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Cone Beam Computed Tomography (CBCT)

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Dedication

We dedicate our graduation thesis to the Imam of our time , the parents , the security forces , the popular crowd and all the martyrs of Iraq.

CONTENTS OF REVIEW :

Abstract

In cone beam computed tomography (CBCT), an X-ray beam in the form of a cone (hence the name) is applied, and during the scan, a certain volume is imaged, which is used to retrieve sectional images in different planes. Advantages of CBCT include high-resolution cross-sectional imaging of bone structures; relatively low patient exposure dose; high and growing availability of CBCT machines for dentists; relatively low cost of facilities, equipment, and examination itself when compared with CT; and relatively high diagnostic accuracy for TMJ bone changes. Disadvantages of CBCT include lower image contrast than in CT, higher image noise than in CT, and no precise estimation of Hounsfield units; thus still no reliable evaluation of soft tissues, image artifacts, and limited reliability for TMJ bone changes. Applications of CBCT in diagnostics of TMJs include evaluation of TMJ anatomy, evaluation of condylar position in malocclusion, developmental anomalies, osteoarthritis diagnosis and follow-up of rheumatoid arthritis and juvenile idiopathic arthritis, and assessment of internal derangement, also in conjunction with MRI, condylar fractures, ankyloses, cysts and tumors, and image-guided puncture.

Introduction:

The discovery of X – rays in 1895 by Sir Wilhelm Conrad Roentgen was an incredible era in the history of medicine. Diagnostic imaging over the last few decades, turned out to be much more refined owing to addition of various imaging technology with complex physical principles. Threedimensional imaging (3D) evolved to meet the demands of advanced technologies in delivering the treatment and at the same time responsible for the evolution of new treatment strategies. Considering the limitations (superimpositions, distortions etc.) of two-dimensional (2D) radiography which was the backbone of diagnostic imaging for many years, doubt exists that it will continue to contribute in the future. G.N. Hounsfield, in 1972 introduced computerized transverse axial scanning (1) which lead to introduction of Computed Tomography (CT) **{1}**. However the high cost, limited access, and high radiation exposure, were the main drawbacks for under utilization of CT in dentistry. Arai et al. (2) in Japan and Mozzo et al. (3) in Italy working independently, introduced the Cone Beam Computed Tomography (CBCT) for the oral and maxillofacial applications and like CT, offered 3D exploration and more accurate imaging compared to 2D imaging. The cost effective technology of CBCT, led to speedy ingress into the field of dentistry with demand for commitment of dental professionals and dental educators to explore the applications of CBCT technology. The purpose of this review is to provide an insight into 3D imaging with CBCT technology, its basic concepts, advantages, disadvantages and applications in dentistry with few illustrations**{2}.**

Indications

The ability to capture three-dimensional (3D) dental and skeletal relationships is a tremendous benefit in the specialty of orthodontics, and cone-beam computed tomography (CBCT) provides this advantage at a relatively low cost. The diagnostic capabilities of CBCT are far more advanced than traditional two-dimensional (2D), or traditional, radiography. As dental hygienists are leaders in patient education, it is important they understand how CBCT is used in orthodontic treatment. This article will discuss specific indications for CBCT in orthodontics.

DEVELOPMENTAL ANOMALIES IN DENTAL POSITION:

CBCT imaging has indications for the assessment and diagnosis of a number of specific conditions in orthodontic patients.Developmental anomalies of tooth structure can lead to disturbances in maxillary and mandibular dental arch lengths, occlusal arch discrepancies resulting in poor esthetics, and inter-arch differences producing malocclusions.

crowding and DENTO-ALVEOLAR MORPHOLOGY the width of the alveolus of the jaws defines anatomic facio-palatal/lingual boundaries for orthodontic torque movement of teeth, or retraction, arch expansion, or labial movement of incisors. Evaluation of fenestrations and dehiscence on the buccal and lingual surfaces can be an important consideration in certain patients, such as those with bimaxillary protrusion, compromised periodontal status, and/or clefts of the alveolus **{3}**.

DENTOFACIAL DEFORMITIES AND CRANIOFACIAL ANOMALIES:

Three-dimensional volumetric imaging is a particularly useful tool in the analysis of severe skeletal discrepancies producing facial or mandibular asymmetry , and anteroposterior, vertical, and transverse deficiencies**{4}**.

