in the United States in March 8, 2001.[14]

Imaging 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. The x-ray source and detector rotate around a rotation fulcrum fixed within the centre of the region of interest. During the rotation, multiple (from 150 to more than 600) sequential planar projection images of the field of view (FOV) are acquired in a complete, or sometimes partial, arc. This procedure varies from a traditional medical CT, which uses a fan-shaped x-ray beam in a helical progression to acquire individual image slices of the FOV and then stacks the slices to obtain a 3D representation. Each slice requires a separate scan and separate 2D reconstruction. Because CBCT exposure incorporates the entire FOV, only one rotational sequence of the gantry is necessary to acquire enough data for image reconstruction.[7,15]

Types of CBCT Equipment [14,15,16]

CBCT systems can be categorized according to the
1. Orientation of the patient during image acquisition
2. The scan volume irradiated
3. 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.

The majority of the CBCT machines scan the patient in a seated position, whereas a few scan the patient in either an upright or supine position.[8]

Scan Volume

The dimensions of the Field of view (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 based on available or selected scan volume height, the use of units can be designed as follows:
1. **Localized region** (also referred to as focused, small field or, limited field)—approximately 5 cm or less, (e.g., dentoalveolar, temporomandibular joint)
2. **Single arch**—5cm to 7 cm, (e.g., maxilla or mandible)
3. **Inter-arch**—7cm to 10 cm, (e.g., mandible and superiorly to include the inferior concha)
4. **Maxillofacial**—10 cm to 15 cm, (e.g., mandible and extending to Nasion)
5. **Craniofacial**—greater than 15 cm. (e.g., from the lower border of the mandible to the vertex of the head)

In general, the smaller the scan volume, the higher the spatial resolution of the image. As the earliest sign of periapical pathology is discontinuity in the lamina dura and widening of the periodontal ligament space, it is desirable that the optimal resolution of the any CBCT imaging system used in endodontics does not exceed 200 μm—the average width of the periodontal ligament space.[14]

The field of view (FOV) of limited CBCT ranges in diameter from 40 –100 mm, whereas the FOV of full CBVT ranges from 100 –200 mm. Another difference between the limited CBCT and full CBCT is that a voxel is generally smaller for the limited version (0.1– 0.2 mm vs 0.3– 0.4 mm).[8]

In endodontics, a limited or focused FOV CBCT is preferred over large volume CBCT for the following reasons.[17]
1. Increased resolution to improve the diagnostic accuracy of endodontic-specific tasks such as the visualization of small features including calcified/accessory canals, missed canals, etc.
2. Highest possible spatial resolution that provides a diagnostically acceptable signal-to-noise ratio.
3. Decreased radiation exposure to the patient.
4. Time savings due to smaller volume to be interpreted.
5. Focus on anatomical area of interest.

CBCT Image Production[15,18]

The four components of CBCT image production are as follows:

Acquisition configuration	Continuous or pulsed x-ray beam and charged couple device detectors moving synchronously around a fixed fulcrum within the patient's head.
Image detection	It is determined by individual volume elements or voxels produced from the volumetric data set. CBCT units provide voxel resolutions that are isotropic.
Image reconstruction	The processing of acquired projection frames to the volumetric dataset is done on the personal computer which is called as reconstruction.
Image display	The compilation of all available voxels is presented to the clinician on the computer screen as secondary reconstructed images in three orthogonal planes.

Endodontic applications of CBCT(19-22)

In 2011, the American Association of Endodontists (AAE) and the American Academy of Oral and Maxillofacial Radiology (AAOMR) issued a joint position statement regarding the use of CBCT in endodontics.(23) Perhaps the most important advantage of CBCT in endodontics is that it demonstrates anatomic features in 3D that intraoral, panoramic and cephalometric images cannot. CBCT units reconstruct the projection data to provide inter-relational images in three orthogonal planes (axial, sagittal, and coronal). Due to the isotropic nature of the voxels constituting the volumetric dataset, image data can be sectioned non-orthogonally. Most software provides for various non-axial 2D images in multiplanar reformation (MPR). Such MPR modes include oblique, curved planar reformation (providing "simulated" distortion free panoramic images) and serial transplanar reformation (providing cross-sections), which can be used to highlight specific anatomic regions for diverse diagnostic tasks. Enhancements including zoom magnification, window/level adjustments and text or arrow annotation can be applied. Cursor-driven measurement algorithms provide the clinician with an interactive capability for real-time dimensional assessment. On-screen measurements are free from distortion and magnification.

