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Role Of Cone Beam CT In Oral & Maxillofacial Surgery – A Diagnostic Boon

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Abstract
Background: Imaging is an important diagnostic adjunct to the clinical assessment of the dental patient. Cone Beam Computed Tomography (CBCT) is a relatively new technology specifically dedicated to imaging of the maxillofacial region.
Aim & Objectives: To provide an overview of role of CBCT in oral & maxillofacial imaging.
Conclusion: CBCT should be used after careful consideration, where conventional two-dimensional imaging techniques are not sufficient or where access to the technological processes such as guided surgery will improve patient management.

Key Words
CBCT, 3D, Conventional, MSCT

INTRODUCTION

Imaging is an important diagnostic adjunct to the clinical assessment of the dental patient. However, intraoral and extraoral procedures, used individually or in combination, suffer from the inherent limitations of all two-dimensional (2D) projections: magnification, distortion, superimposition, and misrepresentation of structures.[2] Cone Beam Computed Tomography (CBCT) is a relatively new technology,[1] introduced to dentistry in 1998, used for the three-dimensional imaging.[12] The introduction of CBCT, dedicated to imaging the maxillofacial region heralds a true paradigm shift from 2D to 3D approach to data acquisition and image reconstruction, expanding the role of imaging from diagnosis to image guidance of operative and surgical procedures by way of third-party applications software.[2]

BACKGROUND

Between 1940 and 1960s, numerous radiographic techniques were reported for the assessment of craniofacial injuries & pathologies. These include lateral-oblique, occlusal, transcranial, posterior-anterior, Waters, Towne, and submentovertex projections. For dentoalveolar trauma & pathologies, evaluation included intraoral periapical and occlusal radiographs. The inherent limitations of these projection-based images included anatomic superimposition of structures requiring the use of multiple projections, effect of soft tissue edema on image contrast, lack of soft tissue imaging, variability in exposure and technique problems related to film coverage, and geometric distortion. In the 1960s, tomography and rotational panoramic radiography were commercialized. While both techniques reduced the untoward effects of the superimposition of highly contrasting structures inherent in conventional radiographs, they each have their own limitations.[3]

Godfrey Hounsfield in 1970, first, applied the mathematical principle of CT clinically and in 1972, he introduced it to imaging world.[4] CT provides three-dimensional imaging and has been used to overcome the inherent problems with conventional two dimensional radiographic techniques. Although offering spectacularly high speed imaging of both hard and soft tissues, X-ray dose is high, the equipment exceptionally expensive and generally only found in hospital settings.[1] CBCT is a recent technology which was developed as an alternative to conventional CT. It provides more rapid acquisition of a data set of the entire FOV and is comparatively inexpensive and small enough to be used in the dental office.[2]

CONE BEAM COMPUTED TOMOGRAPHY

CBCT is a low dose scanning system, which has been specifically designed to produce three-dimensional images of the maxillofacial skeleton. CBCT scanners use back-projection reconstructed tomography to acquire data of the area of interest through a single or partial rotation of the conical X-ray beam and reciprocal image receptor. Remarkably, in most systems scan times of less than 20 seconds may be achieved. Thus a principle difference between CT and CBCT is the method by which data are gathered – while CT acquires image data using rows of detectors, CBCT exposes the whole section of the patient over one detector. The CBCT volumetric data set is usually reconstructed in orthogonal orientations to
allow viewing of the images in the axial, sagittal and coronal planes[1.]

ADVANTAGES OF CONE-BEAM CT IN DENTISTRY[2]

CBCT provides images of highly contrasting structures and is, therefore, particularly well suited for the imaging of osseous structures of the craniofacial area.

1. Because CBCT acquires all projection images in a single rotation, so, it has rapid scan time.
2. Collimation of the CBCT primary x-ray beam enables limitation of the x-radiation to the area of interest. Therefore, an optimum FOV can be selected for each patient based on suspected disease presentation and

region of interest.

3. CBCT imaging produces images with sub millimeter isotropic voxel resolution ranging from 0.4 mm to as low as 0.076 mm. Therefore, image accuracy is on higher side.
4. CBCT causes reduced patient radiation dose. Published reports indicate that the effective dose varies for various full FOV CBCT devices, ranging from 29 to 477 mSv, depending on the type and model of CBCT equipment and FOV selected.
5. Perhaps the most important advantage of CBCT is that it provides unique images demonstrating features in 3D that intraoral, panoramic, and cephalometric images cannot. CBCT units reconstruct the projection data to provide interrelational images in three orthogonal planes (axial, sagittal, and coronal).

