(e) ISSN Online: 2321-9599

(p) ISSN Print: 2348-6805

REVIEW ARTICLE

APPLICATIONS OF CBCT IN SPECIAL REFRENCE TO DENTISTRY

Tarun Vyas

Senior Lecturer ,Dept. of Oral Medicine and Radiology, R R Dental College & Hospital, Umarda, Udaipur (Rajasthan)

ABSTRACT:
Cone beam computed tomography (CBCT) is having three dimensional technology which has revolutionized the imaging of the maxillofacial region significantly in time that it has a very wide range of applications in all the fields of dentistry ranging from diagnosis to the treatment planning. CBCT has often been considered as the "gold standard" for imaging the oral and maxillofacial area and will become a part of everyday life in coming decades. It should not be considered as replacement of panoramic or conventional projection radiographic applications but rather as a complimentary modality for specific applications.
Key words: CBCT, Dental, Cone Beam Computed Tomography.

Corresponding author: Dr. Tarun Vyas, Senior Lecturer, Dept. of Oral Medicine and Radiology, R R Dental College & Hospital, Umarda, Udaipur (Rajasthan)

This article may be cited as: Vyas T. Applications of CBCT in special reference to dentistry. J Adv Med Dent Scie Res 2017;5(4):67-76.

Access this article online	
Quick Response Code	Website: www.jamdsr.com
	DOI: 10.21276/jamdsr.2017.5.4.15

INTRODUCTION:

Conventional two-dimensional (2D) imaging modalities have been used in dentistry since the first intraoral radiograph was obtained in year 1896. Since then, dental imaging techniques have advanced strength by strength with the introduction of tomography and panoramic imaging. More recent advances in digital diagnostic imaging have resulted in lower radiation doses and faster processing times without ampering the diagnostic quality of the intraoral or panoramic images. However, 2D images possess inherent limitations which include magnification, distortion, and superimposition that can make it possible to mis-intert pretcures[1]. Cone beam CT (CBCT) was first developed for use in angiography. In year 1998, Mozzo et al reported the first CBCT unit developed specifically for dental use, the New Tom 9000 (Quantitative Radiology, Verona, Italy)[2]. CBCT is well suited for imaging the craniofacial area. It provides clear images of highly contrasted structures and is extremely useful for evaluating hard tissues of maxillofacial region. CBCT allows the creation in "real time" of images not only in the axial plane but also 2-dimensional (2)D images in the coronal, sagittal and even oblique or curved image planes - a process referred to as multi-planar formation (MPR). In addition, CBCT data are amenable to reformation in a volume, rather than a slice, providing 3-dimensional (3D) information[2,3] Recent decades have given the clear witness about the development of imaging modalities such as Computed Tomography (CT), Magnetic Resonance Imaging (MRI), nuclear medicine and ultra-sonography that have revolutionized dental and medical diagnosis fields. Static projection images were relied upon for diagnoses in the maxillofacial region, but we are now proceeding toward digital, 3-dimensional and interactive imaging applications. Much of this movement is attributed to a recently introduced modern CT technology known as cone-beam computed tomography. It is considered by many as "what was missing" in the field. The original CT technology which is employed extensively in medical diagnosis is designated as medical CT, and the newer modality used primarily in dentistry is Cone-Beam Computed Tomography (CBCT) also termed as Cone-Beam Volumetric Tomography (CBVT), Dental Volumetric Tomography, Cone-Beam Volumetric Imaging (CBVI), or Dental Computed Tomography.

PRINCIPLE OF ACTION:

The principle of CBCT is based on a fixed x-ray source and detector with a rotating gantry. The x-ray source emits a cone-shaped beam of ionizing radiation that passes through the centre of the scan region of interest (ROI) in the patient's head to the x-ray detector on the other side. The gantry bearing the x-ray source and detector rotates around the patient's head in 360 degree arcs. (Figure 1A & B) .While rotating, the x-ray source emits radiation in a continuous or pulsed mode allowing projection radiographs. or "basis images"[2]. These are similar to lateral cephalometric radiographic images, each slightly offset from one another. This series of basis projection images is referred to as the projection data. Software programs incorporating sophisticated algorithms including back-filtered projection are applied to these image data to generate a 3D volumetric data set, which can be used to provide primary reconstruction images in 3 orthogonal planes (axial, sagittal and coronal).[4] (Figure 2)

