Scholars Journal of Applied Medical Sciences
Abbreviated Key Title: Sch J App Med Sci
ISSN 2347-954X (Print) | ISSN 2320-6691 (Online)
Journal homepage: https://saspublishers.com

OPEN ACCESS

Orthodontic

The Fundamentals of Imaging with Cone Beam Computed Tomography

Yagnik Nisarg Sunilkumar[1*]

[1]Private Orthodontic Practitioner, Surat

DOI: 10.36347/sjams.2021.v09i11.015 | **Received:** 16.10.2021 | **Accepted:** 20.11.2021 | **Published:** 24.11.2021

***Corresponding author:** Yagnik Nisarg Sunilkumar

Abstract **Review Article**

In the last few decades, the need for three-dimensional imaging in dentistry has been realized. Because of this, computed tomography, initially applied to medical imaging, started to be used in dentistry. This allowed the dental conditions to be diagnosed with 3D images. But computed tomography was hospital-based, expensive, and resulted in high radiation dose to the patients. In the late 1990's, a new technology cone beam computed tomography was developed specifically for the dental radiographic imaging. This enables a wider use of 3D imaging for dentists worldwide. This article describes the history of CBCT, fundamentals, position, image intensifiers, field of view, and measurements with CBCT. It also discusses the ethical and legal considerations with CBCT.

Keywords: Computed tomography, Cone beam computed tomography, CBCT.

INTRODUCTION

The development of Computed tomography (CT) was done in 1972 and this allowed the medical conditions to be diagnosed with 3-dimensional (3D) radiographs [1]. These devices are used in many fields, and their use in dentistry increased with the introduction of dental implants and the surgical procedures for implant insertion. The use of CT in dentistry was difficult because the devices were large, expensive, and the devices lead to an increased exposure to radiation for dental patients. In 1997, a compact CT apparatus known as cone beam computed tomography (CBCT) was introduced with a specific purpose of dental radiographic imaging [2, 3]. In subsequent years after the development of CBCT, it has been used in multiple cases to analyze conditions such as impacted teeth, periapical lesions, mandibular lesions, and maxillary abnormalities [4]. CBCT enables the 3D imaging of the hard and soft tissues of head such as bone, teeth, maxillofacial region, ear, nose, etc [5].

The CBCT machine known as NewTom QR 9000 received FDA approval in April 2001 and then CDA approval in 2002. This device was specifically designed for imaging of the maxillofacial region. In a single scan, the xray source and a reciprocating xray sensor perform rotation around the head and acquire 360 pictures with 17 seconds of total exposure time. It records 1 image per 1 degree of rotation.

Cone Beam Computed Tomography Fundamentals

CBCT is an extraoral imaging scanner, specially designed for head and neck imaging. It involves a unit that is comparable in size wot that of panoramic radiographic machine. CBCT machines project xrays in the form of a big cone that covers the surface of the head to be evaluated. In contrast to a linear array of detectors in CT, a CBCT machine uses a 2-dimensional (2D) planar detector. Because of these properties, a CBCT irradiates a large volume area and not a thin slice as in CT [6]. Therefore, the CBCT machine does not need to rotate multiple times like a CT but it can gather all the necessary information for reconstruction of the region of interest by just one rotation. CBCT also allows the clinicians to reconstruct the images in 3 different dimensions. It has a low level of exposure to radiation compared to CT [6].

Position, Image intensifiers, and field of view while recording CBCT

There are different types of CBCT machines, and each has its own characteristics. A chief difference in the CBCT machines is the patient position. The patients could be either standing, sitting, or lying on a table while recording the CBCT depending on the machine. Usually sitting or standing positioning is used for in-office imaging. In early generation of CBCT scanners, image intensifiers were used commonly. Currently, flat panel detectors are use in pace of the image intensifier. These detectors have high dose efficiency, and a wide dynamic range. An important advantage is that CBCT can eb recorded in a small field of view or a large field of view with the help of flat panel detectors. CBCT systems used currently mainly used indirect flat panel detectors in which a layer of scintillator material which is either gadolinium oxysulfide, or cesium iodide and is used to convert xray photons to the light photons which are in turn converted into electrical signals [7-9].