MALOCCLUSIONS AND SKELETAL DISCREPANCIES:

Identification of Class II and Class III skeletal malocclusions (Figure 5)8,14–16 and increased or decreased vertical facial height and asymmetry,17 either alone or in combination, involves an appreciation of the contribution of maxillary and mandibular anterior-posterior, vertical, and transverse discrepancies that are well-visualized with CBCT images**{5}**.

TEMPOROMANDIBULAR JOINT:

Temporomandibular joint (TMJ) articulation can be necessary if orthopedic treatment is anticipated that may affect structural development during growth—such as head gear, functional applianceTMJ conditions include developmental disorders such as condylar hyperplasia, hypoplasia, or aplasia, and patients with moderate to severe arthritic degeneration. In these situations, CBCT imaging provides additional diagnostic information, such as the size, shape, and

position of mandibular condyle heads in established positions and the presence of active disease that may influence management{6}.

POST-THERAPY AND AIRWAY ASSESSMENT:

CBCT may be useful in assessing the treatment outcomes of orthognathic surgery, grafting procedures, and the use of nonsurgical devices to affect vertical or transverse discrepancies{7}.

PATHOLOGY:

CBCT imaging demonstrates the location, size, shape, extent, and full involvement of pathology of the jaws. Various conditions which may be encountered—most commonly infections{8}.

Contraindications

There are no absolute contraindications for CBCT, and pregnancy is a relative contraindication. A limitation of CBCT application may be the lack of cooperation resulting in motion artifacts in small children or mentally disabled patients{9}.

Component of CBCT :

1-Acquisition configuration:

There are three major components to CBCT image production Acquisition configuration:

a: X-ray generation: A pulsed or constant beam of radiation can be used. This is one of the reasons for variation in cone-beam dosimetry between different units.

b. Field of view: This depends on the detector size and shape, beam projection geometry, and the ability to collimate the beam. CBCT can be categorized by the available FOV, which usually ranges from 4 to 30 cm. The larger the FOV, the poorer the resolution.

c. Scan factors: During the scan, single exposures (known as basis, frame, or raw images) are made. (These are similar to the lateral view of PA cephalometric images.) The complete series is known as projection data. The number of images comprising a projection data set is determined by the frame rate (i.e., the number of images acquired per second; a faster frame rate results in better image quality, but it also exposes the patient to more radiation); the speed of rotation; and the completeness of the trajectory arc. Most CBCT machines scan for a full 360 degrees to acquire projection data. However, some machines limit the scanning arc, thus reducing the time, radiation dose, and mechanical components required. The disadvantages of this approach are greater noise and a higher possibility of artifacts{10}.

2- image detection:

Current CBCT machines can be divided into two groups based on the detector type: image intensifier tube/charge-coupled device (IIT/CCD) or flat panel imager. The flat panel imager is thought to create less distortion and have fewer artifacts. Flat panel performance limitations are most noticeable at lower and higher exposures**{11}**.

3-image reconstruction:

The projection data must be reconstructed to create a usable volumetric data set. This is computationally complex and can involve two computers (an acquisition computer and a processing [workstation] computer). This phase is divided into two stages: the acquisition stage (usually 160 to 600 basis images are collected) and the reconstruction stage (in which algorithms such as the FDK algorithm are used to recombine the data for visualization)**{12}**.

4- image display:

The data set is presented to the clinician usually in three orthogonal planes (axial, sagittal, and coronal**{13}**.

CBCT technique :

The CBCT technique consists of the use of a round or rectangular cone shaped X- ray beam with a single 360° scan where the X-ray source and a reciprocating array of detector simultaneously move around the patient's head, which is stabilized with a head holder. Single projection images, known as "basis" images, are acquired at certain degree intervals, which are similar to lateral cephalometric radiographic images, each slightly offset from one another. The series of such basis projection images is referred to as the projection data, on which software programs incorporating sophisticated algorithms are applied to generate a 3D volumetric data set, which can be used to provide primary reconstruction images in all three orthogonal planes (axial, sagittal, and coronal)**{14}**.