A. Evaluation of Root canal morphology

The success of endodontic treatment depends on the identification of all root canals so that they can be accessed, cleaned, shaped, and obturated.(3)

CBCT can be used to determine root morphology, to measure the number of roots, canals, and accessory canals. Root morphology can be visualized in 3-D, as can the number of root canals and whether they converge or diverge from each other. Unidentified and untreated root canals may be identified using axial slices, which may not be readily identifiable with periapical radiographs. In contrast, with increasing resolution of CBCT, the detection rate of second mesiobuccal canal (MB2) of maxillary first molar enhanced from 60% to 93.3%. CBCT has also been shown to be a reliable tool to accurately assess the degree of curvatures associated with the roots of teeth.(5) It also easily identifies C shaped root canal system.

B. Diagnosis of Endodontic Pathoses

CBCT is significantly more accurate and sensitive than conventional radiography in the identification of apical periodontitis (AP). It can be used as a gold standard with a sensitivity and specificity of 1.0 to detect the presence or absence of periapical diseases.(3) CBCT detected the periapical lesions 62% more than conventional radiographs.(1) In a study, Bender and Seltzer showed that a lesion becomes radiographically evident only after the cortical plate of the bone has been involved. Such limitations can be overcome by the CBCT technology.(16)

In addition, it can demonstrate bone defects of the cancellous bone and cortical bone separately. As a result, the identification of AP was substantially higher with CBCT than with periapical radiograph. Patel et al. used an in vitro model consisting of 2 mm diameter defects placed in the cancellous bone at the apices of ten first molar teeth on six partially dentate intact human dry mandibles. They reported a detection rate of 24.8% and 100% for intraoral radiography and CBCT imaging, respectively. A few research studies have shown that contrast-enhanced CBCT images can be used to differentiate between apical granulomas and apical cysts by measuring the lesion density.(18) CBCTs can also help in the diagnosis of pathosis of nonendodontic origin in order to determine the extent of the lesion and its effect on surrounding structures. Additional findings such as expansion of the lesion into the maxillary sinus, thickening of the sinus membrane, missed canals and presence of apico-marginal communications were more frequently detected with CBCT than with periapical radiography.(3) Estrela and colleagues proposed a periapical index based on cone beam-computed tomography (CBCTPAI) for identification of AP. The CBCT PAI is a 6-point (0–5) scoring system calculated from determining the largest lesional measurement in either the bucco-palatal, mesio-distal, or diagonal dimension and taking into account expansion and destruction of cortical bone.(22,24)

CBCT Periapical Index Score	
Score	**Quantitative bone alterations in mineral structures**
0	Intact periapical bone structures
1	Diameter of periapical radiolucency > 0.5-1mm
2	Diameter of periapical radiolucency > 1-2mm
3	Diameter of periapical radiolucency > 2-4mm
4	Diameter of periapical radiolucency > 4-8mm
5	Diameter of periapical radiolucency > 8mm
Score(n) +E	Expansion of periapical cortical bone
Score (n) +D	Destruction of periapical cortical bone

C. Assessment of Dental anomalies

CBCT aid in the determination of appropriate treatment, prognosis, assessment and treatment planning of teeth with developmental anomalies, such as the 'Dens Invaginatus' "Concrescence" "Fusion" or 'Dilaceration', 'Taurodontism', which require endodontic treatment.[5,14]

