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CONE-BEAM COMPUTED TOMOGRAPHY IN ORTHODONTICS – A REVIEW

Orthodontics

C.V. Bhavani*	PG Student, Dept. of Orthodontics & Dentofacial Orthopaedics, Mamata Dental College, Telangana, India. *Corresponding Author
C.Sunitha	Professor and Head, Dept. of Orthodontics & Dentofacial Orthopaedics, Mamata Dental College, Telangana, India.
R.Naveen	Reader, Dept. of Orthodontics & Dentofacial Orthopaedics, Mamata Dental College, Telangana, India.
P.Kiran Kumar	Reader, Dept. of Orthodontics & Dentofacial Orthopaedics, Mamata Dental College, Telangana, India.
T.Saritha	Reader, Dept. of Orthodontics & Dentofacial Orthopaedics, Mamata Dental College, Telangana, India.

ABSTRACT

Radiographic imaging is an important part of orthodontic diagnosis and treatment planning. Cone Beam Computed Tomography (CBCT) is a diagnostic imaging technology designed to produce undistorted three-dimensional images similar to computed tomography (CT) but at low equipment cost, simpler image acquisition, and lower patient radiation dose. CBCT technology utilizes a cone beam-shaped source and a two-dimensional detector to provide multidimensional accurate images for diagnosis and treatment planning. CBCT helps in localizing impacted teeth, identifying and quantifying asymmetry, visualizing airway abnormalities, evaluating placement sites for temporary skeletal anchorage devices, viewing condylar position and temporomandibular joint.

KEYWORDS

Cone Beam Computed Tomography

INTRODUCTION:

Cone Beam Computed Tomography (CBCT) is a recent technology that was initially developed for angiography in 1982 and was applied for imaging the maxillofacial region. It uses a divergent or " cone " - shaped source of radiation and a two-dimensional area detector fixed on a rotating gantry to acquire multiple sequential projection images in one complete scan around the field of interest. In the late 1990s, it had become possible to produce clinical systems that were both inexpensive and small enough to be used in the dental office.[1]

CBCT provides three-dimensional reconstructions of hard tissue including bone and teeth and soft tissue reconstructions of air-bound surfaces including the skin and airway spaces. The applications of CBCT in orthodontics include evaluation of palatal bone thickness, skeletal growth pattern, the severity of tooth impaction, and upper airway evaluation for possible obstructions and in the treatment planning of orthodontic cases which need buccal tooth movement and arch expansion. Cephalometric radiography has been the standard for the evaluation of skeletal, dental, and soft tissue relationships since its development in the early 1900s.[2]

With the help of CBCT, two-dimensional reconstructions of panoramic and cephalometric radiographs are possible and they can be combined with 2 dimensional or 3 dimensional light photographs of the patient face and scalp to form an accurate depiction of the patient's head.

Evolution Of Cbct Technology:

Intraoral radiography was first used after the discovery of X-rays by Roentgen in 1895. Later extraoral imaging, including cephalometric radiography followed. There are 8 generations of CT.[3]

First-generation CT:

It had a single radiation detector and showed translate – rotate motion that produced a single image projection per translation with a scan time of 5 minutes.

Second generation CT:

It had a fan-shaped x-ray beam with multiple detectors and showed translate-rotate mode with a scan time of 10-90 sec.

Third-generation CT:

It had a fan-beam x-ray source with curvilinear detector array and 360^0 rotation mode with a scan time of 1 sec or less.

Fourth-generation CT:

developed principally to reduce ring artifacts. X-ray source rotated around a fixed detector. The scan time was 1 sec or less.

Fifth-generation CT:

It used microwave accelerated electron beam incident on a tungsten target. The scan time was as short as 50 milliseconds.

Sixth generation CT:

It used slip ring scanners and helical CT.

Seventh generation CT:

Multislice CT (MSCT) - it had a large number of detector elements in a single row across the irradiated slice to intercept the x-ray fan beam.

Eighth generation CT:

Micro CT - reconstruction of a 3D image was performed by rotating either the sample or the emitter and detector to generate a series of 2D projections that will be transformed using the 3D representation of the digital process.

BASIS OF CBCT TECHNOLOGY:

CBCT scanners were developed for craniofacial imaging in the late 1990s, in order to overcome the limitations of Multislice CT. A practical cone-beam algorithm for tomographic reconstruction of 2-D projection data was first described by Feldkamp in 1984, who used a back-projection formula to directly reconstruct a 3-D image from a set of two-dimensional projections.