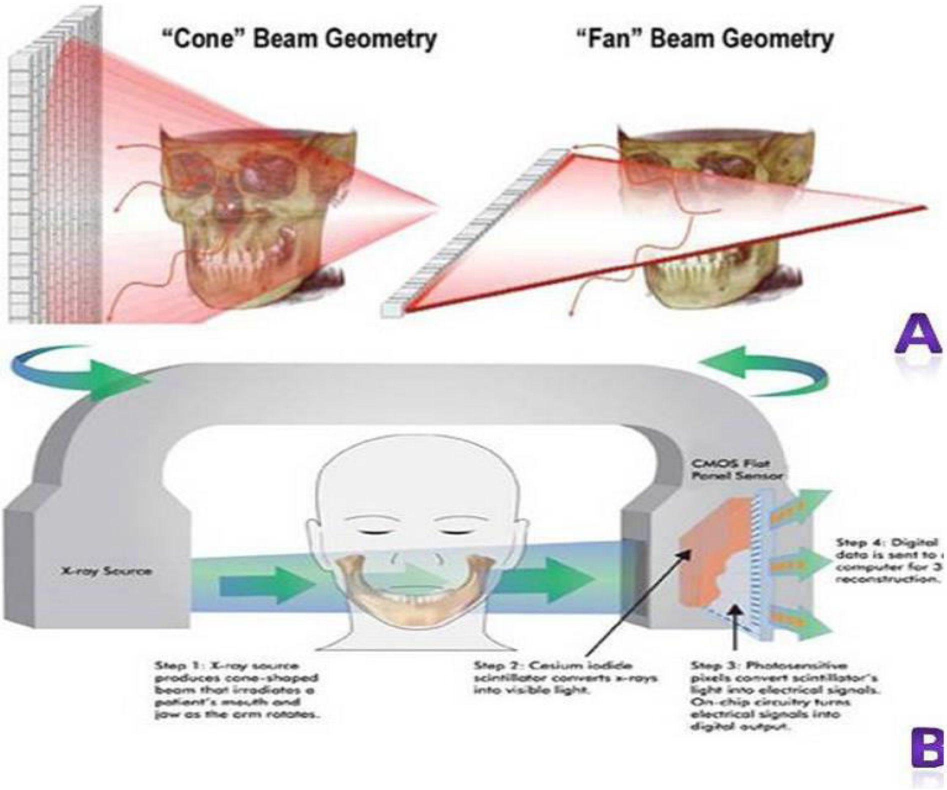

Figure 1. A: Difference between Cone –Beam and Fan-Beam Geometry B: Procedure of Image acquisition in CBCT

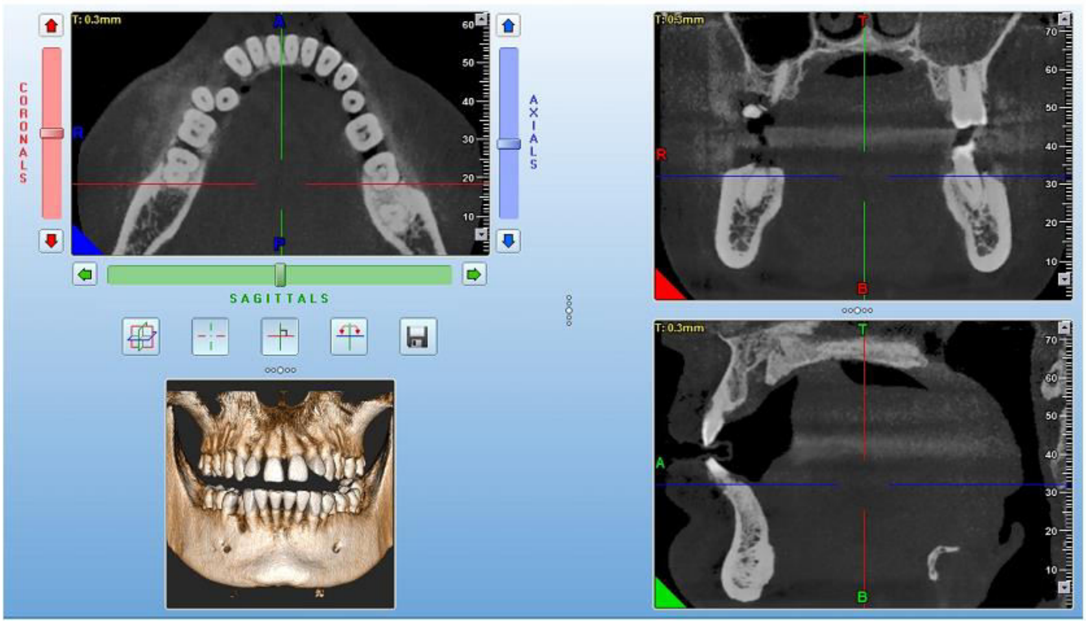

Figure 2. A multiplanar display panel of CBCT showing axial, coronal, sagittal and 3D –reconstructed images

CBCT systems can be categorized according to the available Field Of View (FOV) or selected scan volume height as follows 4:Localized region: approximately 5 cm or less
(eg, dentoalveolar, temporomandibular joint) Single arch: 5 cm to 7 cm (eg, maxilla or mandible)
Interarch: 7 cm to 10 cm (eg, mandible and superiorly to include the inferior concha)
Maxillofacial: 10 cm to 15 cm (eg, mandible and extending to Nasion) Craniofacial: greater than 15 cm (eg, from the lower border of the mandible to the vertex of the head)

DIFFERENT IMAGING TECHNIQUES AND REQUIRED RADIATION EXPOSURE[5]

Imaging	Effective dose μSv
Intra oral radiograph	<8.3
Panoramic	9-26
Cephalometric radiograph	3-6
Cone beam CT(focused field of view) (dento-alveolar)	5-38.3
Full mouth series radiograph	35-388
Cone beam CT-Craniofacial	68-599
Medical fan beam CT–maxilla and mandible	2000

BASIC PRINCIPLES

The SEDENTEXCT project aimed to acquire key information necessary for sound and scientifically based clinical use of dental Cone Beam Computed Tomography (CBCT). As part of this aim, the project set an objective of developing evidence based guidelines for dental and maxillofacial use of CBCT. European Academy of Dento Maxillo Facial Radiology (EADMFR) and SEDENTEXCT, a decision was taken to collaborate in the development of a set of "Basic Principles" for the use of dental CBCT, based upon existing standards. These standards include fundamental international principles, EU Directives (Council of European Union, 1996, 1997) and previous Guidelines (European Commission 2004)[6]. A set of 20 "Basic Principles" on the use of dental CBCT were thus established. These act as core standards for EADMFR and are central to this Guideline publication.

