Review Article - Practice Guidelines

TMJ imaging by CBCT: Current scenario

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ABSTRACT

Radiographic examination forms an integral component of the clinical assessment routine in patients with temporomandibular joint disorders (TMJ). There are several imaging modalities to visualize the TMJ. Cone beam computed tomography (CBCT) is a developing technique that is being increasingly used in dentomaxillofacial imaging due to its relatively low-dose high-spatial-resolution characteristics. Research in TMJ imaging has been greatly inspired by the advent of CBCT. In this paper we aim to discuss the present scenario of the role of CBCT in TMJ imaging.

Keywords: Cone beam computed tomography, temporomandibular joint disorder, temporomandibular joint imaging

INTRODUCTION

Complex etiologic factors like trauma, emotional stress, orthopaedic instability, muscular hyperactivity, inflammatory and degenerative diseases, which compromise the equilibrium of the temporomandibular joint (TMJ), have been implicated in the development of temporomandibular joint disorders (TMD).[1,2] Radiological investigations are of paramount importance in the diagnostic assessment of a patient with TMD. The American Academy of Oral and Maxillofacial Radiology (AAOMR) has established the rationale for image selection for diagnosis, treatment planning and follow up of a patient with conditions affecting the TMJ (parameter 2).[3] Conventional radiographic TMJ projections like transpharyngeal, transcranial, panoramic radiograph, conventional tomographic sections of TMJ may be adequate in a number of clinical situations. But there are bony alterations that occur in these disorders like erosions, osteophytes, pneumatisation of articular eminence that are difficult to be detected in conventional radiographs due to overlapping of the anatomic structures. This warrants the use of advanced imaging modalities like Magnetic Resonance Imaging (MRI), arthrography, conventional Computed Tomography (CT) and Cone Beam Computed Tomography (CBCT).[2,4]

CBCT is a relatively recent increment in the ever expanding horizon of clinical CT technologies. The first prototype clinical CBCT scanner was used in 1982 at Mayo Clinic. The commercial CBCT scanners made their entry almost a decade after the initial adaptation for angiographic applications. Ever since, several CBCT systems have evolved that have been extensively used in the field of medical clinical imaging.[5] This article aims to highlight the role of CBCT research of TMJ imaging.

CONE BEAM COMPUTED TOMOGRAPHY TECHNOLOGY

CBCT is a medical imaging technique in which a cone-shaped X-ray beam centered on a two dimensional (2D) detector produces a series of 2D images. The reconstruction of these images in a 3 dimensional (3D) data set is done using the modified Feldkamp algorithm.[6,7] Hence data can be reformatted in a volume rather than a slice, thereby giving 3D information [Figure 1]. CBCT also allows multiplanar reformation i.e., 2D images in axial, coronal, sagittal and even oblique or curved image planes [Figures 2-6].[3] Advancements in flat panel detector (FPD) technology (digital FPDs which enable direct conversion of x-ray energy into a digital signal with high spatial resolution), improved

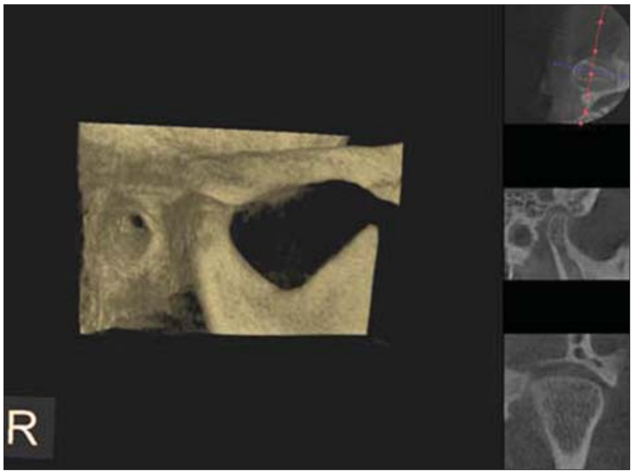

Figure 1: CBCT image showing the right TMJ with 3 dimensional (3D) reconstruction