LIMITATIONS OF CONE-BEAM CT IMAGING[2]

1. Because the CBCT x-ray beam is heterochromatic and has lower mean kilovolt (peak) energy compared with conventional CT, thus, X-ray beam artifacts are more pronounced on CBCT images.
2. Cone beam–related artifacts are of three types:

   Partial volume averaging: It occurs when the selected voxel resolution of the scan is greater than the spatial or contrast resolution of the object to be imaged.

   Undersampling: Undersampling can occur when too few basis projections are provided for the reconstruction.

   Cone-beam effect: The cone-beam effect is a potential source of artifacts, especially in the peripheral portions of the scan volume. Because of the divergence of the x-ray beam as it rotates around the patient in a horizontal plane, projection data are collected by each detector pixel.
3. The scatter-to-primary ratios are about 0.01 for single-ray CT and 0.05 to 0.15 for fan-beam and spiral CT, and may be as large as 0.4 to 2.0 in CBCT. Image noise is the major problemwith CBCT.
4. CBCT provides poor soft tissue contrast. Three factors limit the contrast resolution of CBCT. Although scattered radiation contributes to increased image noise, it is also a significant factor in reducing the contrast of the cone-beam system.

CBCT APPLICATIONS

IMPACTED TEETH[9,13]

Proper localization of an impacted tooth is required to make an accurate diagnosis, determine proper surgical access and plan of removal. Inferior alveolar nerve injury is the most common major complication (4.4%-8.1%) in extracting mandibular third molars. Paresthesia due to inferior alveolar nerve damage (1.3%-5.3%) is often caused by the proximity of the roots of the third molar and the mandibular canal.[13] So, Additional radiographic images are often required to ascertain the exact location of an impacted tooth in all 3 dimensions.[9] The panoramic radiograph is not accurate in imaging the vertical relationships of anatomical structures as well as the location of the mandibular canal. [13] 3D volumetric images are expensive and expose patients to higher doses of radiation whereas CBCT not only provides accurate topographical views of the structures but also their exact position and relationship with anatomical landmarks.[13] Thus, CBCT for impacted teeth helps in diagnosis and treatment plan and inturn result in successful treatment and better patient care.

PRE-SURGICAL DENTAL IMPLANT ASSESSMENT[6,7]

The objectives of diagnostic imaging, when used for pre-implant assessment, include the evaluation of normal anatomical structures, the detection of pathoses in proximity to proposed implant locations and available bone estimation in terms of quantity and quality. When posterior mandibular sites are considered, a crucial factor that may decisively affect the selection of a site to be treated with implants is the location of the mandibular canal.[6] The location of the maxillary sinus, the nasal cavity, bone texture, etc are important when maxilla is considered for implant placement. The radiographic density of these structures is variable. Pawelzik et al, 2002, compared CBCT images with conventional panoramic images for diagnostic accuracy, prior to third molar surgery and concluded that CBCT images were free of magnification, superimposition of neighboring structures, and other problems inherent to panoramic radiology. This may result better assessment of implant sites pre-operatively.[6] Hashimoto et al, 2003, reported that the image quality of CBCT images was better than that of Multi Slice CT images for all of the following: cortical bone, cancellous bone, enamel, dentin, the pulp cavity, lamina dura, and periodontal ligament space.[7]

NEUROVASCULAR ASSESSMENT[10]

The location and course of the mandibular canal, and the location and number of mental foramina, are important in dental implant insertion and any surgical procedures involving the mandible. On CBCT images, one can assess the course of the mandibular canal, such as the bifurcation and anterior loop, mandibular incisive canal and lingual foramen. The detection of the accessory mental foramen using CBCT images might reduce the rates of paralysis and hemorrhage in mental and cheek regions. Munetaka states that the incidence of accessory foramen was 7% with no significant gender difference.

OSTEOMYELITIS OF MAXILLOFACIAL REGION[11]

Osteomyelitis in the maxillofacial region mainly results from contiguous spread of odontogenic infection usually initiated by inoculation of micro-organisms into the jawbones as a result of trauma or of extraction of teeth. The importance of imaging in osteomyelitis, is threefold: to localise the condition, to find out its extent, and to assess the response after treatment. Conventional CT is not considered as the initial choice for imaging in osteomyelitis because of its reported lack of sensitivity in bone marrow disease. CBCT is capable of providing images of <0.5mm resolution that are of high diagnostic quality & facilitates comprehensive and dynamic imaging of the jaws.