D. Assessment of traumatic dental injuries

In the literature, the advantages of CBCT have been emphasized in the assessment and management of dento-alveolar trauma. The exact nature and extent of the injuries to the teeth and the alveolar bone can be assessed accurately by eliminating anatomical noise and image compression, thereby allowing appropriate treatment to be confidently implemented.[5] The degree and direction of displacement associated with luxation injuries can be evaluated easily using CBCT. In addition, CBCT has been shown to be much more sensitive in detection of horizontal root fractures than multiple periapical radiographs. Furthermore, as CBCT is an extraoral imaging modality, patient comfort is enhanced during the imaging process. This is particularly pertinent in the assessment of dental trauma where patient difficulty in accommodating bulky film holders and image receptors for conventional imaging is exacerbated by potentially mobile teeth and painful oral and dental tissues[5]

E. Diagnosis of vertical root fractures

Detecting the presence of vertical root fractures (VRF) is a clinical challenge in endodontics. While a deep, isolated, periodontal pocket is suggestive of VRF, however, even clinical signs of longstanding VRF maybe little more than a draining buccal sinus, which is definitely not pathognomonic of the problem. It should be noted that radiographic appearances suggestive of VRF such as J-shaped and halo-shaped radiolucencies do not appear until considerable bone destruction has occurred and similar shaped radiolucencies may occur in cases of AP not associated with VRF.[1,25] CBCT is considered superior to periapical radiographs in the detection of fractures in buccolingual or mesiodistal directions, and in the measurement of depth in dentin.[18] Small-FOV CBCTs should be used for representing VRFs of endodontically treated teeth. However, because scatter produced by the root filling or other high density intra-radicular materials may incorrectly suggest the presence of a fracture, it should be taken into consideration when assessing root filled teeth for VRF using CBCT.[5] To detect VRFs reliably by CBCT, and considering the ALARA principle, 0.2mm resolution is the best choice for diagnostic use.[3]

F. Pre-surgical Assessment

Pre-surgical case planning is essential to determine the exact location of root apex/apices and to evaluate the proximity of adjacent anatomical structures in order to reduce the risk of post-operative complications. 3D imaging helps in visualizing anatomical relationships of roots and root apices to surrounding anatomical structures in any plane. In addition the thickness of cortical plate, the cancellous bone pattern, fenestration, the shape of maxilla and mandible as well as the inclination of roots of teeth could be determined before surgery.[3] Three-dimensional imaging also allows assessment of the anatomical relationship of the root apices to important anatomical structures, such as the inferior dental canal, mental foramen and maxillary sinus.

Jay Simonton et al in 2009 have evaluated whether age & gender differences have any change in the position of the inferior alveolar nerve which was important for presurgical evaluation using CBCT. They found out that females have a closer distance of the root apices to inferior alveolar nerve & decreased horizontal mandibular bone width than males. Also as age increased from 3rd – 6th decade of life, bone width significantly decreased regardless of the gender.[3] It was concluded that CBCT may 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.

G. Assessment of periapical healing using the cone beam computed tomography periapical index

An important aspect of the postoperative assessment of endodontic patients, is the careful and periodic monitoring of the healing progress of apical lesions. In the study of Paula-Silva et al the comparative outcomes of endodontic treatment in dogs six months after the treatment, the success rates of the treatment were found to be 79% with IOPA and 35% when CBCT was used. In a similar clinical study by Liang et al to compare the outcome of endodontic treatment in humans, success rates of endodontic treatment were found to be 87% when assessed by conventional intraoral radiographs, and 74% when assessed by CBCT.[5] These findings suggest that CBCT is indeed a more sensitive marker for the success of endodontic treatment, as compared to conventional radiography.[15]