The "Basic Guidelines Features "

1. CBCT examinations must not be carried out unless a history and clinical examination have been performed
.2. CBCT examinations must be justified for each patient to demonstrate that the benefits outweigh the risks.
3. CBCT examinations should potentially add new information to aid the patient's Management.
4. CBCT should not be repeated 'routinely' on a patient without a new risk/benefit assessment having been performed.
5. When accepting referrals from other dentists for CBCT examinations, the referring dentist must supply sufficient clinical information (results of a history and examination) to allow the CBCT Practitioner to perform the Justification process.
6. CBCT should only be used when the question for which imaging is required cannot be answered adequately by lower dose conventional (traditional) radiography.
7. CBCT images must undergo a thorough clinical evaluation ('radiological report') of the entire image data set.
8. Where it is likely that evaluation of soft tissues will be required as part of the patient's radiological assessment, the appropriate imaging should be conventional medical CT or MR, rather than CBCT
9. CBCT equipment should offer a choice of volume sizes and examinations must use the smallest that is compatible with the clinical situation if this provides less radiation dose to the patient.
10.Where CBCT equipment offers a choice of resolution, the resolution compatible with adequate diagnosis and the lowest achievable dose should be used.
11.A quality assurance programme must be established and implemented for each CBCT facility, including equipment, techniques and quality control procedures.
12.Aids to accurate positioning (light beam markers) must always be used.
13.All new installations of CBCT equipment should undergo a critical examination and detailed acceptance tests before use to ensure that radiation protection for staff, members of the public and patient are optimal.
14.CBCT equipment should undergo regular routine tests to ensure that radiation protection, for both practice/facility users and patients, has not significantly deteriorated.
15.For staff protection from CBCT equipment, the guidelines detailed in Section 6 of the European Commission document 'Radiation Protection136. European Guidelines on Radiation protection in Dental Radiology' should be followed.
16.All those involved with CBCT must have received adequate theoretical and practical training for the purpose of radiological practices and relevant competence in radiation protection.
17.Continuing education and training after qualification are required, particularly when new CBCT equipment or techniques are adopted.
18.Dentists responsible for CBCT facilities who have not previously received 'adequate theoretical and practical training' should undergo a period of additional theoretical and practical training that has been validated by an academic institution (University or equivalent). Where national specialist qualifications in DMFR exist, the design and delivery of CBCT training programmes should involve a DMF Radiologist.
19.For dento-alveolar CBCT images of the teeth, their supporting structures, the mandible and the maxilla up to the floor of the nose (e.g. 8cm x8cm or smaller fields of view), clinical evaluation('radiological report') should be made by a specially trained DMF Radiologist or, where this is impracticable, an adequately trained general dental practitioner.
20.For non-dento-alveolar small fields of view (e.g.temporal bone) and all craniofacial CBCT images(fields of view extending beyond the teeth, their supporting structures, the mandible, including the TMJ, and the maxilla up to the floor of the nose).

IMPLANTOLOGY

The application of CBCT has left a great impact in the implant area more than any other in dentistry. It provides cross-sectional images in various planes of the alveolar bone height, width and angulation and accurately locates the vital structures such as inferior alveolar canal in mandible and the sinus in the maxilla. The science CBCT in implantology has added safety and accuracy and has minimized or eliminated the need for supportive procedures like bone and tissue grafts in many situations. Radiographic markers can be inserted at the time of scan to which serves as a precise reference of the location of proposed implants. Stents provide fiducial radiographic landmarks that can be used to correlate proposed clinical location and angulation of implants with the available alveolar bone[7]. With the help of DICOM data the computer-generated surgical guides (sterolithographic models, Figure 3) can be fabricated from the CBCT data to eliminate the work and possible inaccuracy of taking impressions and making traditional guide stents.[8] The surgeon can place implants in their optimal and exact positions more accurately, predictably, and safely as planned in virtual software (Figure 3a & b) using technology and minimally invasive surgery is performed without raising a flap, thereby minimizing surgery time, postoperative pain and swelling, and recovery time. The dental laboratory uses the information stored in the surgical template to fabricate presurgically a master cast and provisional restoration that can be placed immediately after surgery (Teeth-in-an-Hour).

Fig.3 (a): A Sterolithographic model.

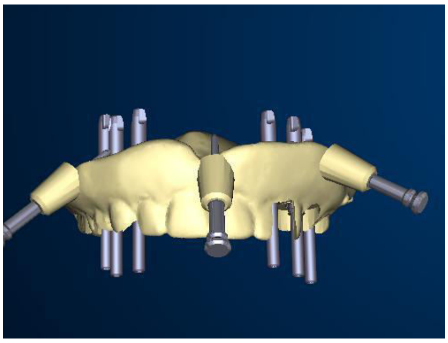

Fig. 3(b): Implant placement site assessment.

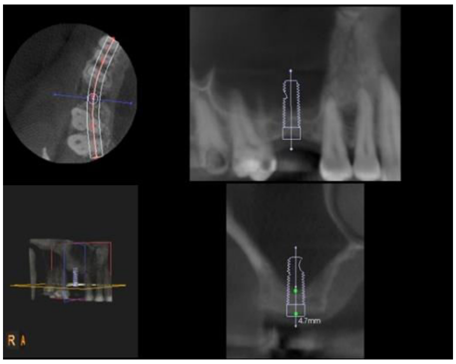

Fig.4: Implant site assessment and imaginary position of implant to be placed.

The use of computer-guided implant surgery has greatly enhanced the dental implant team's ability to plan, place, and restore implants accurately, with a level of precision that was unattainable a few years ago. It offers the patient an advanced level of care with reduced treatment time and a predictable final result.[9]

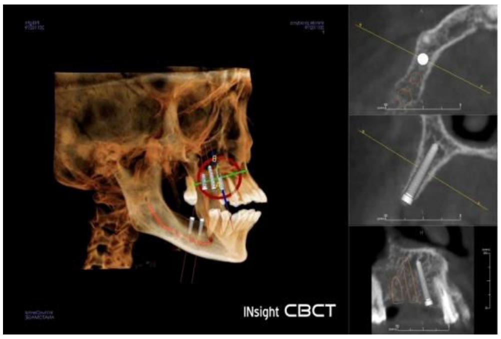

Fig. 5: Evaluation of surrounding bone in all planes after placement of implant.

ORTHODONTICS

Orthodontists have used an arsenal of radiographs to diagnose and treatments plan their patient's cases carefully.[10] Cephalometric, panoramic, periapical, and other radiographs have generally been 2D representations of 3D anatomic structures.[11] CBCT offers a 3D image that can be used to aid in orthodontic tooth movement in all three planes of space. CBCT provides the display of position of impacted and supernumerary teeth and their relationships to adjacent roots and other anatomic structures facilitating planning of the subsequent movement (Figure.6).