The field of view size pertains to the scan volume of a CBCT machine. It depends on the detector's size, shape, geometry of the beam, and it differs from one manufacturer to another. The process of beam collimation helps to reduce the amount of radiation exposure to the patient and limits it to the region of interest (ROI) for the patient. In general, the field of view can be classified into small, medium, and large volume based on the size of their FOV [10]. Small- volume FOV is used for identifying impactions of teeth such as impacted central incisors, canines, third molars, supernumerary teeth, etc [11]. Small volume CBCT is also useful in endodontics to identify the root canals or periodontics to identify the level of bone for implant or periodontal therapy [11, 12]. Large field of view is useful in orthodontics where maxilla and mandible relations are to be observed with each other and cranium. Large FOV also allows growth estimation by the radiographic imaging of the cervical vertebrae [13]. With the help of CBCT, the cervical vertebral maturation can be evaluated to identify whether the patient is still actively growing or patients has completed their growth. Orthodontic treatment planning to a significant degree is based on the cervical vertebral maturation index. It has been reported by Mehta and colleagues that the cervical vertebral maturation index (CVMI) of a patient as seen on CBCT may be observed as a lower CVMI than when observed on lateral cephalogram [13]. This is because the head position errors due to pitch, roll, and yaw lead to errors in lateral cephalometric images which in turn results in increased measurements of the cervical vertebral concavity and higher staging of the cervical vertebral index [13].

Measurements with CBCT

The discovery of CBCT enables us to analyze the dentition, skeleton, soft-tissues, and airway structures in 3 dimensions. The use of CBCT in dental profession requires specific knowledge about the measurements of the structures. With CBCT, the planning of dental implant insertion can be performed [14]. The main aim of CBCT imaging done preoperatively is to identify any pathologic conditions of bone, the bone level, bone width, and distance from anatomic structures such as the inferior alveolar nerve [15, 16]. The measurement of airway with CBCT requires defining the boundaries for pharyngeal airway [17]. The boundaries of nasal cavity, nasopharyngeal airway, oropharyngeal airway, and laryngopharyngeal airway need to be defined by using reliable landmarks that can be identified repeatedly and accurately [17]. Using CBCT, both airway volume and airway area both can be measured. The use of thresholding is important for the measurement of airway volume. Another important point for measuring airway volume is the minimal cross-sectional area which denotes the minimal area in the whole naso-oro-pharyngeal airway [17]. All these parameters such as airway volume, airway area, and minimal cross-sectional area have been shown to increase with the use of orthodontic devices such as miniscrew assisted rapid palatal expansion (MARPE) [17, 18]. Some CBCT imaging software have specialized tools to enable the measurements of airway automatically, semiautomatically, or manually [19, 20]. Some other dental appliances for mandibular advancement, maxillary protraction, and maxillary expansion can also have an effect on the airway and future studies should evaluate the effects of these appliances with the help of CBCT [21-24]. CBCT can be used for accurate measurement of the bone loss and 3D assessment of bony defects due to periodontal diseases. Periodontal assessment before and after surgery can also be done with CBCT to check the progress of the periodontal condition and check if it is stable. CBCT is used after bone grating to identify the dimensions of the graft and to make sure whether any further bone grafting is required [25-28]. Artificial Intelligence is used for identifying landmarks on lateral cephalometric radiographs by identification of specific structures on the bone.[29] In the future, artificial intelligence would be immensely helpful in measuring the bone loss and identify the need for bone grating automatically. CBCT can be used for the assessment of condylar head shape, condylar position, glenoid fossa, and the joint spaces for temporomandibular joint (TMJ) [30-32]. CBCT has a lower radiation dose than CT and it allows a specialized view of the TMJ where cross sections allow the visualization of the condylar head anteroposteriorly and mediolaterally. It allows the evaluation of erosions as well as osteoarthritic changes in the joint [33]. The measurement of root volume, and bone volume can be performed with CBCT. It is not as accurate as micro-CT which is used for animal studies. Micro CT provides a very high resolution and high radiation. The thresholding for root volume is performed in micro-CT to identify root resorption and bone volume [34]. CBCT uses less radiation and does not have the same resolution as micro-CT.

Ethical and Legal considerations with CBCT

If a clinician records a panoramic radiograph, then they are responsible for the identification and interpretation of the radiograph [35, 36]. The same principle also applied to CBCT. If a clinician records a CBCT, then they are responsible for the evaluation of the entire CBCT scan which includes all the areas recorded which may be beyond the interest of the clinician. The clinician can refer to the radiologist to read the scan for them.