H. Root resorption

The diagnosis of root resorption relies on the radiographic demonstration of the process. The sensitivity of conventional radiography is significantly poorer than CBCT in the detection of external root resorption in its early stages and significant hard tissue damage may have potentially occurred to the affected tooth before the resorption becomes evident on conventional radiographs.[5] Patel et al. reported CBCT to be 100% accurate in the diagnosis of the presence, type and extent of the root resorption. The reconstructed images reveal if the resorptive lesion has perforated the root canal or has perforated into the adjacent periodontium (Mainiet al.2008).[3] On CBCT, external resorption presents itself as irregular radiolucency and intact root canal, whereas internal resorption has clearly defined borders with no canal radiographically visible in the defect.[3]

Advantages[13,26,27,28]

The use of CBCT technology in clinical dental practice provides a number of advantages for maxillofacial imaging.

a. It demonstrates anatomic features in 3D that intraoral, panoramic, and cephalometric images cannot.
b. Rapid scan time.
c. Image accuracy. It can generate a size of voxel (a 3D cuboid unit of images) as small as 0.125 mm in dimension, which contributes to its high resolution and quality.
d. CBCT units reconstruct the projection data to provide interrelational images in three orthogonal planes (axial, sagittal, and coronal). In addition because reconstruction of CBCT data is performed natively using a personal computer, data can be reoriented in their true spatial relationships.
e. Reduced patient radiation dose compared to conventional CT. One study reported that the average radiation effective dose of CBCT is within 36.9 and 50.3 microsievert, which is up to a 98 percent reduction compared to fan-beam CT systems.
f. CBCT volumetric data is isotropic, which means all three dimensions of the image voxels are the same. This makes it possible to reorient the images to fit the patient's anatomic features and perform real-time measurements.
g. CBCT units provide choices for field of view (FOV), which allows irradiation of particular area of interest to dentists, while limiting irradiation of other tissues. This function contributes to excellent resolution and minimal radiation risk for patients.

Limitations of CBCT[5,13,26,27]

1. One major disadvantage of CBCT is that it can only demonstrate limited contrast resolution, mainly due to relatively high scatter radiation during image acquisition and inherent flat panel detector related artifacts. If the objective of the examination is hard tissue only, using a CBCT would not be a problem; however, CBCT is not sufficient for soft tissue evaluation.
2. A significant issue that can affect the image quality and diagnostic accuracy of CBCT images is the scatter and beam hardening artifacts caused by high density adjacent structures, such as enamel and radiopaque materials such as metal posts, restorations and root filling materials.[3]
3. Additional artifacts that may obscure radiographic findings are patient movement during the scan and volume reconstruction.
4. Despite the provision of the third dimension, the spatial resolution of CBCT images (0.4mm to 0.076mm or equivalent to 1.25 to 6.5 line pairs permm−1 (lp.mm−1)) is inferior to conventional film based (approx. 20 lp.mm−1) or digital (ranging from 8–20 lp.mm−1) intraoral radiography.[3]

Clinical Recommendations[20,29,30,31,32]

- CBCT must not be used routinely for endodontic diagnosis or for screening purposes in the absence of clinical signs and symptoms. The patient's history and clinical examination must justify the use of CBCT by demonstrating that the benefits to the patient outweigh the potential risks. Clinicians should use CBCT only when the need for imaging cannot be answered adequately by conventional dental radiography or alternate imaging modalities.[7]
- In general, the use of CBCT in endodontics should be limited to the assessment and treatment of complex endodontic conditions such as:
- Identification of potential accessory canals in teeth with suspected complex morphology based on conventional imaging.
- Identification of root canal system anomalies and determination of root curvature.
- Diagnosis of dental periapical pathosis in patients who present with contradictory or nonspecific clinical signs and symptoms, who have poorly localized symptoms associated with an untreated or previously endodontically treated tooth with no evidence of pathosis identified by conventional imaging, and in cases where anatomic superimposition of roots or areas of the maxillofacial skeleton is required to perform task-specific procedures.
- Diagnosis of non-endodontic origin pathosis in order to determine the extent of the lesion and its effect on surrounding structures.