D cone beam computed tomography (CBCT) is an imaging technology that allows dentists to 3 evaluate the underlying bone structure, as well as the nerve pathways and surrounding soft tissues. During a CBCT scan, the imaging machine rotates entirely around the patient's head. In less than a minute, about 150-200 images are captured from a variety of angles and compiled into a single 3D image**{15}**.

CBCT scans are quick and in most cases, a full mouth scan only takes about 20-40 seconds. When having a CBCT scan taken, you can expect to be seated while an x-ray arm slowly rotates around your head. To ensure your head remains still during the scan, your dentist may have you rest your

head against part of the machine and/or use stabilizers in or around your ears to gently hold your head in place. The scan should cause you no discomfort{16}.

In case you are wondering, CBCT scans do use radiation, however they use significantly less . radiation than traditional CT scanners and are considered to be safe. At any given time, we are all exposed to what is known as background radiation. A medical CT scanner produces enough radiation to be equivalent to 63-154 days of background radiation, while a CBCT scan only produces about 6-30 days of background radiation{17}.

CBCT versus CT:

The transmitted radiation used in a CT scanner is projected in a helix-like shape. The images are inserted into the image detector that is set up around the patients. This process can only utilize single sliced images for each scan. However, it is a rapid process that can cover a substantial amount of the body. These CT scans may also generate these images into a 3D depiction{18}.

Another difference between the two units is that the traditional CT scanner uses a high-output anode x-ray tube. In comparison, the CBCT scanner uses a medical fluoroscopy tube that utilizes a low-power output system. We recommend the CBCT as the output system is lower{19}.

One of the most important details that separate the one scanner from the other is the amount of radiation. Since the CBCT scanner has such efficient movement, it can scan a patient a lot quicker. When compared to the traditional CT scanner, the CBCT is a lot safer. When scanning the mandible of a patient with a CT, it exposes them to 200-300 times the amount of radiation. The reduced exposure is more beneficial for your patients' health and well-being{20}.

The positioning of both units is also different. When scanning with the traditional CT scanners the patient has to lie down. With most other CBCT scanners, they don't require the patient to lie down. When using the scanner, the machine utilizes canning using panoramic radiography. a traditional CT scan as to be parallel to the X-ray beam and any slight movement of the patient can result in an error. However, in a CBCT scanner, the orientation of the unit doesn't require the

patient to hold still{21}.

Advantages:

1-CBCT has shown that it is a precise imaging modality and is a valuable tool for use in dental applications{22}.

2- CBCT can accurately capture, display and provide visualization of 3D maxillofacial anatomy. CBCT has a greater degree of precision and clarity and it has advantages over conventional radiography{22}.

3- It offers 3D imaging that adds depth, which can be viewed in the full 360° range and in any desired plane around the immediate area of interest{22}.

4- Unlike conventional 2D imaging methods, this method provides anatomical accuracy and .provides a true reproduction of the patient's anatomy{22}.

5- With cone-beam CT scanning, the patient to far less radiation than common CT due to focused is subjected X-rays. These focused X-rays reduce the scatter that occurs with other imaging devices. In addition, the scan allows for significant reduction of metal artifacts, which allows for a scan of a patient with braces. Restricting the CBCT scanning field of view to only the areas of interest also minimizes the radiation dose{22}.

6- The scan is fast and comfortable for the patient . A scan is completed in 10 seconds and the patient is scanned in normal seated postion . this is due to the use of a focused beam with physically larger sensor allowing capturing all the axial slices covering the face and the jaws in one scan . since , it capturs the entire volume with one scan , there is no redundant overlap of slices, resulting in magor reduction of radiation{23} .

7- One scan yields volumes of images that can be easily viewed and manipulated for in-depth examination{23}.

8- This gives a good description in terms of root resorption, anatomical detail and the labiolingual relationship of the impacted tooth with the roots of the neighboring teeth{23}.

9- Another advantage is that this multislice imaging can show the existence and location of supernumerary teeth, odontomas and soft tissue pathological entities the extent and depth of the resorption process of the neighboring roots and relationship of an impacted tooth to important structures like mandibular canal and maxillary sinus{23}.

10- This offers an accurate one-to-one measurement that can be made on the images and transferred directly to the surgical field{24}.