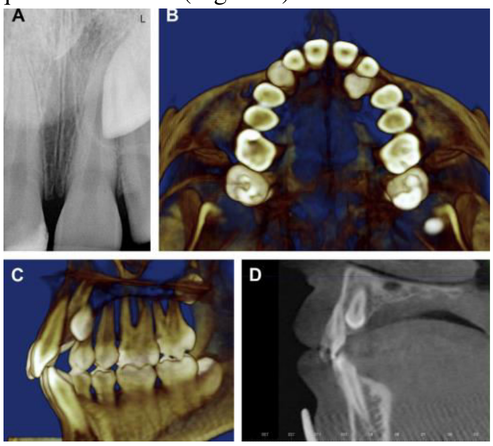

Fig. 6: (A) Periapical radiograph displaying impacted teeth. (B) CBCT axial image showing the palatal position of tooth #11. (C) CBCT image of the relationship between teeth **2**2 and **2**4. (D) Sagittal CBCT image displaying the proximity of **2**3 to the root of **2**4.

Miniscule details about the root resorption, available bone width for the buccolingual movement of teeth, tooth inclination and torque can be obtained. It also provides adequate visualization of the soft tissue relationships. It is possible to extract the topographic features of the skull, soft tissue interfaces in high detail by using a variety of orthodontic-centered products. There are numerous potential benefits to 3D cephalometry including accuracy of linear measurements, visual demonstration of dentoskeletal relationships and facial esthetics, and the potential for assessment of growth and development are perhaps the greatest potential benefits of CBCT in orthodontics. CBCT also enables in Cephalometric analysis (Fig:7)[12,13]

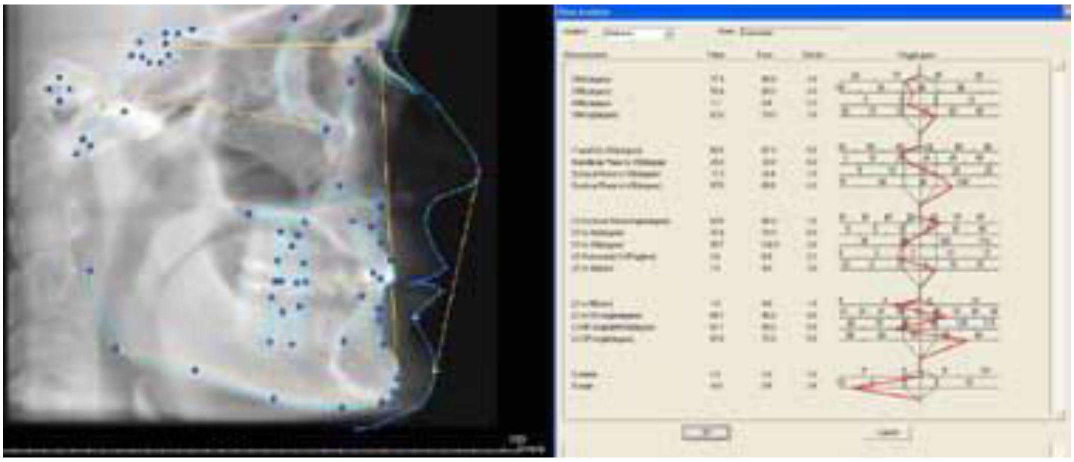

Fig. 7: Cephalometric analysis in CBCT.

TEMPOROMANDIBULAR JOINT

The application of conventional CBCT in imaging the TMJ has been most significant in the evaluation of hard tissue or bony changes of the joint[14] It provides 3D images of the condyle and surrounding structures to facilitate analysis and diagnosis of bone morphologic features, joint space and dynamic function, which serves as critical keys for providing treatment outcomes in patients with TMJ signs and symptoms (Fig8).[15] Pathologic changes, such as osteophytes, condylar erosion, fractures, ankylosis, dislocation, and growth abnormalities such as condylar hyperplasia, rheumatic arthritic disease, degenerative joint diseases are optimally viewed on CBCT.[16]

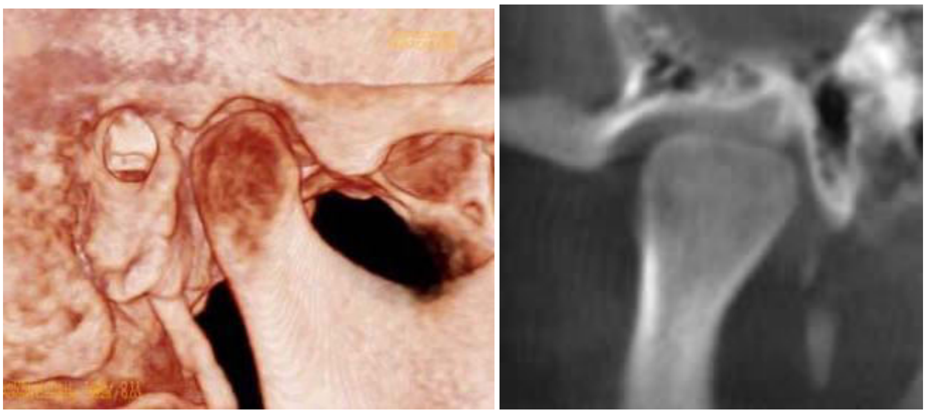

Fig. 8: 3-D reconstructed image of TMJ.

LOCATION OF INFERIOR ALVEOLAR CANAL

The accurate assessment of the position of the inferior alveolar canal to the roots of mandibular third molar (Fig:10) may reduce the injuries to nerve in extraction of impacted third molar and during implant placement which avoids the permanent loss of sensation to the lower lip. Traditional panoramic imaging may be adequate when the third molar is clear of the canal, but in the case of radiographic superimposition it is advisable to use a 3-D imaging approach.[17] This can be achieved at comparatively low radiation dose with CBCT combined either with the proprietary software accompanying the imaging device or with third party diagnostic software (Fig:9).