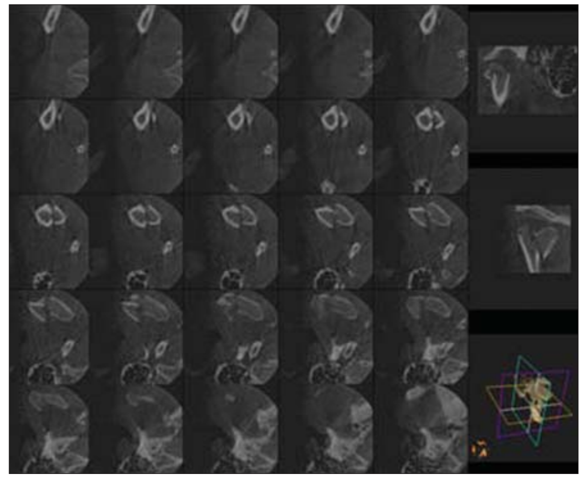

Figure 2: Axial sections of the right TMJ as seen on a CBCT image

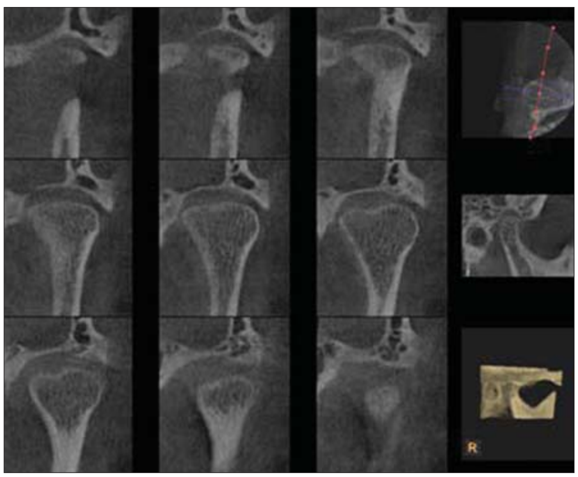

Figure 3: CBCT image of the coronal sections of the right TMJ

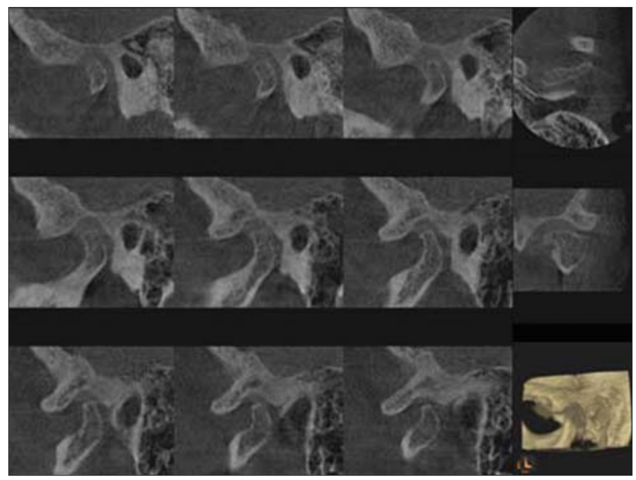

Figure 4: Sagittal slices of the left TMJ taken on a dedicated head and neck CBCT scanner

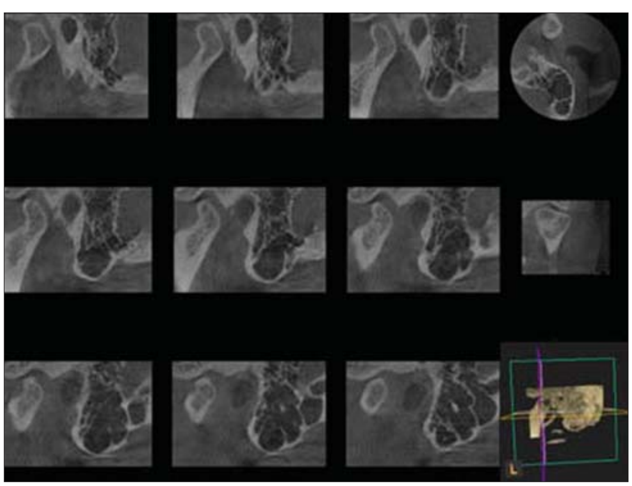

Figure 5: CBCT image of labiolingual sections of the left TMJ

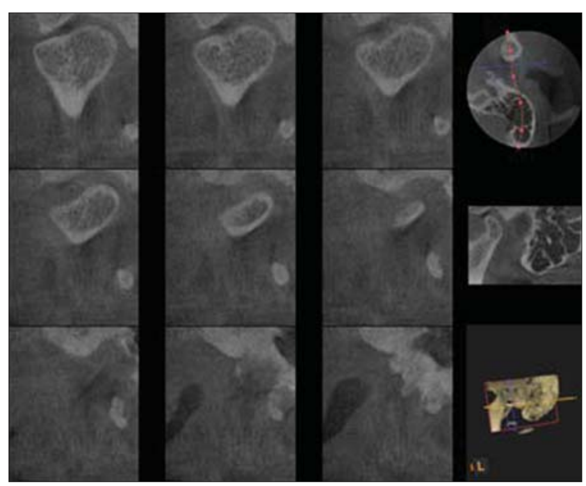

Figure 6: Mesiodistal sections of the left TMJ as seen on a CBCT image

computing power and relatively low power requirements of x-ray tubes in CBCT have resulted in an exponential use of CBCT.[7] This technique finds its use in various industrial and biomedical applications like SPECT, angiography, image guided radiotherapy, neurointerventional application (neuroradiology), spinal, thoracic and orthopaedic procedures.[5,8]