11- CBCT is especially useful when multiple impacted teeth are present in one region and superimposed over one another. This imaging system will provide an accurate, quick and reliable method to understand the labiolingual order of the supernumerary tooth/teeth and the normal teeth, their relative heights, the normalcy of their crown and root anatomy and their comparative root length{24}.

12- CBCT allows the dentist to visualize the position and surgical anatomy of the tooth as it will be seen during surgical anatomy of the tooth as it will be seen during surgical procedure{24}.

13- Clinical diagnosis of existing pathologic lesion can be assessed more accurately{24}.

14- CBCT can be used to assess alveolar bone height bone width, bone quality, pathosis, if any interarchspace, maxillomandibular relationships and tempero mandibular joints, which is otherwise a difficult task{25}.

15-Advantages of machines, such as i-CAT, are easy convenient and low-cost access to this imaging modality for the patient and the clinician{25}.

Disadvantages:

1- Poor contrast resolution:- Probably the most significant disadvantage of CBCT is that it produces a worse contrast resolution compared to fan-beam CT, making it harder to view soft tissue. The contrast resolution of CBCT is limited by high scatter radiation during image acquisition, the divergence of the x-ray beam, and built-in flat panel detector related

artifacts. If the objective of the examination is soft tissue only, using a CBCT would not be a satisfactory solution{26}.

2- Athough the cbct likelihood of exposure to excessive radiation is always low, there still remains a risk of cancer.he effective radiation dose of CBCT varies according to criteria such as the related area, resolution and FOV. All these parameters must be selected carefully to reduce the exposure of the patient to radiation{26}.

Radiation dose:

The average absorbed dose from a CBVT scanner is roughly 12.0 mSv (micro sieverts), which is equivalent to or less than the radiation needed to take five dental x-rays using D-speed film. This amount of radiation is similar to one fourth of a typical panoramic machine. By comparison, medical CT scanners acquire images using effective doses 40 to 60 times these amounts; the radiation dose for medical CT scanners is based on the patient's weight, bone density and whether one jaw or two jaws is being studied{27}.

APPLICATION OF CBCT IN DENTISTRY:

A CBCT exam should be done only when the diagnostic yield will benefit patient care, enhance patient safety or significaly improve clinical outcome.

Application in Endodontics:

CBCT in endodontics have **aided** in:

1- Diagnosis of periapical lesion due to pulpal inflammation.

2- Visualisation of canal.

3- Elucidation of canal.

4-Detection of root fracture. CBCT is formed efficacious in endodontic surgeries and identification of dento-alveolar trauma as well as **{28}**.