Conclusions

CBCT is a useful modality for assessment of dental structures in 3 dimensions. CBCT can be recoded in sitting, standing or supine position. Flat panel detectors are commonly used in the current machines for CBCT recording. The field of view of CBCT allows undertaking 3D imaging with a small, medium or large field of view. It also has an effect on the amount of radiation exposure to the patient. CBCT is useful for performing measurements for implant planning, airway, temporomandibular joint (TMJ), periodontal structures, and root volume. The clinician should scan through the entire CBCT to identify not only the region of interest but also the structures recorded beyond the region of interest.

References

1. Hounsfield, G.N. (1973). Computerized transverse axial scanning (tomography). Description of system. *Br J Radiol*,46; 1016–22.
2. Arai, Y. (1998). Development of ortho cubic super high resolution CT (Ortho-CT). *Car 98 Computer Assisted Radiology and Surgery*.
3. Arai, Y., Tammisalo, E., Iwai, K., Hashimoto, K., & Shinoda, K. (1999). Development of a compact computed tomographic apparatus for dental use. *Dentomaxillofacial Radiology*, *28*(4), 245-248.
4. Terakado, M., Hashimoto, K., Arai, Y., Honda, M., Sekiwa, T., & Sato, H. (2000). Diagnostic imaging with newly developed ortho cubic super-high resolution computed tomography (Ortho-CT). *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology*, *89*(4), 509-518.
5. Arai, Y., Hashimoto, K., Iwai, K., & Shinoda, K. (2000). Fundamental efficiency of limited cone-beam X-ray CT (3DX multi image micro CT) for practical use. *Shika Hoshasen*, *40*(2), 145-154.
6. Scarfe, W. C., & Farman, A. G. (2008). What is cone-beam CT and how does it work?. *Dental Clinics of North America*, *52*(4), 707-730.
7. Pauwels, R., Araki, K., Siewerdsen, J. H., & Thongvigitmanee, S. S. (2015). Technical aspects of dental CBCT: state of the art. *Dentomaxillofacial Radiology*, *44*(1), 20140224.
8. Baba, R., Konno, Y., Ueda, K., & Ikeda, S. (2002). Comparison of flat-panel detector and image-intensifier detector for cone-beam CT. *Computerized medical imaging and graphics*, *26*(3), 153-158.
9. Vano, E., Geiger, B., Schreiner, A., Back, C., & Beissel, J. (2005). Dynamic flat panel detector versus image intensifier in cardiac imaging: dose and image quality. *Physics in Medicine & Biology*, *50*(23), 5731.
10. Abramovitch, K., & Rice, D. D. (2014). Basic principles of cone beam computed tomography. *Dent Clin North Am*, *58*(3), 463-84.
11. Nurko, C. (2010). Three-dimensional imaging cone bean computer tomography technology: an update and case report of an impacted incisor in a mixed dentition patient. *Pediatric dentistry*, *32*(4), 356-360.
12. Scarfe, W. C., Levin, M. D., Gane, D., & Farman, A. G. (2009). Use of cone beam computed tomography in endodontics. *International journal of dentistry*, *2009*.
13. Mehta, S., Dresner, R., Gandhi, V., Chen, P. J., Allareddy, V., Kuo, C. L., ... & Yadav, S. (2020). Effect of positional errors on the accuracy of cervical vertebrae maturation assessment using CBCT and lateral cephalograms. *Journal of the World Federation of Orthodontists*, *9*(4), 146-154.
14. Branemark, P. I. (1983). Osseointegration and its experimental background. *J prosthet Dent*, *50*, 399-410.
15. Abraham, C. M. (2014). Suppl 1: A brief historical perspective on dental implants, their surface coatings and treatments. *The open dentistry journal*, *8*, 50.
16. Tyndall, D. A., & Brooks, S. L. (2000). Selection criteria for dental implant site imaging: a position paper of the American Academy of Oral and Maxillofacial radiology. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology*, *89*(5), 630-637.
17. Mehta, S., Wang, D., Kuo, C. L., Mu, J., Vich, M. L., Allareddy, V., ... & Yadav, S. (2021). Long-term effects of mini-screw–assisted rapid palatal expansion on airway: A three-dimensional cone-beam computed tomography study. *The Angle Orthodontist*, *91*(2), 195-205.
18. Arqub, S. A., Mehta, S., Iverson, M. G., Yadav, S., Upadhyay, M., & Almuzian, M. (2021). Does Mini Screw Assisted Rapid Palatal Expansion (MARPE) have an influence on airway and breathing in middle-aged children and adolescents? A systematic review. *International Orthodontics*.
19. Zinsly, S. D. R., Moraes, L. C. D., Moura, P. D., & Ursi, W. (2010). Assessment of pharyngeal airway space using cone-beam computed tomography. *Dental Press Journal of Orthodontics*, *15*, 150-158.
20. Grauer, D., Cevidanes, L. S., Styner, M. A., Ackerman, J. L., & Proffit, W. R. (2009). Pharyngeal airway volume and shape from cone-beam computed tomography: relationship to facial morphology. *American journal of orthodontics and dentofacial orthopedics*, *136*(6), 805-814.
21. Bamagoos, A. A., Sutherland, K., & Cistulli, P. A. (2016). Mandibular advancement splints. *Sleep medicine clinics*, *11*(3), 343-352.
22. Dzingle, J., Mehta, S., Chen, P. J., & Yadav, S. (2020). Correction of Unilateral Posterior Crossbite with U-MARPE. *Turkish Journal of Orthodontics*, *33*(3), 192.
23. Mehta, S., Chen, P. J., Upadhyay, M., & Yadav, S. (2021). Intermaxillary elastics on skeletal

