Journal of Advanced Medical and Dental Sciences Research

@Society of Scientific Research and Studies

Journal home page: www.jamdsr.com doi: 10.21276/jamdsr ICV 2018= 82.06

(e) ISSN Online: 2321-9599; (p) ISSN Print: 2348-6805

Review Article

Cone Beam Computed Tomography: Applications in Various Branches of Dentistry

Harmanjit Kaur Dhillon

Intern, Sri Guru Ram Das Institute of Dental Sciences and Research, Amritsar, Punjab, India

ABSTRACT

Cone beam computed tomography (CBCT) has upgraded diagnostics in medical field in general and dentistry in particular. It is tremendously being used for diagnosis and treatment planning in various specialities of dentistry and this multiplanar imaging technique is the best diagnostic approach for dental practitioners. The integration of CBCT imaging in dentistry has some ways paralleled the transition of panoramic imaging x-ray machines into dental practice. Greater accuracy of measurements with low radiation dose has made CBCT a preferred option in dentistry. CBCT allows "real time" creation of images not only in the axial plane but also 2D images in coronal, sagittal, and even oblique or curved image planes. Weighing all the advantages in application of this tool it's use in each case has to be considered individually to ensure that the benefits provided overshadow the risks of additional radiation and other concerns.

Key words: Cone Beam Computed Tomography, dentistry, diagnostics.

Received: 26 October, 2019 Revised: 21 November, 2019 Accepted: 23 November, 2019

Corresponding Author: Dr. Harmanjit Kaur Dhillon, Intern, Sri Guru Ram Das Institute of Dental Sciences and Research, Amritsar, Punjab, India

This article may be cited as: Dhillon HK. Cone Beam Computed Tomography: Applications in Various Branches of Dentistry. J Adv Med Dent Scie Res 2020;8(1): 110-113.

Introduction

CBCT is a medical imaging technique consisting of divergent X-Rays which is increasingly being used in diagnosis and treatment planning in various aspects of dentistry and medicine. CBCT is a boon to dentistry in imaging of the maxillofacial region and has brought a true paradigm shift from 2D to 3D imaging. Several terminologies are used for CBCT such as dental volumetric tomography, cone-beam volumetric tomography, cone-beam imaging, and dental computed tomography.[1]

First commercial CBCT unit marketed to dental use was introduced in Europe in 1999.[2] This imaging technique is based on a cone-shaped X-ray beam centred on a 2-D detector that performs one rotation around the object, producing a series of 2-D images. These images are reconstructed in 3-D using modifications of the original cone beam algorithm developed by Feldkamp *et al.* in 1984.[3] CBCT imaging is performed using a rotating platform to which the X-ray source and detector are fixed. As the X-ray source and detector rotate around the object, it produces multiple, sequential, and planar images that are mathematically reconstructed into a volumetric dataset. A single rotational sequence would capture enough data for volumetric image construction. The entire scanning of the target region is performed in a single rotation thereby significantly reducing the radiation exposure.[4] Soft tissue enhancement is one of the benefits and this is utilised to showcase eye popping color images and videos.

Radiography has been playing an important role in endodontics since Kells first described how we can visualise lead wire in a root canal in establishing the length of root canal. Hence, CBCT heralds an important role in various aspects of dental and medical field. The most common indication for cone-beam imaging in dentistry are evaluation of the jaws for placement of dental implants, examination of teeth and facial structures for orthodontic treatment planning, assessment of temporomandibular joints (TMJs) for osseous degenerative changes, estimation of the proximity of the lower wisdom teeth to the mandibular nerve before surgical procedure, evaluation of teeth for root fracture or periapical disease, and assessment of bone for signs of infections, cysts, or tumors.[1] Alongwith above applications, it has also been employed in periodontics, sleep disorders, airway analysis, forensic dentistry. This article will review how CBCT can be used to best effort when imaging a dental patient and its use in different dental specialities, assessing its principles and limitations.

