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Cone beam Computed Tomography: Third Eye in Diagnosis and Treatment planning

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Abstract:

Orthodontic treatment of adult patients with complex dental problems is done in interdisciplinary teams where different specialist of dental medicine have to manage a vast quantity of data. In such complicated cases good diagnostic tools and easy communication are essential. Computer science has an increasing impact in almost every aspect of the orthodontic practice, research and education. Within the past decade, technology termed "cone beam computed tomography" (CBCT) has evolved that allows 3-D visualization of the oral and maxillofacial complex from any plane. With the development of Cone Beam Computed Tomography, there has been a drastic reduction in radiation exposure to the patient, which allows its use for safely obtaining 3 dimensional images of the craniofacial structures. This should allow the clinician to visualize the hard and soft tissues of the craniofacial region from multiple perspectives, which could have far-reaching implications for treatment planning in orthodontics and orthognathic surgery. This paper shall discuss in detail the principles of the Cone Beam computed tomography and its applications in the field of orthodontics.

KEY WORDS: 3-D images, orthodontic diagnosis, CBCT

Introduction

At the beginning of the 20th century, plaster was the primary material used to capture dentofacial morphology. Almost all practitioners used plaster to make casts of the teeth and alveolar bone. Orthodontic study models are an important part of treatment planning[1,2]. A study model is a precise 3-dimensional (3D) replica of a patient's dentition on which certain measurements can be made more easily and accurately than in the patient's mouth. With the increasing use of computers in orthodontic offices over the past 25 years, many digital multi-media applications have become available to the clinician and his or her staff to facilitate standard procedures in practice and management; the final goal is a fully digital orthodontic office.[3,4].

In the last decades, the introduction of three dimensional imaging characterized by Cone beam Computed Tomography has a tremendous impact on the diagnosis and treatment planning in orthodontics. The tomographic nature of CBCT provides thin slices at much higher inherent detail than what is achievable with 2D projection radiography, which in turn allows for a better delineation of the bone and soft-tissue boundaries and a deeper appreciation of the intricate interrelations of the complex anatomy in the maxillofacial region. Cone Beam Computed Tomography (CBCT) scanners capture the entire maxillofacial region by a single rotation of the x-ray tube and detector around the patient's head while providing sub-millimeter resolution[5-8].

CONE BEAM COMPUTED TOMOGRAPHY:

Cone beam CT (CBCT) was first developed for use in angiography. In 1998, Mozzo et al[9] reported the first CBCT unit developed specifically for dental use, the NewTom 9000 (Quantitative Radiology, Verona, Italy). Other similar devices introduced at around that time included the Ortho-CT, which was renamed the 3DX (J. Morita Mfg Corp, Kyoto, Japan) multi-image micro-CT in 2000.[10] (Figure 1) In 2003, Hashimoto et al[11] reported that the 3DX CBCT produced better image quality with a much lower radiation dose than the newest multidetector row helical CT unit (1.19 mSv vs 458 mSv per examination).

The technology was initially developed as an alternative to the fan-based conventional CT scanners due to an increasing demand for rapid imaging coupled with the ability to cover large scan area in a single arm rotation. The principle of CBCT is based on a fixed x-ray source and detector with a rotating gantry. The x-ray source emits a cone-shaped beam of ionizing radiation that passes through the centre of the scan region of interest (ROI) in the patient's head to the x-ray detector on the other side. The gantry bearing the x-ray source and detector rotates around the patient's head in full 360 degree , or sometimes, partial 180-270 degree arcs. While rotating, the x-ray source emits radiation in a continuous or pulsed mode allowing the detector to acquire multiple'basis' projection radiographs. Those two-dimensional projections are then reconstructed with the help of a special reconstruction algorithm into a 3D volume (Figure 2).

Figure 1: Some currently available CBCT scan devices: New Tom 9000 Volumetric Imaging Device and J. Morita's **3D** Accuitomo **cone-beam CT**

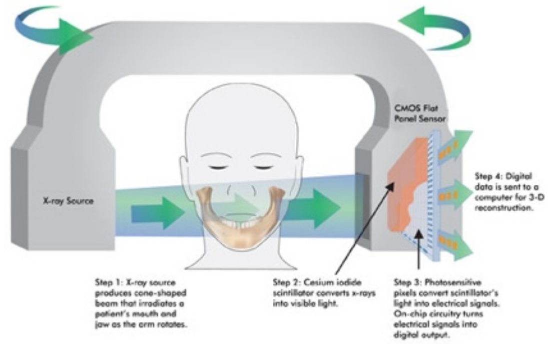

Figure2. In cone beam computed tomography, a cone-shaped x-ray beam irradiates a patient's jaw. The transmitted x-rays are detected by a sensor. The data is then sent to a computer and reconstructed into 3-D images by software.

