Mini Review Article

Cone Beam Computer Tomography: Uses in Dentistry (A Mini Review)

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Received Date: February 11, 2021
Publication Date: March 01, 2021

Abstract

The twenty-first century is the era of advanced technology, Cone Beam Computer Tomography (CBCT) being one of them. It has changed the way oral and maxillofacial radiology is practiced. Its use is profoundly increasing for diagnosis and treatment planning in different fields of dentistry. It is acclaimed for its accuracy and diverse clinical utility. The three- dimensional imaging has made the complex craniofacial structures more accessible for examination. Early and accurate diagnosis of the deep-seated lesion is possible. This manuscript provides an overview of the basics of CBCT technology and reviews its specific applications to the oral and maxillofacial region.

Keywords: *Cone Beam Computer Tomography, Diagnosis, Treatment planning*

Introduction

The X-ray was discovered by Sir Wilhelm Conrad Roentgen in 1895. It was used incredibly in the field of medicine. But this had various disadvantages such as more exposure to radiation, longer processing time, and more distortion of the image **(1)**. These lead to the discovery of three-dimensional (CBCT) imaging. This Cone Beam Computer Tomography introduced in maxillofacial imagining held a paradigm shift from two-dimensional to three-dimensional. It is a technology that uses three-dimensional images of teeth, maxillary sinus, nerve pathway, and bone in the maxillofacial region in a single scan. It is a

preferred substitute for conventional CT diagnosis and treatment planning. The first commercial CBCT was introduced in Europe in 1999. However, in developing countries like India, its use was limited due to its high cost. It is used in diagnosis various cysts, tumors, temporomandibular joint-related disorders, and developmental anomalies **(2)**. Various types of CBCT are Next Generation i-CAT, Scanora3D, NewTom 3G, AccuiTomo MTC-1, Galileos 3D **(3)**. The difference in these occurs in their detector type and characteristics, scan FoV selection, and voxel size.

Principle

CBCT rotates around the patient in about 30 seconds for capturing the data. It uses a cone-shaped divergent beam of ionizing radiation mounted on a rotatory gantry and a reciprocating solid-state flat panel detector which rotates once around the patient in 180-360 degrees, covering the anatomical volume that is complete dental or maxillofacial volume rather than slice by slice imaging found in conventional CT. It collects multiple, sequential, full volume, planar projection images within an assigned field of view each individually known as basis images **(4)**. X-ray beam attenuated by the patient detected by the receptor. This raw data is assembled by the computer algorithm that generates cross-sectional components of an image called pixels. Complete series of images are called projection data. CBCT acquires volumetric data. Each unit of which is called a voxel **(5)**. The size of each voxel corresponds to the size of the pixel of the detector **(6)**.

Components

It includes image production, visualization, and interpretation**.**

1. X-ray generator

An x-ray tube is composed of a cathode and an anode placed in a vacuum glass tube. The cathode consists of a tungsten filament of 2mm in diameter and 1 cm in length which lies in a molybdenum focusing cup. The anode consists of a tungsten target, which is embedded in a copper stem. The filament is heated to incandescence by application of a low voltage tube current of about 10 volts. With all the systems immobilization of the patient's head is very important than position because any movement degrades the final image. This can be achieved by chin cup, bite fork, and other mechanical restraint. A high voltage generator modifies incoming voltage and current to provide the x-ray tube with the power needed to produce an x-ray beam of desired peak kilovoltage and current. It consists of an x-ray tube

(anode, cathode, tube housing, and tube envelop) and a collimator. The size of the anode is important. The smaller the size of the anode, the greater is the intensity of the x-ray. Scanner time is longer than panoramic due to pulsed exposure. So, actual exposure time is markedly reduced. ALARA (As Low As Reasonably Achievable) principle of dose optimization states that CBCT exposure factors should be adjusted based on patients size **(7)**.

