IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 17, Issue 4 Ver. 10 (April. 2018), PP 17-22
www.iosrjournals.org

Cone Beam Computed Tomography in Orthodontics –Review

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Abstract: *Computed tomography (CT) offered the medical and dental community great opportunity to enhance the diagnosis and treatment planning through non-invasive three-dimensional imaging technologies. Initially high radiation exposure to patients, high equipment costs and complexity in image capture and interpretation limited the use of helical CT's orthodontic applications. The advent of cone-beam CT (CBCT) technology in the late 1990's removed many of the hurdles. The clinical applications of CBCT in dentistry are then discussed as evidenced in the literature. Several important applications in different dental specialities are detailed including tooth impaction, TMJ imaging, maxillofacial surgery, jaw defects, dental implant rehabilitation, endodontic and orthodontics.*

***Key Words**: Computed tomography, Cone beam CT, Imaging.*

Date of Submission: 02-04-2018 Date of acceptance: 17-04-2018

I. Introduction

Orthodontics and dentofacial orthopaedic treatment address the correction of malocclusions and facial disproportions due to dental/skeletal discrepancies to provide aesthetic, psychosocial, and functional improvements. For almost a century, two-dimensional (2D) planar radiographic imaging and cephalometry have been used to assess the interrelationships of the dentition, maxillofacial skeleton, and soft tissues in all phases of the management of orthodontic patients, including diagnosis, treatment planning, evaluation of growth and development, assessment of treatment progress and outcomes, and retention. However, the limitations of 2D imaging have been realized for decades as many orthodontic and dentofacial orthopaedic problems involve the lateral or third dimension [1, 2, 3].

CBCT technology offers the opportunity to view maxillofacial structures in three dimensions at a resolution and accuracy far beyond, what is available with conventional two dimensional (2-D) panoramic and cephalometric radiographs. While for orthodontic purposes linear and angular measurement accuracy has been established for cephalometric analysis, length measurements in the dentoalveolar region to monitor root resorption[4]. This may have been due in part to orthodontist's treatment planning need to apply the 2-D analyses to the 3-D imaging technology until new standards of 3-D analyses are well developed. The aim of this review article was to explore some of the potential clinical applications of CBCT in dentistry. The emphasis was to assess the efficacy of CBCT for selected clinical applications in the fields of orthodontics. . It decreased equipment size and cost; reduced radiation exposure for patients; improved, user-friendly software for image reconstruction and interpretation; more powerful personal computers; and reduced dependency on radiologists for routine image interpretation, malocclusions and craniofacial anomalies adversely affect quality of life. [5, 6].

Evolution of CBCT

On the other hand, the first commercial Computerized Tomography (CT) scanner appeared in 1972. Soon after, it was apparent that a stack of CT sectional images could be used to generate 3D information. Three-dimensional imaging has evolved into a discipline of its own, dealing with various forms of visualization, manipulation and analysis of multi-dimensional medical structures [7].

Computerized tomography was introduced by Sir Godfrey Hounsfield, in 1967. The method of classification for each system is based on the organization of the individual parts of the device and the physical motion of the beam in capturing the data.

First generation scanners consisted of a single radiation source and a single detector. The second generation was introduced as an improvement and multiple detectors were incorporated within the plane of the scan.

The third generation was made possible by the advancement in detector and data acquisition technology. These large detectors reduced the need for the beam to translate around the object to be measured and were often known as the 'fan beam' CTs. Ring artefacts were often seen on the images captured distorting the three-dimensional image and obscuring certain anatomical landmarks.

The fourth generation was developed to counter this problem. A moving radiation source and a fixed detector ring were introduced. This meant that direction and angle of the radiation source had to be taken into account and more scattered radiation was seen.