Background

Sir Godfrey N. Hounsfield developed the first CT scanner in 1967. In 1982, the first CBCT scanner was built for angiography at Mayo. After 1990, an initial period of rapid development, CT technology was rapidly established. In 1997, the department of radiology of the Nihon University School of Dentistry developed a dental radiology unit using a new technology known as limited cone-beam computed tomography. In 2000, the first CBCT to be approved by the FDA for dental use in the US was NewTom from Verona (Italy).[1]

During the early development of CBCT, the technology was being advanced primarily for dental offices. The integration of CBCT imaging in dentistry has some ways paralleled the transition of panoramic imaging x-ray machines into the dental offices. Early panoramic units were mainly sit-down, but there was also a lay-down unit.[5], the NewTom 9000 (QR srl Verona, Italy), which was one of the very first commercially available cone beam machines. It was a large unit that scanned the patient lying in a supine position. It was then followed by NewTom 3G. These eventually lost appease to smaller, stand-up units or sit-down chair units. CBCT units scanning patients in supine position have made a comeback. Currently available are NewTom 5G(QR srl) and SkyView (MyRay, Imola, Italy).

Intra-oral and extra-oral radiographs captured on plain films and digital sensors are two-dimensional shadowgraphs, which represent the absorption of incident X-ray beam as it penetrates different structures before exposing the image receptor. The amount of useful information gained from these radiographic techniques is limited as the complex anatomical structures between X-ray source and image receptor are compressed into this two-dimensional shadowgraph [6] but there is often a degree of geometric distortion and magnification of the resultant image . Wherein, three-dimensional imaging is provided in CT and has been used to defeat the innate problems with conventional two dimensional radiographic techniques.

It is interesting to note that as imaging technology has evolved the emphasis has shifted from complex to simple mechanisms and from simple film-based image acquisition to sophisticated electronic data acquisition and computer processing.[6]. It offers striking high speed imaging of hard and soft tissues but X-ray dose is high and the equipment is exceptionally expensive and generally only found in hospital settings.

Principle

The CBCT imaging utilises the principle of tomosynthesis. In a single scan, the X-ray source and a reciprocating solid state flat panel detector rotates around the patient's head using a cone shaped beam. The patient's anatomy is replicated into a single, 3D volume that comprises volume elements (VOXELS).[1] 2D digital array is used in CBCT scanners which provides area detector rather than linear detector. the voxel resolutions are isotropically equal in all three dimensions. The software allows viewing and reformatting of the image data from any point of view and the anatomy can be seen in all 3 dimensions layer by layer.

The X-ray parameters of CBCT is comparable to that of panoramic radiography with a usual operating range of 1-15 mA at 90-120 kVp, while that of CT is considerably higher at 120-150 mA and 220 kVp. The captured 2D images are instantaneously conveyed to the computer, which reconstructs them, using modified Feldkamp algorithm into the anatomical volume for viewing at 1:1 ratio in axial, coronal, and sagittal planes.[7]

There are four components[1] of CBCT image production:

(1) Acquisition configuration
(2) Image detection
(3) Image reconstruction
(4) Image display.

The various display modes provided in CBCT apart from basic orthognathic views are oblique slicing, curved slicing, cross-sectional view, ray sum, volume rendering.

Applications

Implantology

CBCT is particularly useful in implant dentistry. Greater accuracy of measurements with low radiation dose has made CBCT a preferred option in implant dentistry.[2] Preoperative imaging is done to determine the quality, height and width of alveolar bone available for implant placement. It helps to assess the proximity to vital anatomical structures such as the inferior dental canal as in mandibular posterior region, mental foramen, maxillary sinus, ostium, and floor of the nasal cavity. Any possible incidental pathology can also be assessed. CBCT aids in selecting appropriate implant size and type. CBCT-derived implant surgical guides can be fabricated. Communication of diagnostic and treatment planning information to all the members of implant team becomes easy. It also significantly reduces surgery time. It helps to assess both bone quantity and quality hence is useful in evaluating the post-treatment success of bone grafts.