Fig 9: Third party software used to demonstrate location of the inferior alveolar canal to impacted third molar in 3D images.

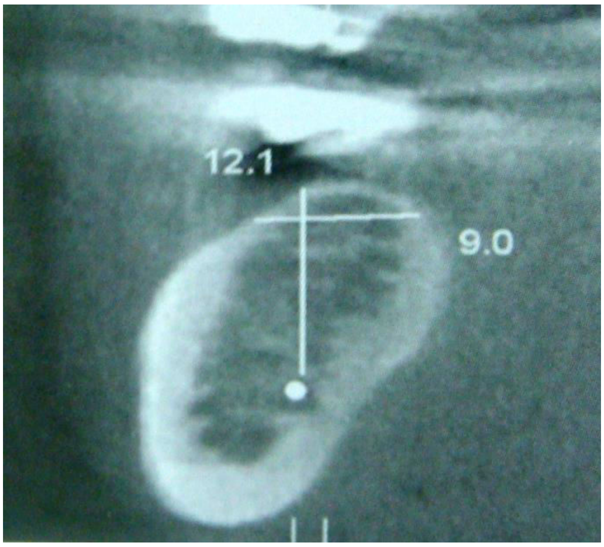

Fig. 10: The white dot indicates the location of inferior alveolar canal for the implant site assessment and for allowing the measurement of alveolar bone height and width.

ENDODONTICS

The technology has not yet been perfected for accurate caries detection using the cone beam scanner[18] CBCT imaging for caries should be limited to non restored teeth. Still we do not know the effect of beam hardening on producing possible artifacts and false-positives. Apparently, sensitivity may increase with CBCT but it should not be at the cost of specificity.

The three-dimensional scanning of all the roots of a tooth during endodontic treatment to detect perforation or aberrant canals is useful.[19] This application alone can prevent the loss of countless numbers of teeth each year. CBCT for endodontic purposes appears to be the most promising use of CBCT, in many instances instead of 2D images. Applications would include apical lesions, root fractures, canal identification, and characterization of internal and external root resorption (Fig11).[17]

PERIODONTICS

The time-honored method for monitoring periodontal bone loss has been through the use of a periodontal probe and bitewing radiographs.[48] Although this method is inexpensive, it is technique-sensitive and does not allow full visualization of the area. In addition to added visualization with CBCT images, most software includes tools for evaluating and monitoring bone density, which may help assess the effectiveness of treatment, predict the results of treatment, or identify areas of future concern (Fig: 12). As for periodontal disease, CBCT promises to be superior to 2D imaging for the visualization of bone topography and lesion architecture but no more accurate than 2D for bone height.[21] This factor should be tempered with awareness that restoration in the dentition may obscure views of the alveolar crest.

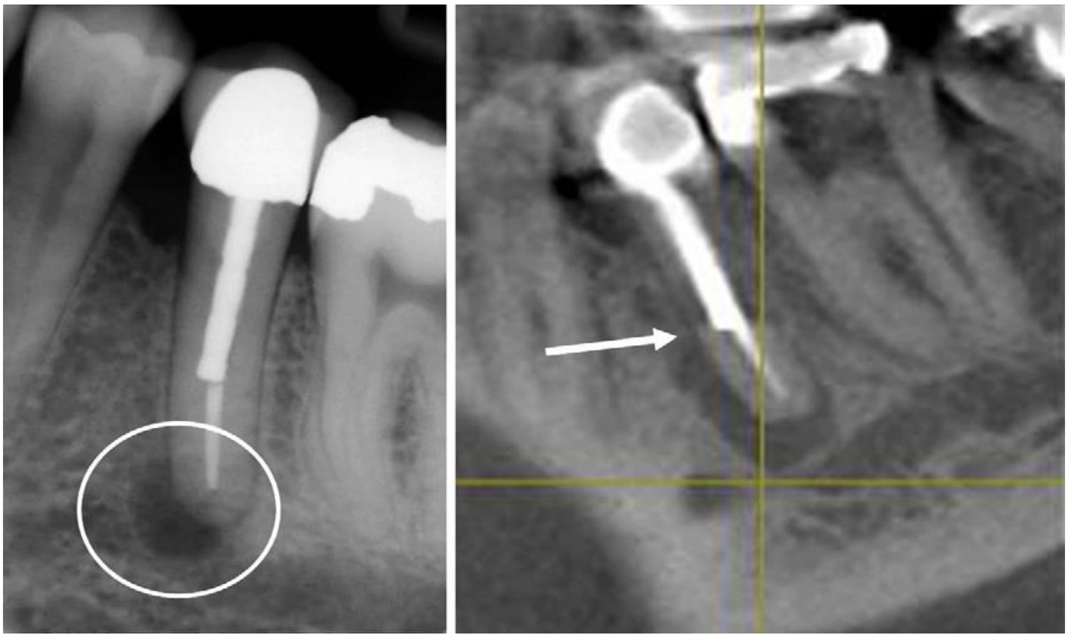

Fig. 11: In this case, the standard 2D periapical radiograph did not reveal the true extent of the apical lesion (circle). The pattern of the lesion suggests a root fracture (arrow). In this case, the treatment of the tooth was changed from re-treating the root canal to extracting the tooth.