Mazzo, *et al*. and Arai, *et al*. independently pioneered the characterization of the dedicated CBCT scanners for oral and maxillofacial region in the late 1990s.[5] Since then a large number of systems are available in the market which have application-specific exposure parameter protocols, with field of views (FOV) designed to capture the area of interest and minimize exposure to adjacent structures.[7] CBCT scanners can be classified based on the type of detector, patient position during the procedure (sitting, standing or supine) field of view and use of fixed radiation settings or user controlled settings. A CBCT machine can also be either a dedicated or hybrid scanner.[9] CB MercuRay and CB Throne (Hitachi Medical, Kashiwi-shi, Chiba-ken, Japan), 3D Accuitomo – XYZ Slice View Tomograph (J Morita Mfg Corp., Kyoto, Japan), iCAT (Xoran Technologies, Ann Arbor, Mitch; and Imaging Sciences International, Hatfield, Pa), MiniCAT (Xoran Technologies) 3D Accuitomo 170 (J Morita Mfg Corp., Kyoto, Japan), ILLUMA Cone Beam CT (IMTEC, Ardmore, Okla and GE Healthcare, Chalfont St. Giles, UK) are commercially available CBCT systems for head and neck imaging.[5]

There are potential advantages of CBCT over CT in the imaging of the maxillofacial region. The dedicated head and neck CBCT systems can be adjusted to scan small regions for specific diagnostic tasks by efficient collimation of the primary x-ray beam. Thereby the size of the irradiated area is significantly reduced. CBCT provides superior diagnostic quality of images. This is possible due to the isotropic (equal in all 3 dimensions) voxel resolutions which produces sub-millimeter spatial resolution ranging from 0.4mm to as low as 0.125mm. A rapid scan time of 10-70 seconds is a great advantage with the CBCT as it acquires all basic images in a single rotation.[3] Another important attraction of the dentomaxillofacial CBCT is the low effective patient dose which is reported to be between 30-80 μSv.[5] This indicates that the dose is significantly reduced by up to 98% when compared to the conventional CT and amounts to 4-15 times the dose of a single panoramic radiograph.[3] Unique display modes and reduced image artifacts enable the clinician to perform chair-side image analyses, multiplanar reconstruction (MPR) and volume reconstructions. All these features have greatly enhanced the use of CBCT in the various disciplines of dentistry.

CBCT IN TEMPOROMANDIBULAR JOINT IMAGING

Diagnostic radiology plays an important part in treating patients with TMD effectively and efficiently. The 1992 version of the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) concludes that imaging helps to substantiate clinical impressions. Also a hierarchical model for the efficiency of an imaging technique has been described in six-levels by Fryback and Thornbury.[10] Panoramic radiography, plain radiography, conventional and computed tomography, arthrography and MRI are used with varying frequency in clinical practice to image the TMJ. However they all have shortcomings in enabling the clinician to effectively visualize the TMJ structures. Hence it is imperative to understand the reliability and accuracy of each modality and also the influence they have on the choice of treatment and on the prognosis of the patient with TMD. Panoramic radiograph is a widely used and relatively simple technique to obtain an image of the TMJ. But the diagnostic accuracy is greatly reduced due to the low sensitivity for bony changes of the condyle and also a low reliability and accuracy of the temporal component.[9,10] Conventional plain radiographs in the form of various TMJ projections depict only mineralized structures of the TMJ. These are, however, plagued by the numerous superimpositions of the adjacent structures which make visualization cumbersome. Since these have very limited value in the present TMJ imaging, they have not even been considered in the RDC/TMD validation project.[10,11] Hussain *et al*. in their systematic review mentioned that axial corrected tomography was the imaging technique of choice for diagnosing erosions and osteophytes in the TMJ.[12] However predicting the value of TMJ tomography in TMD patients is difficult since though it reduces the problems of superimposition significantly, it complicates the interpretation of the radiograph in a clinical set up.[10] The RDC/TMD validation project recommends the use of CT both in clinical and research setting since it is superior to the aforementioned modalities in showing osseous abnormalities of the TMJ.[11] High cost of the equipment, infrastructural demands and concerns over radiation dose to the patients have confined the use of medical CT largely to the hospital settings.