anchorage and MARPE to treat a class III maxillary retrognathic open bite adolescent: A case report. *International orthodontics*.

24. Zimmerman, J. N., Vora, S. R., & Pliska, B. T. (2019). Reliability of upper airway assessment using CBCT. *European journal of orthodontics*, *41*(1), 101-108.
25. Guo, Y. J., Ge, Z. P., Ma, R. H., Hou, J. X., & Li, G. (2016). A six-site method for the evaluation of periodontal bone loss in cone-beam CT images. *Dentomaxillofacial Radiology*, *45*(1), 20150265.
26. de Faria Vasconcelos, K., Evangelista, K. M., Rodrigues, C. D., Estrela, C., De Sousa, T. O., & Silva, M. A. G. (2012). Detection of periodontal bone loss using cone beam CT and intraoral radiography. *Dentomaxillofacial Radiology*, *41*(1), 64-69.
27. Pour, D. G., Romoozi, E., & Shayesteh, Y. S. (2015). Accuracy of cone beam computed tomography for detection of bone loss. *Journal of Dentistry (Tehran, Iran)*, *12*(7), 513.
28. Ramesh, R., & Sadasivan, A. (2017). Oral squamous cell carcinoma masquerading as gingival overgrowth. *European journal of dentistry*, *11*(03), 390-394.
29. Trivedi, I. (2021). Comparison of Conventional Rapid Palatal Expansion with Bone Anchored and Tooth-Bone Anchored Rapid Palatal Expansion Appliances. *Sch J Dent Sci*, *9*, 284-287.
30. Bae, S., Park, M. S., Han, J. W., & Kim, Y. J. (2017). Correlation between pain and degenerative bony changes on cone-beam computed tomography images of temporomandibular joints. *Maxillofacial plastic and reconstructive surgery*, *39*(1), 1-6.
31. Mehta, S., Chen, P. J., Vich, M. L., Upadhyay, M., Tadinada, A., & Yadav, S. (2021). Bone-anchored versus tooth-anchored expansion appliances: Long-term effects on the condyle–fossa relationship. *Journal of the World federation of orthodontists*.
32. Caruso, S., Storti, E., Nota, A., Ehsani, S., & Gatto, R. (2017). Temporomandibular joint anatomy assessed by CBCT images. *BioMed research international*, *2017*.
33. Larheim, T. A., Abrahamsson, A. K., Kristensen, M. L. Z. A., & Arvidsson, L. Z. (2015). Temporomandibular joint diagnostics using CBCT. *Dentomaxillofacial Radiology*, *44*(1), 20140235.
34. Mehta, S., Chen, P. J., Kalajzic, Z., Ahmida, A., & Yadav, S. (2021). Acceleration of orthodontic tooth movement and root resorption with near and distant surgical insults: An in-vivo study on a rat model. *International Orthodontics*.
35. Woelber, J. P., Fleiner, J., Rau, J., Ratka-Krüger, P., & Hannig, C. (2018). Accuracy and Usefulness of CBCT in Periodontology: A Systematic Review of the Literature. *International Journal of Periodontics & Restorative Dentistry*, *38*(2).
36. Merrett, S. J., Drage, N. A., & Durning, P. (2009). Cone beam computed tomography: a useful tool in orthodontic diagnosis and treatment planning. *Journal of orthodontics*, *36*(3), 202-210.