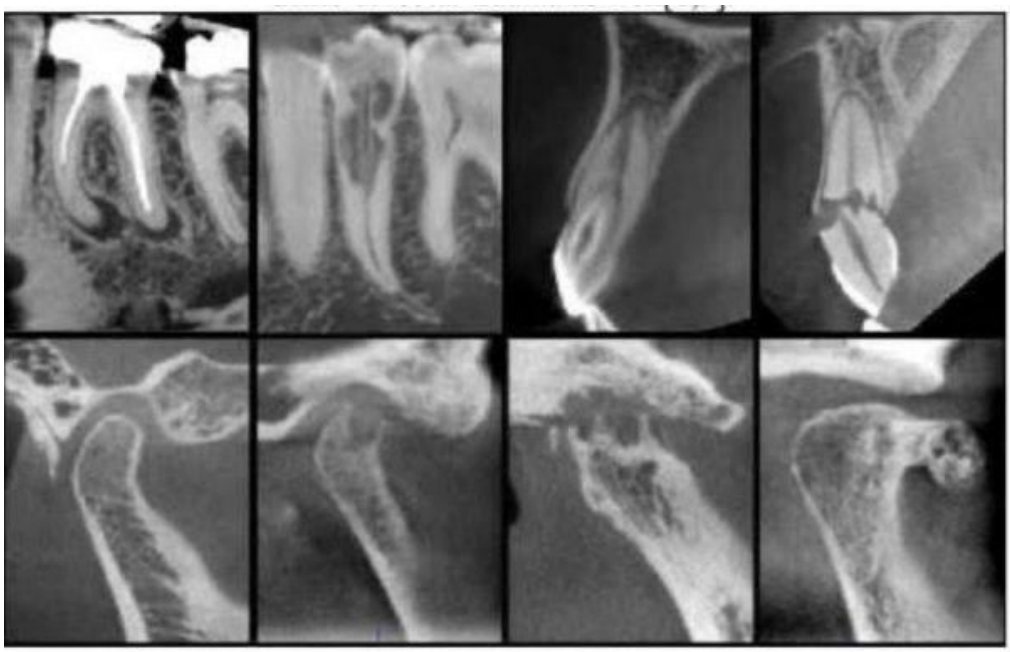

Figure 1 :applicationof CBCT in endodontics courtesy:UCLA CBCT radiology images.

Application in Periodontics: More defined visualisation of lamina dura , crater defect ,furcation involvement and bone quality is possible through CBCT[10]. CBCT image was much superior to conventional radiographs. This can contribute to the clinical decision and improve clinical efficiency**{29}**.

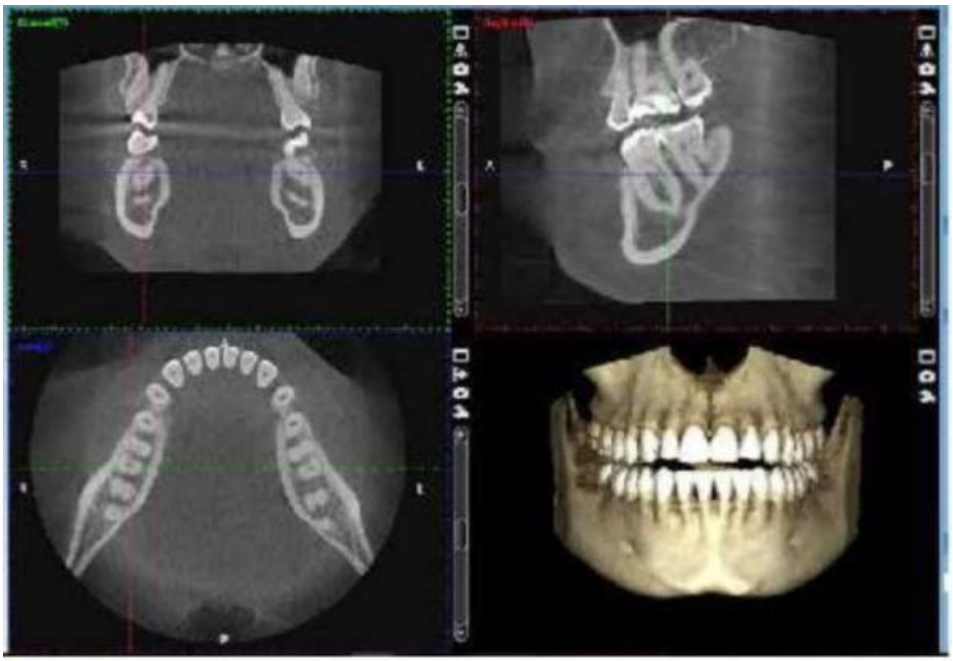

Figure 2 :3D image of mandible courtesy.

TMJ(temporo mandibular joint): CBCT images can be produced in all 3 different planes hence all the components of the joint is simulated in reconstruction of the defect**{30}**.

Figure 3: CBCT scan of the jaws courtesy:www.wikipedia/com Bony surface can be checked in all dimesion for the identification of pathologies like cortical erosion,subchondral sclerosis,flattening and subchondral cysts.

Implant site assessment: Implant site assessment involves assessment of bone density,quality and accurately depicting the vital structure in the area of interest,virtual implant placement allows us to plan surgery before the surgery is performed**{31}**.