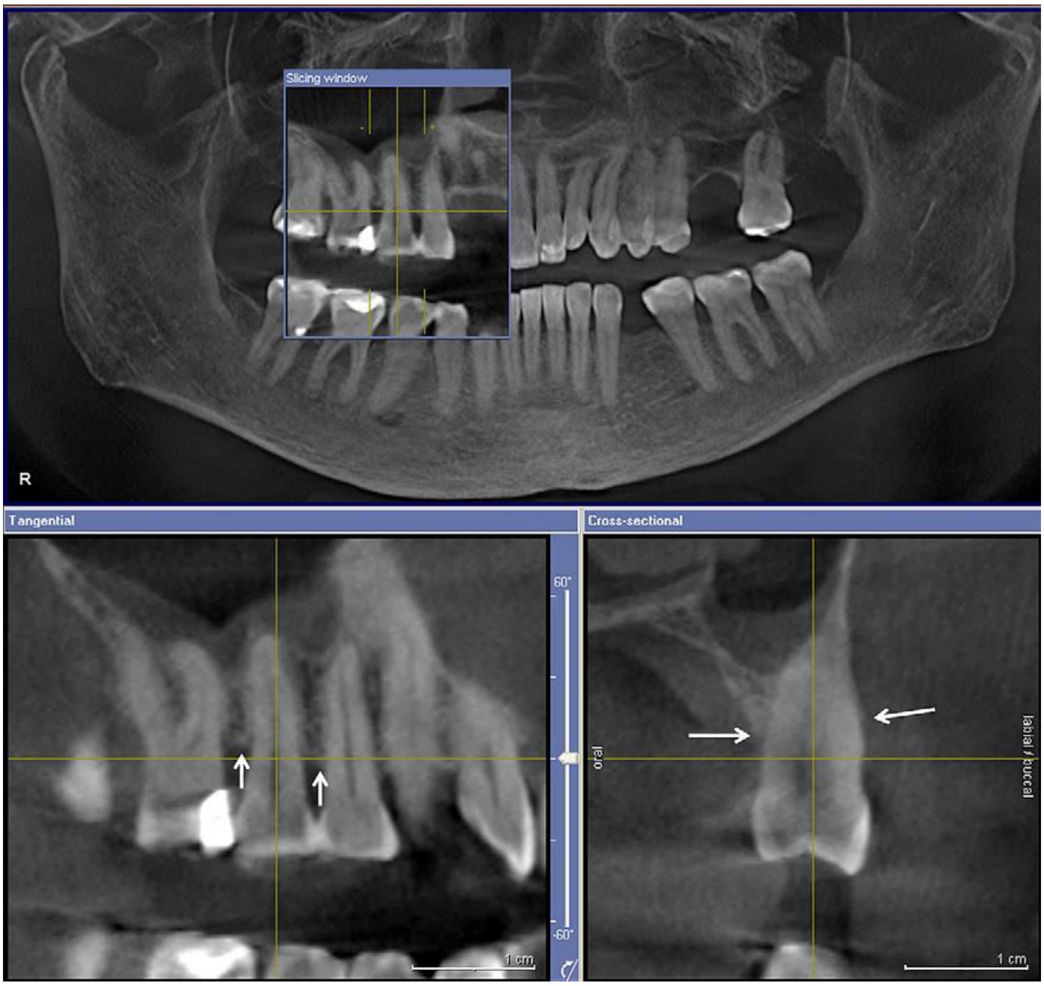

Fig. 12: Three-dimensional depiction of periodontal bone loss around maxillary second premolar tooth. The arrows indicate the extent of bone loss on the facial, palatal, mesial, and distal aspects of the tooth.

ORAL AND MAXILLOFACIAL SURGERY

In the areas of oral surgery and oral pathology, the data from the CBCT can have a profound impact on decision making. The location and root configuration of impacted and erupted teeth can be seen with exceptional clarity. The proximity to adjacent structures can be seen and measured with digital accuracy. The extension of periapical lesions, areas of bone destruction, and involvement of the maxillary sinus are all clearly defined. Even those ''spots'' seen on traditional radiography can be pinpointed and diagnosed, eliminating the question of artifact and allowing the dentist to give patients definitive diagnoses.

Visualizing oral and maxillofacial pathologic entities in three dimensions assists in the diagnosis, as well as in planning the appropriate treatment. As compared with plain film tomograms, CBCT technology requires less time for the images to be captured, which is useful for patients who are not comfortable or are unable to keep still. In addition, the images generated via CBCT are less distorted and give the practitioner a better understanding of the density of the bone being imaged.

While panoramic radiography has been the workhorse for most dental and oral and maxillofacial surgery practices, the images generated do have some shortcomings. Only flat, two dimensional, supero-inferior or postero-anterior images are created.

In addition, as is typical with plain film radiography, panoramic X-rays suffer from superimposition of all structures that lie in the path between the x-ray source and the film or detector. CBCT allows these anatomic entities to be viewed in three dimensions and be included or excluded in the final image by simple digital manipulation (Fig. 13). Furthermore, panoramic images are both distorted and magnified, which means that unreliable result are produced when measuring distance on panoramic radiographs, even when the magnification factor is known.