APPLICATIONS OF CBCT IN ORTHODONTICS :

CBCT has revolutionized maxillofacial imaging, facilitating the transition of dental diagnosis from 2D to 3D images and expanding the role of imaging from diagnosis to image guidance of operative and surgical procedures. Not only that we are able now to provide more accurate diagnosis with this imaging modality, but also we are able based on the new radiographic data to guide and assess various surgical and clinical interventions.

CBCT is an imaging modality that is being more frequently applied to orthodontic assessment[12].From a radiation-protection point of view, conventional images may deliver the lowest doses to patients. CBCT technology saves time and effort in the orthodontic practice. With a cone beam system, all possible radiographs can be captured in under 1 minute[13], and the orthodontist has the diagnostic quality of periapicals, panoramics, cephalograms, occlusal radiographs, and of TMJ along with views that cannot be produced by regular radiographic machines, such as axial views and separate cephalograms for the right and left sides.

1. **Dental implants:** CBCT helps in examination of the mandible and maxilla for possible placement of dental implants[14]. It helps in determination of the status of existing implants and reduction of possible complications involving the nerves and sinuses in dental treatment.

2. **Anomalies of teeth and roots:** Impacted and transposed teeth are possibly the most common reason for use of CBCT imaging in orthodontics. CBCT scans can provide diagnostic information on roots of the adjacent teeth that are in close proximity to the impacted or transposed tooth or in its traction path that can be moved proactively and avoid causing damage to vital structures e.g mandibular canal[15-17].(Figure 3). Another advantage of CBCT over routine radiographs includes the accurate measurement of the impacted tooth to aid in determining and developing the space needed for the tooth. The presence of supernumerary teeth can pose a challenge to the clinician's ability to distinguish which tooth is actually the supernumerary and which one is the normal tooth. Accurate measurements and the determin-ation of the precise location of the tooth from CBCT images allow the clinician to make an informed

decision on which tooth, or teeth, to extract, the optimal surgical approach and help to minimize damage to the real tooth.

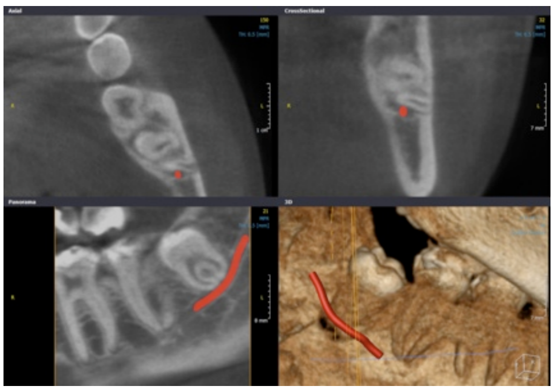

Figure 3:
Visualization of the intimate relation of the mandibular canal and an impacted wisdom tooth, imaged with the Scanora 3D.

3. Pathological conditions: CBCT diagnostic applications in the maxillo facial region include evaluating the presence of osseous defects in the jaws, cysts, lesions, calcifications, teeth and bone traumas and fractures. CBCT is also playing an increasingly important role in the detection of 'incidental' pathology in patients referred to dental treatment. Since most CBCT systems currently available acquire volumes that extend beyond the dentition and the surrounding alveolus, unsuspected lesions in the para-nasal sinuses, parotic region, masticatory space, floor of the mouth and the hyoid region are
frequently detected and reported[18-24] . Evidently the three dimensional nature of CBCT allows determination of the exact extension of the lesion in the affected region.(Figure 4)

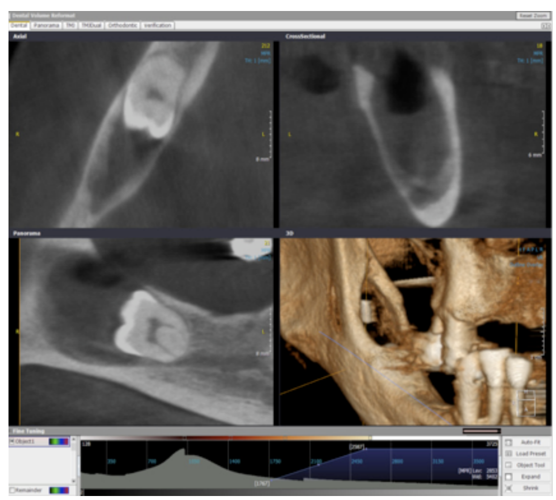

Figure 4: Folicular dentigerous cyst in the right mandible associated with an impacted tooth, imaged with the Scanora 3D

4. **Orthognathic surgery:** Several applications of CBCT in orthognathic surgery treatment simulation, guidance and outcome assessment have been developed.