2. X-ray detection

It converts the incoming photons into an electrical signal. It uses either of the detectors such as Image Intensifier Tube/ Charged Couple Device of fibreoptic coupling which are image area spherical volume and flat-panel detector (FPDs).

Image Intensifier Tube/ Charged Couple Device comprises of an x-ray IIT to a CCD by way of a fiber optic coupling. The input phosphor screen converts the x-ray beam into an optical signal which is then converted to electrons by the photocathode screen. The optical iris adjusts the optical signal which is detected by the CCD.

Flat-panel detector technology was first introduced by Jaffray and Siewerdsen in 2002. It is composed of a large area pixel array of scintillating material of hydrogenated amorphous silicon thin-film transistors. They have excellent efficiency of converting liquid photons into electrical signals and hence improved imaging is possible with high uniformity over a large area, high optical absorption. X-rays are detected indirectly using scintillation, such as terbium activated gadolinium oxysulphide or thallium doped cesium iodine which converts X-ray into visible light that is subsequently registered in the photodiode array.

Advantages

i. Offer a greater dynamic range

ii. Reduced peripheral distortion

iii. The configuration of such detectors is less complicated

iv. Distortion free

v. Higher dose efficiency

Disadvantages

These detectors require more radiation exposure.

3. Image reconstruction

Data received by the computer are then transferred to the processing computer. It depends upon acquisition parameters such as voxel size, size of the image field. The measured cone-beam projections are pre-weighted, filtered and finally back-projected along with the same ray geometry as initially used for forwarding projection.

Stages of the reconstruction process

Pre-processing stage

a. Performed at acquisition computer

b. Inherent pixel imperfections should be corrected

c. Exposure normalization

Reconstruction stage

a. Corrected images are converted into a special representation called a **sinogram.**

b. It is a composite image developed from multiple projection images.

c. The horizontal axis of a sinogram represents individual rays at the detector whereas the vertical axis represents projection angles. If there are 500 projections, the sinogram will have 500 rows.

Uses in Dentistry:

It is used in the diagnosis and extent of a variety of infections, osteomyelitis, tumor, and lesions of the bone.

1. General Dentistry

It is useful in assessing proximal caries and its depth. However, cannot be used for the diagnosis of occlusal caries as its dose is much higher than conventional radiographs.

2. Endodontics

- CBCT is a very useful tool in diagnosing apical lesions.
- Crown morphology, pulp chamber, proximal caries.
- Root morphology, number of the root canal, course and direction of canals, accessory canals, and root resorption and root fracture.
- It helps in diagnosis and management of cases with dens invaginatus, luxation, displacement, root perforation, and for better visualization of fractures instrument **(8)**.
- To evaluate obturation, filling, under and over the filling, sinus problem.
- Useful in planning periapical endodontic surgery.
- It helps detect the pulpal extensions in the Talon cusp.
- To evaluate the proximity of adjacent anatomical structures.
- Diagnosis of non-endodontic origin pathology to determine the extent of the lesion and its effect on surrounding structures.

3. Implant dentistry

- CBCT is very helpful in implantology. It is done to evaluate bone height and bone width, quality and quantity of bone available for implant placement and to assess the proximity to any vital structure in both maxilla and mandible.
- In maxillary the posterior region, it is used to assess the maxillary sinus and in the anterior region proximity to incisive foramen. In mandibular region proximity to mental foramen and mandibular canal.
- It is involved in accurate planning with a surgical guide.
- Evaluation of root of upper posterior teeth in respect to the maxillary sinus, sinus lift **(9)**.

4. Orthodontics

- It is useful in patients with cleft palate, craniofacial anomalies, facial asymmetry, large anterior open bite, unerupted tooth, supernumerary teeth, root resorption, and for the planning of orthodontic surgery.