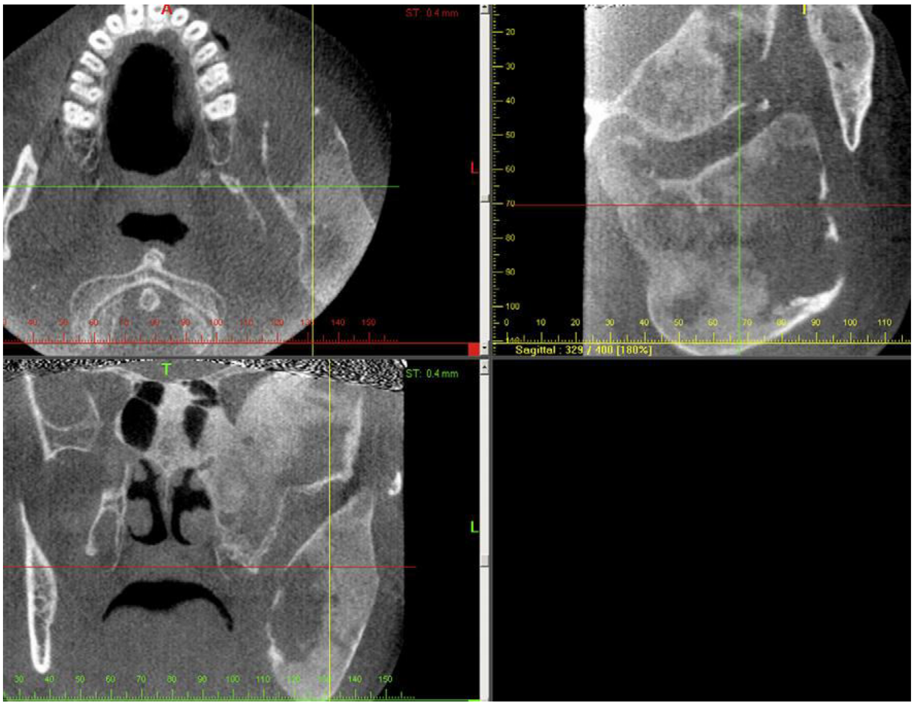

Fig. 13: Axial, sagittal, and coronal images present a more complete extent of the lesion, showing its penetration to include the complete ramus, coronoid process, and condyle, as well as the maxilla and malar bone.

3-D RECONSTRUCTION

CBCT utilizes the data to reconstruct 3-D study models which with be helpful for physician's analysis and as well as patient's education.[22,23] Augmented 3-D reconstructed models can provide accurate visualization of the interocculsal relationship (Fig: 14). The more advanced 3-D reconstruction consists of reconstructions of various structures like hard tissues, soft tissues and other tissues[24](Fig: 15). Using 3-D reconstruction data surgeries can be planned and osteotomies can be performed. Hence, presurgical and post surgical treatment planning can be evaluated.[25]

Fig.14: 3D study models.

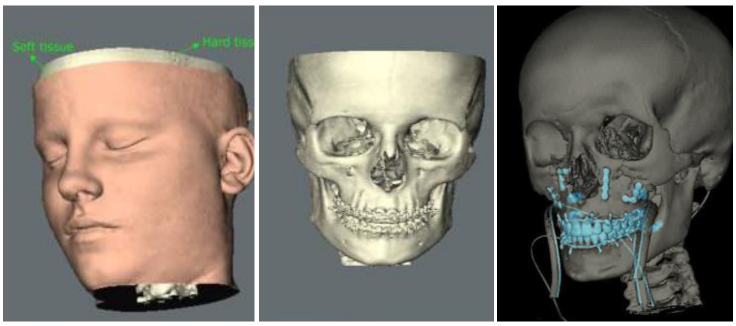

Fig.15: Soft tissue and hard tissue.

VIRTUAL IMAGING / COMBINED 3D PHOTOGRAPHY AND CBC

The patients photograph can be superimposed over the reconstructed CBCT image to obtain a picture, which will enable in the education of the patient treatment plan and also used to evaluate the outcome of the treatment planning.[26]

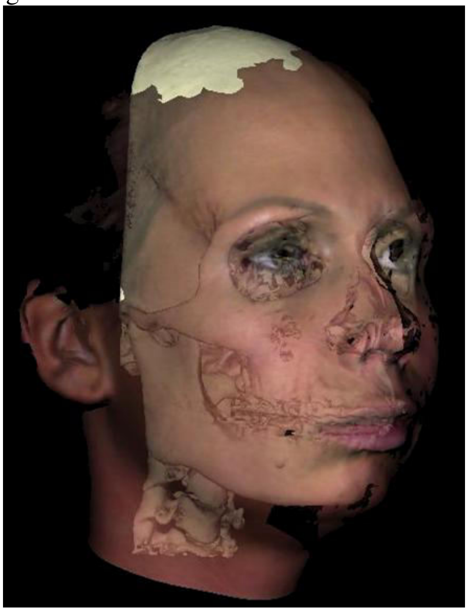

Fig. 16: Photograph superimposed over the 3D reconstructed image.

SLEEP APNOEA

Sleep apnoea occurs due to abnormalities in the upper respiratory airway. CBCT helps to visualize the source of obstruction.[27,28]

DISCUSSION

Cone Beam Computed Tomography (CBCT) is an exciting array of imaging modality which provides outstanding images contributes to the accuracy of diagnostic tasks in the maxillofacial region. The first CBCT was used for angiography in 1982. Since then with the rapidly progressing technology the current CBCT systems have shaped into such a way that the images produced by the capable of providing 3-D visualization of complexity of maxillofacial region. All current generations of CBCT systems provide useful diagnostic images. A thorough understanding and knowledge about the appearances of the anatomic structures in various sections (coronal, axial, sagittal) on a CBCT is necessary to interpret the images.

It has got varied applications in the field of dentistry chiefly includes implantology, orthodontics, oral and maxillofacial surgery, periodontics, location of inferior alveolar canal and to lesser extent in fields of endodontics, oral and maxillofacial pathology, detection of sleep apnoea and the advance applications include 3-D reconstruction, virtual imaging.

CBCT has got innumerable advantages like beam limitation, image accuracy , interactive display modes applicable to maxillofacial imaging, multi -planar reformation, ray sum or ray casting, three – dimensional volume rendering , radiation dose, room space, time taken for imaging, relative with conventional CT as well it has got a very few disadvantages like poor soft tissue contrast, image noise and artifacts, cone beam related artifacts, patient related artifacts, partial volume averaging, scanner related artifacts.

No doubt, future improvements in CBCT technology with Computer Added Advanced Technology will result in systems with even more favorable diagnostic yields and lower doses. If a drop in prices occurs, then an age where CBCT imaging is the primary form of dental imaging may dawn. For now, CBCT imaging can be seen as highly useful, indispensable part of the dental imaging armamentarium.

CONCLUSION

It is an exciting time in dentistry, where we can reach beyond the limitations of our senses to see what is really happening in the mouth and associated hard structures with the help of the most advanced technology the Cone Beam Computed Tomography.