An important feature of the CBCT is that the rotational scan captures multiple planar projections and produces a volume dataset that can produce interrelated images.

There are four components to CBCT image acquisition:

1. X-ray generation
2. Image detection system
3. Image reconstruction
(a) Acquisition stage
(b) Reconstruction stage.
4. Image display

Protocols For Utilizing And Interpreting CBCT In Orthodontics:

Clinical / Radiographic Finding	Region imaged	Field Of View (FOV)
• Impacted & transposed teeth • Root resorption • Supernumerary teeth	Individual teeth, quadrant or one jaw	Small FOV

• Temporomandibular joint • localized asymmetries • boundary conditions • cleft lip and palate cases • conditions involving both the jaws	Both jaws including TMJ	Medium to large FOV
• Orthognathic surgeries • Craniofacial anomalies • Moderate to severe facial asymmetries	Full head	Large to extended FOV

Advantages Of CBCT:

1. Rapid scan time
2. Beam limitation
3. Image accuracy
4. Image resolution
5. Reduced patient radiation dose
6. 3D Reconstruction
7. Less space occupancy of the machine
8. Cost effective
9. Good patient compliance
10. Virtual imaging/combined 3D photography and CBCT

Applications Of Cone-beam Computed Tomography In Orthodontics:

1. Orthodontic diagnosis

I) Evaluation of skeletal and dental structures:

CBCT imaging in association with computer software allows anatomical structures to be represented in sagittal, coronal, and cross-sectional views. It eliminates the superimposition of anatomical structures that interferes with landmark identification and enhances the landmark identification with magnification and adjustments in contrast.[4]

ii) 3D evaluation of impacted teeth:

CBCT enhances the ability to localize impacted canines accurately, evaluate their proximity to other teeth, determine the follicle size and presence of pathology, estimate space conditions, assess resorption of adjacent teeth and the relationship of the roots of an impacted tooth to important anatomical structures, such as the inferior dental canal or maxillary sinus; the root apex location and the orientation of the long axis of the canine.[5]

iii) Growth assessment:

Skeletal maturity can be assessed by observing morphologic changes within the cervical vertebrae with the use of CBCT. CBCT should not be used solely for the purpose of evaluation of skeletal maturity; instead, when it is used as an investigating tool for the purpose of orthodontic treatment then the morphological changes should be, evaluated. This not only reduces the cost but also reduces the radiation load with the patient.[6]

iv) Pharyngeal airway evaluation

Lateral cephalograms have been routinely used to evaluate the airway using techniques involving both hard tissue and soft tissue regions. The axial cuts of 3D CBCT scans offers soft tissue points that are clearly visible in axial CBCT cuts compared with conventional X-rays, thereby enhancing airway assessment. Three-dimensional CBCT-assisted airway analysis facilitates the diagnosis and treatment planning of complex anomalies such as enlarged adenoids and obstructive sleep apnea (OSA).[7]

v) Assessment of TMJ complex in three dimensions:

CBCT imaging helps in evaluating bone structures, articular space, and dynamic function of the temporomandibular joint in all three dimensions without superimposition and distortion. It is useful in diagnosing condylar morphology, disturbances, and erosion.[8]

vi) 3D imaging in craniofacial anomalies

a) Facial asymmetries:

CBCT provides the 3D imaging data necessary to generate precise knowledge of the location and the magnitude of specific features contributing to the asymmetry thereby helping in the diagnosis of facial deformities and planning of corrective procedures. It also helps in the formation of 3D models based on the data obtained by CBCT imaging reproducing a patient's teeth and surrounding bone structures.[9]

b) Cleft lip and palate:

CBCT imaging determines the volume of the alveolar defect, the amount of bone needed for grafting in CL/P patients and also determines the success of bone fill following surgery. It gives information regarding the number, quality, and location of teeth in the region of the cleft, the eruption status of canines and path of canines in grafted cleft sites,and diagnosing for implant placement.[10]

c) Cleidocranial dysplasia:

CBCT provides a 3D image of the jaws and teeth of patients with Cleidocranial dysplasia. It gives the precise location of a supernumerary tooth in relation to structures such as the cortex of the nasal floor, labial cortex of the nasal ridge, nasopalatine duct, or adjacent root apices. This accurate localization results in minimally invasive surgery and helps in planning effective orthodontic tooth movements.[11]

2. Treatment Planning:

I) Orthognathic surgical planning:

CBCT 3D surface reconstructions of the jawbones are used for preoperative surgical planning in patients with traumas and skeletal malformations. It couples with software tools simulates the virtual re-positioning of the jaws, osteotomies, and distraction osteogenesis. Pre and post-operative 3D CBCT skull models can also be registered (superimposed on each other) to assess the amount and position of alterations in the mandibular rami and condylar head following orthognathic surgery.[12]

ii) Orthodontic implant placement:

During the placement of TADs, CBCT scan images aid in macro-anatomical analyses which helps in visualization of neighboring structures such as tooth roots, sinuses, and nerves that are valuable for avoiding damage or complications, as well as in the micro-anatomical evaluation of the quantity and quality of cortical bone that may determine primary and secondary TAD stability.[13]

iii) Estimation of space requirement for impacted teeth:

CBCT scans provide information regarding the teeth neighboring the impacted teeth in terms of root proximity. This information helps in placing the adjacent teeth and their roots away from the traction path of the impacted tooth so as to avoid unwanted changes in these teeth. It also aids in estimating and creating the necessary space to accommodate the tooth within the arch.

iv)Fabrication of custom orthodontic appliances:

The custom lingual orthodontic appliances can be fabricated using CBCT image data along with the existing technology which virtually plans the patient's treatment and the manufacturing of these custom appliances can be done with 3D printing technology. These advances are rapid and also promise efficient and effective patient-specific treatments.[14]

3. Assessing Treatment Progress And Outcome:

I) Dentofacial orthopedics:

CBCT imaging helps in the comparison of treated and untreated controls by using 3D regional superimpositions which has the potential to assess bone displacements (shift in position) and remodeling (change in size and shape) of skeletal and soft-tissue facial components in relation to the cranial base.[15]

ii)Orthognathic surgery superimposition:

The assessment of soft tissue changes during and after surgery requires three-dimensional analysis and superimposition due to the complexity of the soft tissues. Surgical treatment outcomes can be assessed by superimposing a custom surface mesh of the first CBCT image onto a second CBCT image of the anterior cranial base.[16]

iii)3D planning and treatment outcomes of bone-anchored maxillary protraction:

The precise response to the protraction of the maxilla with bone-anchored maxillary protraction, such as remodeling and adaptation of the adjacent bones, sutures, and soft tissues and their clinical relevance can be evaluated using advances in 3-dimensional (3D) imaging of facial structures such as CBCT imaging. It also identifies the location and nature of the orthopedic effects after bone-anchored maxillary protraction.[17]

4. Application Of Cbct In Risk Assessment:

I) Orthodontic associated sensory disturbances:

Sensory disturbances of the lower lip and chin area are commonly reported after orthognathic surgery, or following removal of the mandibular third molars. The neural disturbances during orthodontic

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treatment occur as temporary conduction blockade due to compression of the inferior alveolar nerve bundle. CBCT scan helps to evaluate the position of the mandibular canal and determines the course of the inferior alveolar nerve bundle in order to minimize the risk of neuropathy.[18]

ii) Root resorption:

The periapical radiograph is commonly used for measuring tooth length and estimating root resorption. The errors during orientation and overlapping problems inherent with periapical radiographs can be overcome with CBCT imaging as it produces multiplanar reformatted (MPR) images and allows 2D views in all 3 dimensions. It also helps in localizing the root resorption in the case of multi-rooted teeth.[19]

iii) Post-treatment temporomandibular joint disorder:

CBCT images provide concurrent visualization of TMJs and maxillomandibular spatial relationships and occlusion thereby helping to visualize and measure the local and regional effects associated with TMJ abnormalities. It is useful in cases involving centric occlusion versus centric relation (CO/CR) discrepancies, unilateral Class II malocclusions, or a retrognathic mandible involving displacement of the TMJ in CO versus CR.

Limitations Of Cbct:

1. Image noise
2. Poor soft-tissue contrast
3. Artifacts

- X-ray beam
- Patient related
- Cone beam related
- Scanner related

CONCLUSION:

The use of CBCT in orthodontics has gained popularity over a period of time. The incorporation of a third dimension into practical dental and craniofacial imaging has made this imaging modality exciting and intriguing imaging of choice as the paradigm has shifted from landmarks, lines, distances, and angles to flashing a volumetric narration of surfaces, areas, and volumes. CBCT has got innumerable advantages like less expensive equipment, radiation dose, room space, time is taken for imaging, compared with conventional CT as well it has got a very few disadvantages like poor soft-tissue contrast, image noise, and artifacts.

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