- CBCT is used in cephalometric tracing.
- It is useful for the placement of endosseous dental implants and temporary anchorage devices.
- It is useful in hard tissue examination type of dentition present, the symmetry of arches, anteroposterior and transverse maxillomandibular relationship **(10)**.
- CBCT is also very useful in cases where mini screw implants are placed. They serve as a temporary anchorage, for ensuring a safe insertion.
- It is used to assess the bone dentist before, during, and after the treatment.

5. Forensic dentistry

- It is used as a non-invasive method to estimate the age of a person based on the pulp-tooth ratio.
- CBCT of the face helps in the measurement of soft tissue thickness of the facial region **(11)**.

6. Prosthodontics

- They are successfully used in maxillofacial prosthodontics for craniofacial reconstruction. The augmented virtual model of the patient's face, bony structures, and dentition can be created out of CBCT DICOM data by software volume rendering for treatment planning. Obturators for cleft closures are milled with CAD/CAM units thereby eliminating the entire hectic process of obturator construction.
- They also help in carrying out Finite Element Analysis (FEA) to calculate the stress distribution in dental implants.
- It is an effective method to inspect and identify diffuse narrowing or focal narrowing of the airway **(12)**.
- It also helps in comprehensive treatment planning for patients with implant overdenture.

7. Periodontics

- CBCT can be used to assessing a detailed morphogenic description of the intra-oral bony defect.
- Measuring of bone defects, buccal and lingual defects. It also provides high accuracy for detecting the furcation involvement.
- CBCT has also proved its superiority in evaluating the outcome of regenerative periodontal surgery **(13)**.
- They help in evaluating post grafting imaging to reveal the amount of bone formed and the bone density.

8. **Temporomandibular Joint disorders**

- It is used to examine the joint space and the true position of the condyle within the fossa, which helps to reveal likely dislocation of the joint disk **(14)**.
- It is also useful in cases of trauma, pain, dysfunction, fibro-osseous ankylosis, cysts and in detecting condylar cortical erosion.
- With the technology treatment for TMJ disk adhesion such as Puncture Technique can be carried out.
- With its accuracy, measurements of the roof of the glenoid fossa can be done easily.

9. Oral and maxillofacial Surgery

- It is used to analyze the benign and malignant lesions of the oral and maxillofacial region.
- Used for fracture assessment and its treatment planning.
- Helps in evaluation of location, size, extent, and involvement of any surrounding vital structures due to disease process.
- It helps in the diagnosis of oral cancer **(15)**.
- CBCT is considered as the third eye in implant placement.
- It is used for nerve mapping.
- It is used to evaluate the changes in the cortical and trabecular bone related to bisphosphonate-associated osteonecrosis of the jaw.
- It is useful in the analysis of paranasal sinus and obstructive sleep apnea.
- Used in the assessment of impacted teeth.
- It is a technique of choice in the mid-face fracture, orbital fracture assessment and management and for visualization of the facial bone after a fracture.
- It is the best option for intra-operative navigation during the procedure such as gun-shot wounds.

Benefits of CBCT **(16)**

1. Rapid scan time

2. Image accuracy

3. Reduced radiation dose to the patient

4. Multiplanar reformatting

5. Better images with a good spatial resolution

6. Economical, safe, and comfortable

7. Interactive display modes

8. Imaging can be obtained at any angle

9. Powerful diagnostic 3-D planning tool

Limitations

1. X-ray beam artifacts

2. Detector sensitivity

3. Projection geometry

4. Patient-related artifacts

5. Scanner artifacts

6. Cone-beam related artifacts

   - Partial volume averaging
   - Undersampling
   - Cone-beam effect

7. Poor soft-tissue contacts

8. Image noise

Conclusion

CBCT technique hugely expands the fields of diagnosis and treatment possibilities but it should be used with careful consideration. It is well accepted diagnostic tool for the care of dental patients. Design changes in the evolution of CBCT scanner making the units smaller. The principle for using it is to maximize the clinical benefit to the patient while minimizing the risk of ionizing radiation.