It is the imaging system introduce for the imaging of the maxillofacial region which is capable of providing accurate sub millimeter resolution images at a shorter scan times, lower dosage and costs compared to medical fan beam CT. The increasing availability of this technology provides practitioner with an imaging modality capable of providing a 3-D representation that is extending maxillofacial imaging from diagnosis to image guidance of operative and surgical procedures.

CBCT is being increasingly used for point-of-service head and neck and dentomaxillofacial imaging. This technique provides relatively high isotropic spatial resolution of osseous structures with a reduced radiation dose compared with conventional CT scans.

CBCT has often been described as the ‘‘gold standard’’ for imaging the oral and maxillofacial area and will no doubt become a part of the everyday life of most practices in the coming decades.

REFERENCES:

1. Scarfe WC, Farman AG. What is cone-beam CT and how does it work? Dent Clin North Am 2008;52(4):707-730.
2. Scarfe WC, Farman AG, Sukovik P. Clinical Applications of Cone-Beam Computed Tomography in Dental Practice. J Can Dent Assoc 2006; 72(1):75–80.
3. Ziegler CM, Woertche R, Brief J, Hassfeld S. Clinical indications for digital volume tomography in oral and maxillofacial surgery. Dentomaxillofac Radiol 2002;31(2):126–30.
4. Kawamata A, Ariji Y, Langlias R Three dimensional computed tomography in dentistry Dent Clin North Am 2000,44:2:395-410.
5. Nomura Y, Watanabe H, Honda E, Kurabayashi T.Reliability of voxel values from cone-beam computed tomography for dental use in evaluating bone mineral density. Clinical Oral Implants Research. 2010;21(5):558-62.
6. Horner K, Islam M, Flygare L, Tsiklakis T, Whaites E. Basic principles for use of dental cone beam computed tomography: Consensus guidelines of the European Academy of Dental and Maxillofacial.Radiology. Dentomaxillofac Radiol 2009; 38(4):187-195.

7. Parel SM, Triplett RG. Interactive imaging for implant planning, placement, and prosthesis construction. J Oral Maxillofac Surg 2004;9:41–7.
8. D' Urso PS, Barker TM, Earwaker WJ, et al . Stereolithography biomodelling in craniomaxillofacial surgery: a prospective trial, J Craniomaxillofac Surg 1999: 27:3037.
9. Marchack CB. CAD/CAM-guided implant surgery and fabrication of an immediately loaded prosthesis for a partially edentulous patient. J Prosthet Dent 2007;97:389–94.
10. Holberg C, Steinhauser S, Geis P, et al. Cone beam computed tomography in orthodontics, benefits and limitations. J Orofacac Orthop 2005 66: 434-444.
11. Rakosi T. Cephalometry and radiographic analysis. In: Carruthers GB, editor. An atlas and manual of cephalometric radiography. London: Wolfe Medical Publications Ltd; 1982. p.7.
12. Moshiri M, Scarfe W, Hilgers M, et al. Accuracy of linear measurements from imaging plate and lateral cephalometric images derived from cone-beam computed tomography. Am J Orthod Dentofacial Orthop 2007;132 (4):550–60.
13. Swenen GR, Schutyser F. Three dimensional cephalometry: spiral multi-slice vs cone beam computed tomography, Am J Orthod Dentofacial Orthop 2006. 130:410-416.
14. Epstein J.B, Rea A, Chahal O. The use of bone scintigraphy in temporomandibular joint disorders. Oral Dis 2002;8:47–53.
15. Brooks SL, Brand JW, Gibbs SJ, et al. Imaging of the temporomandibular joint. A position paper of the American Academy of Oral and Maxillofacial Radiology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1997;83:609–18
16. Frederiksen N. Specialized radiographic techniques. In: White S, Pharoah M, editors. Oral radiology: principles and interpretation. 4th edition. St. Louis (MO): Mosby; 2000.p. 217–40.
17. Scarfe Wc, Farman AG, Sukovic P. Clinical applications of Cone beam computed tomography in dental practice. J Can Dent Assoc 2006. 72:75-80.
18. Kalathingal SM, Mol A, Tyndall DA, et al. In vitro assessment of cone beam local computed tomography for proximal caries detection. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;104:699–704.
19. Cotton TP,Geisler TM, holden DT, et al. Endodontic applications of Cone beam volumetric tomography, J Endod 2007: 33:1121-1132.
20. Mol A. Imaging methods in periodontology. Periodontol 2000;2004(34):34–8.
21. Lascala CA, Panella J, Marques MM. Analysis of the accuracy of linear measurements obtained by cone beam computed tomography (CBCT-NewTom). Dentomaxillofac Radiol 2004;33:291–4.
22. Danforth RA. Cone beam volume tomography: a new digital imaging option for dentistry. J Calif Dent Assoc 2003;31:814–5.
23. Endo M, Tsunoo T, et al: Effect of scattered radiation on image noise in CBCT.Med Phy 2001. 28:469-474.
24. Feldkamp LA,et al.Practical cone beam algorithm.J Opt Soc Am.1984. 612-619.
25. Siewerdsen Jh, Jaffray DA: Cone beam computed tomography with a flat panel imager : magnitude and effects of X-ray scatter. Med Phys 2001.28:220-231.
26. Punjabi NM. The epidemiology of adult obstructive sleep apnea. Proc Am Thorac Soc 2008. Feb;5(2):136–43.
27. Koo BB, Dostal J, Ioachimescu O, et al. The effects of gender and age on REM-related sleep disordered breathing. Sleep Breath 2007;12(3):259–64.
28. Bixler EO, Vgontzas AN, Lin HM, et al. Prevalence of sleep-disordered breathing in women: effects of gender. Am J Respir Crit Care Med 2001;163(3 Pt 1):608–13.

Source of support: Nil **Conflict of interest:** None declared