- Intra- or post-operative assessment of endodontic treatment complications, such as overextended root canal obturation material, separated endodontic instruments, calcified canal identification, and localization of perforations.
- Diagnosis and management of dento-alveolar trauma, especially root fractures, luxation and/or displacement of teeth, and alveolar fractures.
- Localization and differentiation of external from internal root resorption or invasive cervical resorption from other conditions, and the determination of appropriate treatment and prognosis.
- Pre-surgical case planning to determine the exact location of root apex/apices and to evaluate the proximity of adjacent anatomical structures.
- According to the recommendations made by the American Association of Endodontics and the American Academy of Oral and Maxillofacial Radiology, dental clinician must justify the need to use CBCT and select clinical cases carefully.

Conclusion

This review paper highlights the potential uses of CBCT in the assessment and management of endodontic problems. Traditional 2-D imaging will always be an acceptable first choice in the diagnosis and treatment of dental pathology. However, cone beam imaging is now becoming a complementary technology and in many instances a necessary part of the diagnostic armamentarium in endodontics. This technology offers surprisingly low amounts of absorbed radiation while offering information never before available in clinical practice. Based on the limited number of studies included, a routine use of CBCT imaging for endodontic patients in clinical practices could not be justified. It should only be prescribed when traditional 2-D imaging is unable to provide the necessary information for diagnosis and treatments, especially in assessment and treatment of complex endodontic conditions. CBCT is a complementary modality for specific applications rather than a replacement for 2D imaging modalities.

References

1. Amir Hosein Kiarudi, Mohammad Jafar Eghbal, Yaser Safi, Mohammad Mehdi Aghdasi, Mahta Fazlyab. The Applications of Cone-Beam Computed Tomography in Endodontics: A Review of Literature. Iranian Endodontic Journal 2015;10:16-25.
2. Scarfe WC, Levin MD, Gane D, Farman AG. Use of cone beam computed tomography in endodontics. Int J Dent. 2009;63:45-67.
3. Dr. Shibu Thomas Mathew. Newer dimensions in Endodontics: Cone Beam Computed Tomography. IRJEI.2015;1:66-86.
4. Deepak B.S, Satyajith Naik, Nandini D.B. Seeing the Unseen: Cone Beam Volumetric Tomography and Endodontics: A Review Article. Annals and essence of Dentistry. 2010;2:110-113.
5. Conor Durack, Shanon Patel. Cone Beam Computed Tomography in Endodontics. Braz Dent J 2012; 23: 179-91.
6. Langland OE, Langlais RP. Early pioneers of oral and maxillofacial radiology. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology. 1995;80:496–511.
7. Nandita Shenoy, Junaid Ahmed, Sanjay M. Mallya. Add a third dimension to your patient care with cone beam computed tomography. Journal of Interdisciplinary Dentistry.2014;4:118-123.
8. Taylor P. Cotton, Todd M. Geisler, David T. Holden, Scott A. Schwartz and William G. Schindler. Endodontic Applications of Cone-Beam Volumetric Tomography. J Endod 2007;33:1121–32.
9. Li Jingyi, Lim J Z Adrienne, Lum H B Song, Saion A M Muhamad and Mei Li. Clinical Applications of Cone-Beam Computed Tomography in Endodontics: A Systematic Review. J Dent App. 2014;1:16-20.
10. Tynd all DA, Rathore S. Cone beam CT diagnostic applications: Caries, periodontal bone assessment and endodontic applications. Dent Clin North Am. 2008;52:825-41.
11. Alamri HM, Sadrameli M, Alshalhoob MA, Sadrameli M, Alshehri MA. Applications of CBCT in dental practice: a review of the literature. Gen Dent. 2012;60:390-400.
12. Mol A. Imaging methods in periodontology. Periodontol 2000. 2004;34:34-48.
13. Arai Y, Tammisalo E, Iwai K, Hashimoto K, Shinoda K. Development of a compact computed tomographic apparatus for dental use. Dentomaxillofac Radiol. 1999;28:245-8.
14. William C. Scarfe, Martin D. Levin, David Gane, Allan G. Farman. Use of Cone Beam Computed Tomography in Endodontics. International Journal of Dentistry. 2009;1-20.
15. William C. Scarfe, Allan G. Farman. What is Cone-Beam CT and How Does it Work? Dent Clin N Am.2008;52:707–30.
16. Varsha H Tambe. Cone-Beam Computed Tomography (CBCT) in endodontics: A Review. American Journal of Advances in Medical Science. 2014;2:64-74.
17. Laxmish Mallya, Nandita Shenoy, Junaid Ahmed, Almas Binnal, Kanchana Kamath. An Update on the Use of Endodontics in CBCT. British Biomedical Bulletin.2014;2:467-71.
18. Mobeen Khan, Anjani Kumar Shukla, Md Asad Iqubal, Swetarchi, Moazzam Jawaid. International Journal of Medical Science And Clinical Inventions.2015;2:682-90.
19. Kishoreraju Kothapalli, Ravishankar PL, Koganti Vijayprasad, Goutham Chakravarthy. Cone-Beam Computed Tomography (CBCT) -Three Dimensional Diagnoses in Dental Practice. Res Adv Dent 2013;2:1-6.
20. Low KM, Dula K, Burgin W, von Arx T. Comparison of periapical radiography and limited cone-beam tomography in posterior maxillary teeth referred for apical surgery. J Endod. 2008;34:557-62.
21. Lofthag-Hansen S, Huumonen S, Grondahl K, Grondahl HG. Limited cone-beam CT and intraoral radiography for the diagnosis of periapical pathology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2007;103:114-9.
22. C. Estrela, M. R. Bueno, C. R. Leles, B. Azevedo, and J. R. Azevedo. Accuracy of cone beam computed tomography and panoramic and periapical radiography