Finally, the fifth and sixth generation scanners were introduced to reduce 'motion' or 'scatter' artefacts [8, 9]. As with the previous two generations, the detector is stationary and the electron beam is electronically swept along a semi-circular tungsten strip anode. The radiation is produced at the point, where the electron beam hits the anode and results in a source of X-rays that rotates about the patient with no translation components or moving parts. Projections of the X-rays are so rapid, that even the heart beats of a person may be captured. This has led some clinicians to hail it as a 4D motion capture device. Nevertheless, there are several limitations with these systems. They require a considerable physical space and are much more expensive than conventional radiographic machines. The images captured on the detector screens are made up of multiple slices, to obtain a final image making it time consuming and less cost efficient. In orthodontics, the radiation exposure to the patient was partially responsible in limiting the CT usage to complex craniofacial problems and specialised diagnostic information. Although CBCT imaging increases clinician confidence in orthodontic diagnosis [10]

CONVENTIONAL CT WITH CBCT

Most hospital CT scanners acquire image data, using a thin broad fan-shaped radiograph beam with images acquired as axial slices that are integrated to provide volumetric data (Fig 2) [11].

Drawbacks of such fan beam CT systems include high cost, large physical size, and the relatively high radiograph dosages needed to acquire images. Fan beam CT scanners produce images in slices. Depending on the selected distance between slices programmed at acquisition, voxels can be non-isotropic (not identical in all planes) and precision in measurement can be compromised.

The CBCT approach to image acquisition obviates most of the disadvantages of the conventional CT. There is a lot of difference between CT and CBCT in image acquisition, 2D detector, which allows a single rotation of the gantry to generate a scan of the entire region of interest (ROI), scanning time and radiation dose. With CBCT, voxels are isotropic and measurements are generally precise in all dimensions (Fig 1).

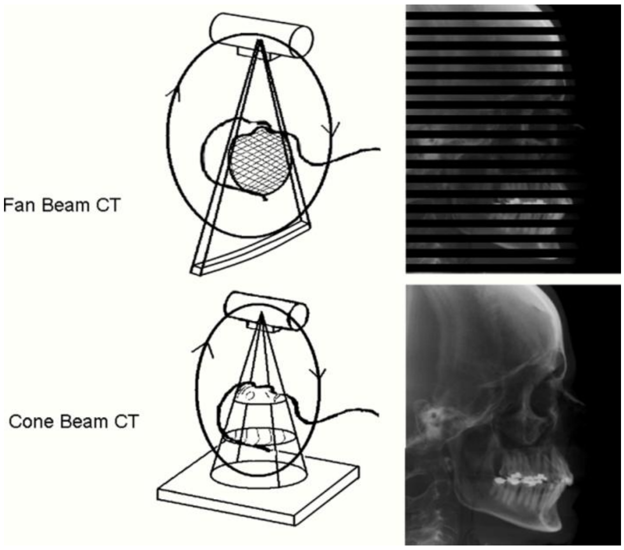


Fig: 1-conventional CT and CBCT

Technological factors that help us to use in orthodontic office include:

1. The development of compact, relatively low cost, high quality, large, flat-panel detector arrays.
2. The availability of low cost computers with processing power sufficient for cone beam image reconstruction.
3. The fabrication of highly efficient radiograph tubes capable of multiple exposures which is necessary for cone beam scanning
4. The Limited volume scanning (e.g., head and neck) time. No need for sub-second gantry rotation speeds. [12, 13]

APPLICATION OF CBCT IN ORTHODONTICS

CBCT will allow the orthodontist to automatically measure such things, as the Bolton tooth size and arch length discrepancy quickly and accurately .This information can also allow for evaluation of different treatment options, such as different extraction patterns (serial extraction versus later phase extraction) and for minimum, moderate, or maximum anchorage requirements. It will allow for the evaluation of possible expansion or up righting of buccal and/or anterior segments, and/or interproximal stripping gaining arch length.

In non-extraction cases, if the treatment plan calls for expansion or up righting of the dental or skeletal arches, then the gains in arch length can be measured by the computer, and the orthodontist can decide if this treatment fits into the treatment scheme. The orthodontist will also be able to evaluate what effects different treatment plans may have on the face in three dimensions [14, 15]. Treatment planning from the outside in may become the standard of treatment planning. In other words, evaluating the 3D facial surface and deciding what the best face that is can be achieved and then deciding which orthodontic and/or surgical treatment may be best for the individual patient. Cone beam imaging offers the advantages of a 3D rendering of the facial structures without magnification or distortion. It also provides cross-sectional views of the hard and soft tissues, without superimpositions, thus allowing improved location of the anatomic landmarks used in the cephalometric analyses and accurate linear measurements and angulations between the landmarks not on the same plane [16, 17].Cone beam imaging offers improved means for assessing treatment outcomes and different patterns of bone remodelling following orthognathic surgery. Techniques have been devised to allow superimposition of 3D models to help evaluate changes in morphology, as a result of treatment and growth.