A large body of literature has been published in recent times due to the fact that CBCT has inspired research in TMJ imaging. An important advantage of CBCT imaging of TMJ is that it allows accurate measurements of the volume and surface of the condyle. These measurements are extremely advantageous in clinical practice when treating patients with TMJ dysfunctions.[13]

Osteoarthritis of the TMJ is an age – related degenerative disease seen in almost 40% of patients above the age of 40 years. It causes bony changes in the TMJ like flattening, sclerosis, formation of osteophytes, erosion, resorption of the condylar head, erosion of the mandibular fossa and reduced joint space. Flattening (59%) and osteophyte (29%) are the most prevalent degenerative changes seen on CBCT.[14] Many *in vitro* cadaveric studies have explored the role of CBCT in assessing bony defects and osteophytes. Erosive changes in the TMJ are most effectively diagnosed using CBCT in the 6 inch FOV as compared to the 12 inch FOV.[15] Alexiou, *et al*. used CBCT to evaluate the degenerative changes and concluded that patients in older age groups are expected to have more frequent and more severe bone changes than those in younger patients.[16] Alkhader, *et al*. performed a comparative study between CBCT and MRI. According to them CBCT is better than MRI in detecting changes in shape (flattening, osteophyte formation or erosion) rather than changes in size. They concluded that this was probably because MRI had limited spatial resolution and increased slice thickness (>3mm) in clinical use. Also other problems like presence of fibrous tissues inside the TMJ, proximity of lateral pterygoid muscle to the articular surface of the condyle and presence of air spaces in the temporal bone can impede the accuracy in the interpretation of MRI.[17] However there is a poor correlation between condylar changes observed on CBCT images and clinical signs and symptoms seen in patients with TMJ osteoarthritis (TMJOA).[18]

CBCT plays an important role in diagnosing early stages of juvenile idiopathic arthritis (JIA) in children which, when undetected, can damage facial development and cause growth alterations. Farronato, *et al*. concluded from their study that CBCT can be used to volumetrically quantify the TMJ damage in these patients by measuring condylar and mandibular volumes.[19] Condylar asymmetry is very common in children with JIA. CBCT shows a wide variety of condylar destruction patterns which could be small erosions within the cortex to almost complete deformation of the head of the condyle.[20]

The TMJ is often involved in patients with multiple maxillofacial fractures. Here again in most cases neither medical CT nor conventional dental radiography alone can address all the diagnostic challenges that are encountered. CBCT enables us to meet the patient needs by providing adequate information regarding the nature of fracture, its extent and relative locations of important anatomic structures.[21]

As with any new technology, CBCT has been criticized just as it has been lauded. The most researched applications for head and neck CBCT are in sinus, middle and inner ear implant and dentomaxillofacial imaging.[5] TMJ imaging has also benefitted tremendously from the exponential research in this field. But preliminary experiments have not yet translated into systematic clinical and prospective studies that convincingly demonstrate the superiority of CBCT over existing modalities in TMJ imaging that can reinforce its use clinically. Beam hardening artifacts like the metal artifacts are reduced in the newer CBCT scanners with the FPD. But movement artifacts still remain an area of concern with the CBCT. Also another drawback is that there is a distortion of the Hounsfield Units (HU), hence CBCT cannot be used for the estimation of the bone density. It is established that CBCT has an advantage over other imaging modalities due to the low patient radiation exposure. But till date agreement on how the CBCT dosimetry should be measured in terms of radiation detector setup in phantoms has not been reached upon. Also most studies published do not give the reader sufficient information on the CBCT device settings and radiation dose, image quality and reproducibility. There is also an inherent shortcoming with the CBCT in that there is a low contrast resolution and limited capability to visualize the internal soft tissue.[2] Hence the role of CBCT in TMJ disc disorders is questionable. Currently, CBCT has been largely adopted as a dental office-based imaging technique. Though this does expedite patient diagnosis and treatment while also reducing the operational costs, there is mounting concern among oral and maxillofacial radiologists on issues regarding the enthusiastic overuse of CBCT and patient safety.

CONCLUSIONS

Several radiographic methods are used to assess the TMJ, an area that is difficult to be imaged due to factors like superimposition of adjacent structures and morphological variations. The complexity of the TMD however, demands a clear and precise image of the region for effective management of the patient. CBCT provides a definite advantage over other techniques due to its low radiation dose to patient, smaller equipment and ability to provide multiplanar reformation and 3D images. There is promising research in the field of CBCT in TMJ imaging. However more systematic clinical studies, adequate training of the personnel and complete understanding of the anatomical and functional dynamics of the TMJ are required to harness the true potential of this breakthrough technology.

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