References

1.Arai, Y., Tammisalo, E., Iwai, K., Hashimoto, K. and Shinoda, K., 1999. "Development of a compact computed tomographic apparatus for dental use". Dentomaxillofacial Radiology, 28(4), pp.245-248.

2.Jaju, P.P. and Jaju, S.P., 2014. "Clinical utility of dental cone-beam computed tomography: current perspectives". Clinical, cosmetic and investigational dentistry, 6, p.29.

3.Hassan, B., Metska, M.E., Ozok, A.R., van der Stelt, P. and Wesselink, P.R., 2010. "Comparison of five cone beam computed tomography systems for the detection of vertical root fractures". Journal of endodontics, 36(1), pp.126-129.

4.Scarfe, W.C. and Farman, A.G., 2008. "What is cone-beam CT and how does it work?". Dental Clinics of North America, 52(4), pp.707-730.

5.Spin-Neto, R., Gotfredsen, E. and Wenzel, A., 2013. "Impact of voxel size variation on CBCT-based diagnostic outcome in dentistry: a systematic review". Journal of digital imaging, 26(4), pp.813-820.

6.Kwong, J.C., Palomo, J.M., Landers, M.A., Figueroa, A. and Hans, M.G., 2008. "Image quality produced by different cone-beam computed tomography settings". American Journal of Orthodontics and Dentofacial Orthopedics, 133(2), pp.317-327.

7.Pauwels, R., Beinsberger, J., Collaert, B., Theodorakou, C., Rogers, J., Walker, A., Cockmartin, L., Bosmans, H., Jacobs, R., Bogaerts, R. and Horner, K., 2012. "Effective dose range for dental cone beam computed tomography scanners". European journal of radiology, 81(2), pp.267-271.

8.Kiarudi, A.H., Eghbal, M.J., Safi, Y., Aghdasi, M.M. and Fazlyab, M., 2015. "The applications of cone-beam computed tomography in endodontics: a review of literature". Iranian endodontic journal, 10(1), p.16.

9.Kumar, M., Shanavas, M., Sidappa, A. and Kiran, M., 2015. “Cone beam computed tomography-know its secrets”. Journal of international oral health: JIOH, 7(2), p.64.

10.Kapila, S., Conley, R.S. and Harrell Jr, W.E., 2011. “The current status of cone beam computed tomography imaging in orthodontics”. Dentomaxillofacial Radiology, 40(1), pp.24-34.

11.Fourie, Z., Damstra, J., Gerrits, P.O. and Ren, Y., 2010. “Accuracy and reliability of facial soft tissue depth measurements using cone beam computer tomography”. Forensic science international, 199(1-3), pp.9-14.

12.John, G.P., Joy, T.E., Mathew, J. and Kumar, V.R., 2016. “Applications of cone beam computed tomography for a prosthodontist”. The Journal of the Indian Prosthodontic Society, 16(1), p.3.

13.Walter, C., Schmidt, J.C., Dula, K. and Sculean, A., 2016. “Cone beam computed tomography (CBCT) for diagnosis and treatment planning in periodontology: A systematic review”. Quintessence Int, 47(1), pp.25-37.

14.Tsiklakis, K., Syriopoulos, K. and Stamatakis, H.C., 2004. “Radiographic examination of the temporomandibular joint using cone beam computed tomography”. Dentomaxillofacial Radiology, 33(3), pp.196-201.

15.Czerwonka, L., Bissada, E., Goldstein, D.P., Wood, R.E., Lam, E.W., Yu, E., Lazinski, D. and Irish, J.C., 2017. “High-resolution cone-beam computed tomography for assessment of bone invasion in oral cancer: Comparison with conventional computed tomography”. Head & neck, 39(10), pp.2016-2020.

16.Scarfe, W.C., Farman, A.G. and Sukovic, P., 2006. “Clinical applications of cone-beam computed tomography in dental practice”. Journal-Canadian Dental Association, 72(1), p.75.

Volume 2 Issue 3 March 2021