Oral and maxillofacial surgery

CBCT is gaining popularity amongst dentists because of its extensive accessibility. CBCT enables the assessment of impacted teeth, jaw pathologies (odontogenic and non-odontogenic tumours, cysts). Osteomyelitis, pathologic calcifications (salivary gland stones, tonsilloliths, lymph nodes). Facial trauma such as mandibular head fracture, dental root fractures and other craniofacial fractures is an insightful application of CBCT. Since it is not a magnetic resonance technique, it is the best option for intra-operative navigation during procedures, including gun-shot wounds.[3] It helps in reviewing benign and malignant lesions of the oral and maxillofacial region. Benign lesions of the jaws have varied radiographic appearances.[2] These advantages of CBCT have made it the choice for exploring and handling midfacial and orbital fractures including dentoalveolar fractures, post fracture evaluation, interoperative visualization of the maxillofacial bones, and intraoperative navigation throughout procedures.[7]

Orthodontics

CBCT is recommended in orthodontics in those cases where diagnostic information delivered by conventional radiography is not satisfactory. It has enhanced precision in localization, an additional precise angulation of canine and other impacted and transposed teeth. CBCT scans can be used to reliably assess cervical vertebrae maturity, which provides for a consistent evaluation of skeletal maturity [8]. It is a vital tool in patients with cleft palate, craniofacial anomalies, facial asymmetry, large anterior open bite, unerupted tooth, supernumerary teeth, root resorption, and for planning of orthognathic surgery. Three-dimensional CBCT-assisted airway analysis also facilitates diagnosis and treatment planning of complex anomalies including enlarged adenoids and obstructive sleep apnoea.[9] It allows assessment of TMJ complex in 3D and cleft palate evaluation. Placement of temporary anchorage devices (TADs) are supplemented by CBCT. Orthognathic growth assessments and treatment planning is in true 1:1 imaging with its help.[1]

Endodontics

CBCT is an important diagnostic tool in endodontics. It is used for identification and measurement of extent of periapical lesions. Inconspicuous cases of vertical root fractures are best diagnosed with CBCT. [10] It is preferred to periapical radiographs in detection of root perforations, fractures in mesiodistal or buccolingual direction, horizontal root fractures and in locating the second mesiobuccal canal (MB2) on maxillary first molar. It aids in demonstrating lesion juxtaposition to maxillary sinus, sinus membrane involvement and lesions located relative to mandibular canal. Furthermore, CBCT has been suggested for classifying the source of the lesion as endodontic or non-endodontic, which may influence treatment plan [7]. It gives an accurate assessment of root canal fillings, helps in the detection of pulpal extensions in talon cusps and also helpful in detecting the position of fractured instruments[10]. The accuracy of CBCT in detecting surface defects is much higher than conventional imaging modalities, but is not perfect and appears to increase with increasing voxel resolution of the volumetric dataset. [11]

Periodontics

Until very recently, 2-D imaging was the mainstay in diagnosing periodontal diseases. But now it is comprehensive that CBCT in morphometric analysis of periodontal diseases is as precise as direct measurement using a periodontal probe. In addition, CBCT is far better than 2D radiographs in visualization of buccal and lingual defects due to absence of superimposition of the structures [7]. CBCT offers supremacy in evaluating furcation involvement, dehiscence, fenestration, assess periodontal cysts and the outcome of regenerative periodontal therapy. This technique has demonstrated advantages when more invasive treatment is required. [2]

Forensic dentistry

CBCT was established as a non-invasive method to estimate the age of a person based on the pulp–tooth ratio.[3] A previous study showed that CBCT images of the face could be used for measuring soft-tissue thickness in the facial region; thus helping in identification of subjects in mass disasters and natural calamities.[2]

TMJ Imaging

CBCT imaging offers multiplanar and possibly three-dimensional images of condyle and surrounding structures to enable analysis of TMJ and function. [7] TMJ imaging should comprise of reformatted panoramic and axial reference images also, corrected paracoronal and parasagittal cross sectional slices and volumetric reconstruction as required. CBCT enables to examine the joint space and true position of the condyle within the fossa which helps to divulge any dislocation of the joint disk. Another advantage of some of the available devices is their ability to visualise soft tissue around the TMJ, which may reduce the need for magnetic resonance imaging in these cases.[3] CBCT thus offers optimal diagnostic information for detection of developmental anomalies of the condyle, trauma, fibro-osseous ankylosis, pain, dysfunction, condylar cortical erosion, rheumatoid arthritis and cysts.