Assessment of impacted canine

Impacted canines are relatively common in orthodontic practice. The maxillary canine is the most frequently impacted tooth. The mandibular canine is much less of a concern, because it is 10 times less frequently impacted. Impacted canines can also lead to the resorption of neighbouring permanent teeth, particularly the lateral incisors.[18]

Various degrees of resorption on the permanent incisors have been reported, and, root resorption was associated with approximately 48% of impacted maxillary canines. Additionally, resorption can be difficult to diagnose with conventional methods, especially if the canine is located in a direct palatal or buccal position relative to the incisor roots. It is important to define the exact position relative to neighbouring structures and the inclination of the longitudinal axis of the impacted tooth.

1. Diagnosis and treatment planning can be difficult with conventional radiographic methods, because of superimposition of structures on the film; this often makes it difficult to distinguish details. Distortion and projection effects are also encountered with conventional radiographs. Recently, computed tomographic scanning (CT) has been used, because it can provide more reliable information than conventional methods. CBCT provides excellent tissue contrast, eliminating blurring and overlapping of adjacent teeth. Despite its advantages, until now, the use of CT for location of impacted teeth and assessment of resorption has been restricted because of issues related to cost, risk/benefit, access, and expertise in reading the CT [19, 20, 21]. Difficult positional diagnosis and 3-dimensional orientation of long axis of the impacted tooth.
2. Assessment of pathology such as supernumerary teeth, odontomes, apical granulomas, or cyst , and their spatial relationship with impacted tooth
3. Evaluation of unusual morphology of impacted tooth root or crown.

Temporomandibular joint (TMJ) signs and/or symptoms

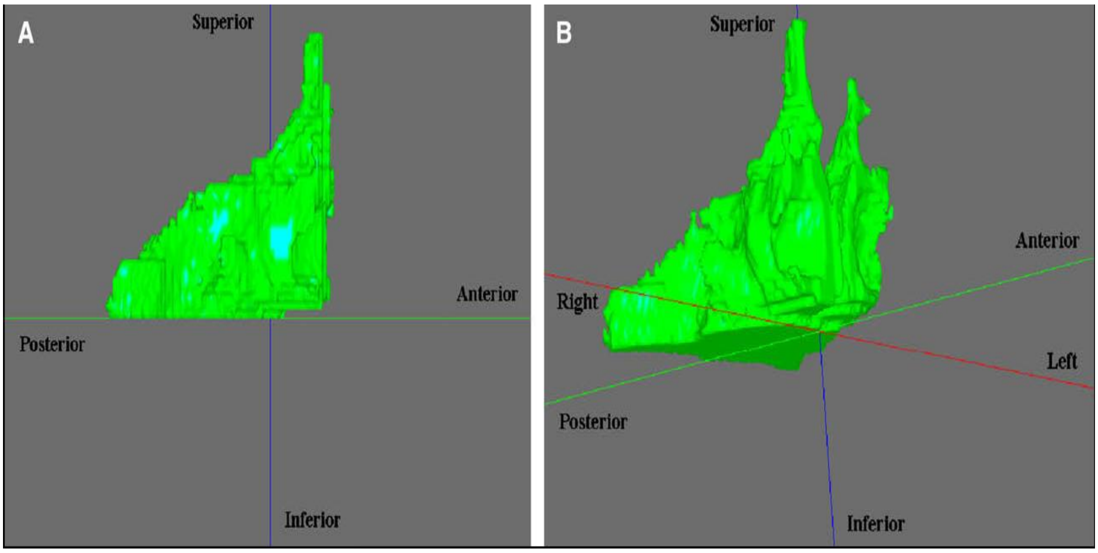
TMJ pathoses that results change in morphology of the osseous joint components may lead to skeletal and dental discrepancies. In affected condyles, perturbed resorption and/or apposition can lead to progressive bite changes and compensations in the maxilla.[23,24]. The sequelae of these changes are unpredictable orthodontic outcomes.