SIALOLITHIASIS[12]

Approximately 1% of patients who present to dentists suffer from problems related to sialoliths. Imaging-based diagnostic measures for this condition include ultrasonography, 2-D radiography, sialendoscopy, sialography, MRI or CT. Despite the advantages of CT or MRI evaluations, US and 2D radiography are routinely used owing to cost-effectiveness and availability. Current concepts show that superimposition-free, 3D CBCT images have high sensitivity and specificity for salivary calculus diagnoses than those obtained with other diagnostic methods.

INTRABONY LESIONS[14]

Conventional radiography is widely used to detect alveolar bone loss. However, this method projects the alveolar process onto a 2-D plane so that many anatomic structures may overlie lesions in the trabecular bone. The use of CT is common in dentomaxillofacial imaging for diagnosis and treatment planning; however, CBCT is a comparatively new technology for diagnosing dental diseases. It seems to be a very promising technique in the detection and assessment of early bony lesions.

CBCT vs PANORAMIC RADIOGRAPHY[15]

It has been established that panoramic radiography (PAN) distorts both size and location of anatomic structures. CBCT provides a reliable standard to measure PAN distortion so that clinicians will have a more accurate assessment of the true location of anatomic structures. Distortion varies throughout a PAN, with increased distortion in premolar area. Measurements involving alveolar ridges are likely to be distorted, owing to buccolingual ridge projection. CBCT is indicated for selected surgical cases, especially in the premolar area and in cases involving alveolar ridge measurements, owing to the difficulty of identifying canal in PAN. Also, measurements made using CBCT are more precise and accurately repeated than PAN.

CBCT vs MULTISLICE SPIRAL COMPUTED TOMOGRAPHY (MSCT)[16]

In surgical simulations, bone models are used for planning of various oral & maxillofacial surgeries. Such bone models are typically obtained from image data acquired with MSCT. Considering the fact that conventional CT protocols are generally associated with relatively high radiation dose levels, CBCT holds a promising potential for oral and craniofacial imaging applications. To assess the image quality of the bone models generated from the CBCT images, bone thicknesses measured in the CBCT images are compared with thickness values measured at anatomically corresponding points in the MSCT images. Anatomical correspondence established between the MSCT and CBCT image volumes has accuracy better than 0.5 mm everywhere in the image.

CBCT & MODEL SIMULATION[17]

3Dmodels can be used in initial diagnosis and assessing changes as a result of treatment. Three-dimensional CBCT models provide additional diagnostic information on (1) size, shape, and position of mandibular condyle heads; (2) width of the tooth-bearing portion; (3) morphology, inclination, displacement, or deviation of the lateral and medial surfaces of the mandibular rami and body; (4) dental root positioning; (5) localization of impacted or super- numerary teeth; (6) palatal morphology; and (7) morphology of sites for placing implants or osteotomies. This information can help in identification of affected structures, treatment planning, and future comparisons with long-term follow-up of treatment stability. The identification of the soft-tissue profile allows assessment of hard- and soft-tissue relationships.

CBCT & RADIOTHERAPY[18,19]

Intensity-modulated radiation therapy (IMRT) delivers highly conformal radiation to the targets while minimizing doses to normal tissues and critical organs. Positioning accuracy is even more critical for patients with head and neck (H&N) cancer undergoing IMRT because of the complexity of the anatomy and the proximity of tumors to many critical and radiation-sensitive tissues. A recent study by Zeidan et al, 2007, revealed that even if every other treatment is image guided, about 11% of all treatments still are subject to 3D setup errors.18 When the accuracy of CBCT setup is evaluated based on a phantom study, the quality of CBCT images was acceptable for setup correction. The preliminary study for overall accuracy indicated CBCT setup was feasible with IGRT system. [19]

CONCLUSION

CBCT technology is increasingly accessible in maxillofacial surgical practice. It expands diagnostic and treatment possibilities for patients. CBCT equipment costs one-fifth the cost of conventional CT. However, CBCT should be used after careful consideration, where conventional two-dimensional imaging techniques are not sufficient or where access to the technological processes such as guided surgery will improve patient management. When selecting the best CBCT examination for an individual, it is important to minimise X-ray dose while striving for an image that enables appropriate diagnosis and management.

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