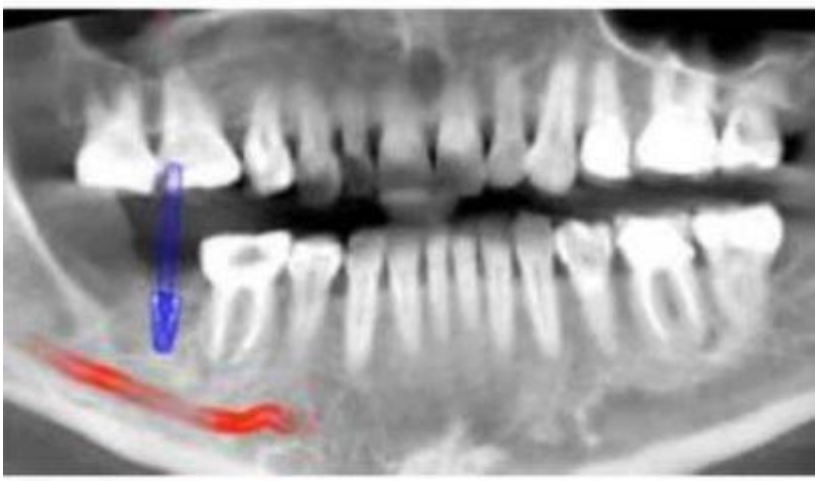

Figure 4 : virtual implant surgery through CBCT courtesy:Cone beam CT in dental practise.,British dental journal vol 207 2009.

Cleft lip and cleft palate assessment: Cleft lip and cleft palate being a congenital anomaly, radiological imaging's are to be carried out in younger individual. CBCT has low radiation exposure compared to conventional CT**{32}**.

CBCT in oral and maxillofacial surgery: The exact location of impacted tooth can be indentified . It is always necessary to access the proximity of the impacted tooth to inferior alveolar canal in mandible. Maxillary sinus in maxilla and palatal orientation of canine{33}.

CBCT in identification of pathological condition: It is used to access any pathological conditions such as lesions , cyst, or tumours{34}.

CBCT and MRI together are gold standard for imaging the intra-articular soft tissue components of TMJ.

Figure 5 :CBCT finding in the mandible courtesy :ARC journal of dental science.

Due to its lower doses of radiation CBCT has been made the best imaging devices for cases involving trauma,fibro-osseous ankylosis, pain, dysfunction, condylar cortical erosion and cyst.

Artefacts

are common in today's cone beam CT (CBCT). They are induced by discrepancies between the mathematical modelling and the actual physical imaging process. Since artefacts may interfere with the diagnostic process performed on CBCT data sets, every user should be aware of their presence{35}. This article aims to discuss the most prominent artefacts identified in the scientific literature and review the existing knowledge on these artefacts. We also briefly review the basic three-dimensional (3D) reconstruction concept applied by today's CBCT scanners, as all artefacts are more or less directly related to it{36}.

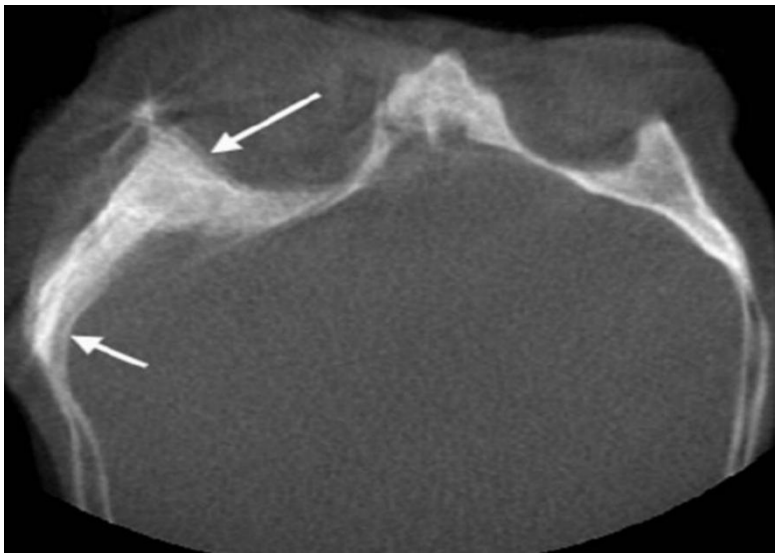

Figure 6 : Typical double contours (arrows) induced by patient movement during the acquisition process of the projection images.

Conclusion:

CBCT technology has expanded maxillofacial CBCT imaging from diagnosis and image guidance of operative and surgical procedures into 3D printing. The use of CBCT has allowed greater predictability in the diagnosis and subsequent care of patients, especially those with complex conditions. This imaging tool brings with it an increased practitioner responsibility in the performance, optimal visualization, and interpretation of volumetric data sets.

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