Root angulation

One of the major goals orthodontists try to achieve is to obtain ideal angulations and positions of all teeth at the end of treatment. Three-dimensional CBCT images have been shown to capture the target at a 1:1 ratio with very little dimensional and angular distortions and the trough used to generate the panoramic-like images can be customized to closely follow the dental arch size and shape [25, 26].

CBCT in airway assessment

CBCT technology provides 3D images that provide the third dimension in dental/airway imaging. The rapid growth in numbers of new CBCT imaging units being readied for the marketplace evidences the interest of industry in this sector of medical imaging. It assess the size and shape of the pharynx is critical to diagnose obstructive sleep apnea and when contemplating surgery, particularly maxillary or mandibular setback procedures [27, 28]. In cross-section, the pharynx is more elliptical than round and thus 2D information from a lateral cephalogram may be insufficient or misleading for diagnosis of obstructive sleep apnea. CBCT, with its 3D presentation of the airway and its surrounding structures, offers this increased visualization of both untreated obstruction tendencies and potentially of changes in the airway by treatment modality [29].



Fig; 2- Three-dimensional volume of the nasopharyngeal airway of a subject: A, lateral view and B, at an angle.

Assessment of thickness of bone for orthodontic mini implants

CBCT imaging as being clinically useful in identifying optimal site location for placement of orthodontic mini-implants .Cone beam imaging can be used to determine the thickness and morphology of bone at sites including, where mini-implants may be placed or in patients for whom rapid maxillary expansion is being considered. Cone beam images can provide views of unparalleled clarity for determining root angulations, as well as resorption on buccal or lingual surfaces not imaged by conventional periapical or panoramic views [30, 31, 32].

Assessment of asymmetry in orthodontics

As the demand for improved facial aesthetics increases, more patients complain of the development or the progression of facial asymmetry, particularly mandibular asymmetry, during or after orthodontic treatment. Patients who undergo orthognathic surgery for sagittal relationship problems, such as maxillary protrusion or mandibular prognathism, also tend to become aware of facial asymmetry after the surgical procedure. Because a misdiagnosis of facial asymmetry can result in the wrong treatment for a patient, accurate evaluations of facial asymmetry are crucial in orthodontic practice [33, 34].

In most cases, the presence and degree of facial asymmetry can be diagnosed by using posteroanterior cephalometry. However, a cephalometric radiograph does not provide sufficient information for identifying the causes of asymmetry or determining a suitable treatment plan.

Cone beam images provide the opportunity to examine facial asymmetries, soft tissues and the airway in three dimensions. The utility of cephalometric films for this purpose may be compromised by inaccurate head positioning or unequal magnification [35, 36].

Limitations for use in orthodontics.

● Supine position may alter the shape of facial soft tissues. However, this is the preferred orientation for evaluating for sleep apnea.

● There may be difficulty in identifying anatomic landmarks, with some cone beam units due to lack of fine detail or ambiguities in the definition of landmarks including sella, porion, and articulare.

● Metal artifacts from dental restorations and implants compromise image quality in the

Radiation exposure

Even apart from cone beam imaging, there is evidence that patient dose from conventional orthodontic imaging is increasing in recent years. It is clear that a decision to make any radiograph, and particularly a cone beam examination, is best justified when the clinician can identify a diagnostic question influencing patient care that is dependent on information provided only by this modality.[37,38]

II. Conclusion

Cone beam computed tomography (CBCT) has been available to the medical profession for more than 30 years. With 3D Dental CBCT accelerating to the forefront of diagnostic imaging, dental professionals can now avail themselves of relatively low radiation scans that create 360° virtual models. Just one scan provides images of the teeth, bone structure, TMJ, sinuses, nasal cavity, alveolar nerve canal and all related anatomy.

In the future, we hope that CBCT acquisition will be faster and more flexible to prevent patient motion during acquisition. We cannot be afraid of new technology that provides us with infinitely more diagnostic data. We have to accept it and increase the scope of our diagnostic abilities and incorporate this data into our everyday treatment planning. The bottom line is that we have an opportunity to improve our patients care.

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Ramya R1" Cone Beam Computed Tomography In Orthodontics –Review."IOSR Journal of Dental and Medical Sciences (IOSR-JDMS), vol. 17, no. 4, 2018, pp 17-22.