Limitations

CBCT is one of the very significant advances in medical and dental diagnosis and treatment in the last decade, but it has such limitations which need to be considered.

As hounsfield units (HU) do not apply to CBCT images, yielding it impossible to compare grey values among or within patients over time. [12] This lack of HU standardization is also a major issue with most CBCT devices. There are several CBCT equipment manufacturers in the dental imaging field. This has resulted in significant variability in radiation dose, scanning times, ease of use, image resolution, and software dynamics among CBCT machines.[13] the most significant limitation of CBCT though is the lack of accurate representation of internal structure of soft tissue such as salivary glands, muscles etc. Various metal artifacts can interfere with the diagnosis as they mask the underlying structures. Hence, use of CBCT in each case has to be considered individually to ensure that the benefits provided outweigh the risks of additional radiation and other concerns.

Conclusion

CBCT ranks extremely high when considering the balance between high diagnostic yield, low cost and low risk to the patient.[1] However, it should be implemented after careful consideration, as when 2D imaging techniques are not sufficient and to assess technological processes such as guided surgery will improve patient management. CBCT allows “real time” creation of images not only in axial plane but also 2D images in coronal, sagittal, and even oblique or curved image planes.[1] It is highly informative in cases of craniofacial deformities, supernumerary teeth, planning for orthognathic surgery, cleft palate, root resorption identification caused by impacted teeth and has heaps of other advantages. Huge scope is available for further applications and needs exploration from diagnosis to image guidance of dental procedures.

References

1. Ghali RS, Katti G, Shahbaz S, Katti C. Cone Beam Computed Tomography: A boon for Maxillofacial Imaging. J Indian Acad Oral Med Radiol 2017; 29:30-4.
2. Hegde S, et al. Importance of cone-beam computed tomography in dentistry: An Update. SRM J Res Dent Sci 2018; 9:186-90.
3. Alshehri MA, Alshalhoob M. CBCT applications in dental practice: A Literature review. Gen Dent.2012 Sep-Oct;60(5):390-400.
4. Aljehani YA. Diagnostic Applications of Cone-Beam CT for Periodontal Diseases. International Journal of Dentistry Volume 2014, Article ID 865079, 5 pages.
5. Abramovitch K, Rice DD. Basic Principles of Cone Beam Computed Tomography. Dent Clin North Am. 2014 Jul;58(3):463-84.
6. Dawood A, Patel S, Brown J. Cone Beam CT in dental practice. B Dent J 2009; 207:23-28.
7. Venkatesh E, Elluru S VA. Cone Beam Computed Tomography: basics and applications in dentistry. J Istanb Univ Fac Dent 2017; 51(3 Suppl 1): S102-S121.
8. Sunil G, Ram RR, Ranganayakulu I. CBCT A swap to conventional orthodontic imaging. J NTR Univ Health Sci 2018;7:85-8.
9. Machado GL. CBCT imaging – A boon to orthodontics. Saudi Dent J 2015 Jan; 27(1): 12–21.
10. Kumar M, et al. Cone Beam Computed Tomography – Know its Secrets. J Int Oral Health 2015;7(2):64-68.
11. Scarfe WC, Levin MD, Gane D, [3] and Farman AG. Use of Cone Beam Computed Tomography in Endodontics. Int J Dent. 2009; 2009: 634567.
12. Jacobs R, et al. Cone beam computed tomography in implant dentistry: recommendations for clinical use. BMC Oral Health (2018) 18:88.
13. Benavides E, et al. Use of Cone Beam Computed Tomography in Implant Dentistry: The International Congress of Oral Implantologists Consensus Report. Implant Dent. 2012 Apr;21(2):78-86.