CBCT 3D surface reconstructions of the jawbones are used for preoperative surgical planning and simulation in patients with traumas and skeletal malformations (Figure 5). [25-27] Coupled with dedicated software tools, simulations of virtual re-positioning of the jaws, osteotomies, distraction osteogenesis and other interventions can now be successfully implemented. Pre and post-operative 3D CBCT skull models can also be registered (i.e. superimposed on each other) to assess the amount and position of alterations in the mandibular rami and condylar head following orthognathic surgery of the maxilla and the mandible.[28,29]

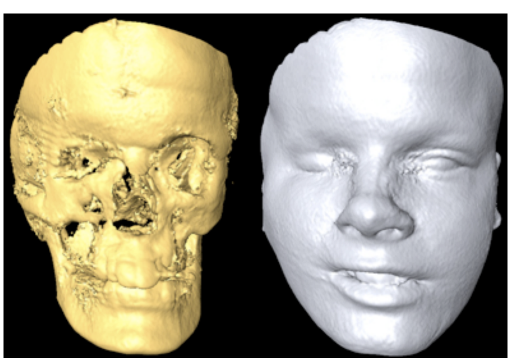

Figure 5: A patient with deviation in the face in the right side, imaged with the NewTom 3G

5. **TMJ imaging:** The temporomandibular joint (TMJ) is a complex entity with hard and soft tissue components. TMJ disorders (TMDs) are common but widely variable. CBCT para-sagittal and coronal slices show clear images of the condylar head and the glenoid fossa. Additionally, provides images from different orientations and different reconstruction views thus providing axial, coronal and para-sagittal imaging of the condylar head. CBCT is more accurate than panoramic radiography and conventional tomography for detecting TMDs (Figure6). [30-34]

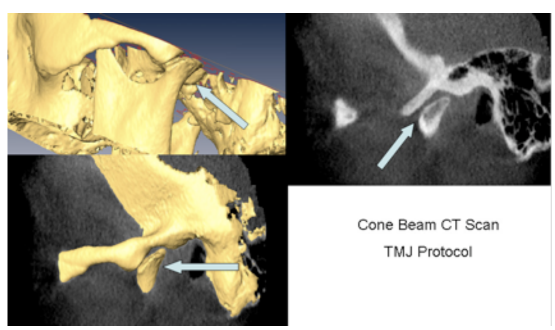

Figure 6: Patient with flattening in the temporomandibular joint, imaged with the NewTom 3G.

6. **Cleft lip and palate:** In cleft lip and palate patients, information regarding the number and orientation of teeth, dental and skeletal age, the amount and quality of available bone and bone graft in the cleft region are considered vital for the clinical management of such cases. CBCT provides excellent 3D visualization of the palate at the pre-maxilla region at a lower patient dose (Figure7). [35]CBCT is used to determine dental age and when a large scan field of view FoV selection is available, 3D reconstructions of the cervical vertebra can be made and employed to determine skeletal age. [36] Additionally, CBCT has been used to show any deformities in the piriform margin in the nasal platform and the antero-posterior depression of the nasal alar base.[37] Three-dimensional CBCT reconstructions of the skin surface of the face and nose for cleft lip assessment are also possible.

Figure 7: Patient with unilateral cleft palate with tooth impaction, imaged with the Scanora 3D

ADVANTAGES OF CBCT:

1. CBCT offers high quality in-office imaging, as the technique is easy to apply and has easy-to-use postprocessing and viewing software.

2. Compared with classic radiographs, measurements obtained by the use of CBCT are very exact, because the resulting images are actual size and high-resolution 3D.

3. It is the most accurate method for assessing the bony structures of the TMJ.

4. The resulting data have the potential for generating all 2D images in a single

scan (e.g., dental panoramic tomogram, lateral cephalogram).

5. Compared to traditional CT, CBCT is emits less ionising radiation, has a shorter exposure time and gives better image resolution.

DISADVANTAGES OF CBCT:

1. It is definitely more expensive than classic two-dimensional radiologic investigations.

2. The dose of ionising radiation generated is greater than in a pantomography investigation.

3. As a new technology, it requires new competences from the clinician and the value of information obtained is interpretation-sensitive.

4. Any movement artefacts affect the whole data set and the whole image rather than just one part.

5. It provides limited resolution of deeper (inner) soft tissues, and MRI and classic CT are better for soft-tissue imaging.

6. It has low contrast range (dependent on the type of x-ray detector).

7. It has increased noise from scattered radiation and concomitant loss of contrast resolution.

CONCLUSION:

The expanding use of CBCT technology is beneficial to both patients and practitioners and is especially important to orthodontists because its ability to capture the entire anatomy needed for orthodontic treatment planning. When used correctly and responsibly, the data derived from CBCT imaging provides insight into treatment planning that is unachievable with other imaging methods, and allows clinicians to provide more predictable patient care.

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