for detection of apical periodontitis. Journal of Endodontics. 2008;34:273– 9.

23. Joint Position Statement of the American Association of Endodontists and the American Academy of Oral and Maxillofacial Radiology. Use of cone-beam computed tomography in endodontics. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2011;111:234–7.
24. C. Estrela, M. R. Bueno, B. C. Azevedo, J. R. Azevedo, and J. D. Pecora. A new periapical index based on cone beam computed tomography. Journal of Endod. 2008;34:1325–31.
25. Tamse A, Fuss Z, Lustig J, Kaplavi J. An evaluation of endodontically treated vertically fractured teeth. J Endod. 1999;25:506-8.
26. William C. Scarfe, Allan G. Farman, Cone beam computed tomography: A paradigm shift for clinical dentistry. Australasian Dental Practice. 2007;102-8.
27. Shawn Adibi, Wenjian Zhang, Tom Servos, Paula N. O'Neill. Cone Beam Computed Tomography in Dentistry: What Dental Educators and Learners Should Know. Journal of Dental Education. 2012;76:1437-42.
28. Schulze D, Heiland M, Thurmann H, Adam G. Radiation exposure during midfacial imaging using 4 and 16-slice computed tomography: cone beam computed tomography systems and conventional tomography. Dentomaxillofac Radiol 2004;33:83–6.
29. Cotton TP, Geisler TM, Holden DT, Schwartz SA, Schindler WG. Endodontic applications of cone-beam volumetric tomography. J Endod. 2007;33:1121-32.
30. Cohenca N, Simon JH, Mathur A, Malfaz JM. Clinical indications for digital imaging in dentoalveolar trauma. Part 2: root resorption. Dent Traumatol. 2007;23:105-13.
31. Nair MK, Nair UP. Digital and advanced imaging in endodontics: a review. J Endod. 2007;33(1):1-6; Low KMT, Dula K, Bürgin W, von Arx T. Comparison of periapical radiography and limited cone-beam tomography in posterior maxillary teeth referred for apical surgery. J Endod. 2008;34:557-62.
32. Noujeim M, Prihoda TJ, Langlais R, Nummikoski P. Evaluation of high-resolution cone beam computed tomography in the detection of simulated interradicular bone lesions. Dentomaxillofac Radiol. 2009;38:156-162.

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