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Imaging Modalities of Temporomandibular Joint: An Overview

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ABSTRACT
Accurate diagnosis of TMJ problems, requires both clinical and radiographic examinations to produce a comprehensive assessment of the joint, its function, and the surrounding bone and tissues. The choice of imaging technique is typically determined by the specific diagnostic objectives, which involves the assessment of cortical integrity, disc position, meniscal perforation, joint dynamics, and changes in condylar position. The results of imaging studies must be correlated with the patient history and clinical findings in order to arrive at a diagnosis and plan treatment. Complicated anatomical configuration of the temporomandibular joint was the reason for developing standardized radiographic techniques which would provide accurate anatomical images. various techniques are available for imaging the TMJ, such as plain film radiography, arthrography, ultrasonography, CBCT, CT, MRI, and functional imaging. Nowadays , within the advances of technology, a single imaging approach is not sufficient for TMJ imaging. However, multiple imaging methods are used for evaluation.

Keywords: Temporomandibular joint, Computed tomography, Cone beam computed tomography, Ultrasonography, Magnetic resonance imaging functional imaging

1. Introduction

Diagnosis of TMDs cannot be reached through clinical examination only, however using different imaging techniques is a must because of complexity of TMJ anatomy and variation of pathological conditions.
A variety of modalities could be used for imaging TMJ Such as conventional radiographs, ultrasonography, computed tomography (CT), and magnetic resonance imaging (MRI), cone beam computed tomography (CBCT), as well as invasive imaging techniques such as arthrography. Each has its own applications. The radiographic assessment involves the evaluation of soft and hard tissue components of joint structures. (Bag AK 2014, Farman AG 1995)

2 -Imaging of hard tissue structures

TMJ was traditionally examined using two-dimensional (2D) imaging. Conventional radiographs, such as transcranial(oblique lateral view), Trans pharyngeal, Transorbital and reverse open town's projection, Submentovertex projection, panoramic radiography, each is suitable for specific conditions. (Hunter A 2013)
The most common one is panoramic projection which considered as a quick and simple "screening" projection and must be used in combination with other hard tissue imaging techniques to image TMJ structures adequately. It offers an overall view of the TMJs, mandible, maxilla, and teeth which is particularly useful for assessing mandibular symmetry and ruling out odontogenic disorders that may refer pain to the TMJs. Gross abnormalities of the condyles, such as fractures or large osteophtyes, can be visualized. This technique has several limitations as distortion of image of the condyles, visibility of only gross osseous abnormalities, and inability to assess condylar position and function because the mandible is in a slightly open. (Pharoah M 2001)

Nowadays, Advanced Three-dimensional (3D) imaging techniques are widely used for their advantages which offers more accurate information on the hard tissue morphology such as computed tomography (CT) and cone beam computed tomography (CBCT).

2.1-Computed tomography (CT)

CT is considered to be the best method for assessing osseous pathologic conditions of TMJ. It allows a multi planar reconstruction (sagittal, axial, coronal) of TMJ structures, obtaining 3D images in closed and opened-mouth positions.

Basically, any CT examination of the TMJ should focus on the following: cortex intactness, normal size and shape of the condyles and their centered position in the glenoid fossa, sufficient joint spaces, and centric relation loading zone. It is used for the diagnosis and treatment of bone defects due to its high sensitivity and specificity.Signs of degenerative changes in the joint, like surface erosions, osteophytes, remodelling , subcortical sclerosis, articular surface flattening can be evaluated using CT.

The main disadvantage of CT regarding TMJ examination is that it is inability to produce accurate images of the disc and the high radiation exposure compared with conventional techniques. (Talmaceanu D 2018)

2.2-Cone Bean Computed tomography (CBCT)

Most dental practitioners are familiar with the thin slice images produced in the axial plane by conventional helical fan-beam CT. CBCT allows the creation in "real time" of images not only in the axial plane but also 2-dimensional (2D) images in the coronal, sagittal and even oblique or curved image planes a process referred to as multiplanar reformation (MPR). Silvia Caruso et al pointed out the main contributions of cone beam CT in the field of TMJ: Allows the calculation of volume and surface of the condyle, Improves qualitative analyses of condylar surface and allows detecting the mandibular condyle shape, Improves the accuracy of linear measurements of mandibular condyle, Clarifies cases of facial asymmetry. (Caruso S 2017)

The use of CBCT technology in clinical practice provides a number of potential advantages for maxillofacial imaging compared with conventional CT. The main advantage of CBCT, is the lower radiation dose to the patient which is (0.092 to 0.184 mSv) for bilateral TMJ scan that significantly reduced up to 98% than conventional CT, the spatial resolution of cone beam CT is higher because of smaller voxel size that are isotropic (equal in all 3 dimensions) , rapid scanning time (10–70 seconds) and lower cost. Although, data can be "converted" and imported into proprietary programs for use on personal computers (e.g., Sim/Plant, Materialise, Leuven,Belgium) this provides the clinician with the opportunity to use chairside image display, real time analysis and MPR modes that are task specific. (Kadesjö N 2015 , Scarfe WC 2006)

A major disadvantages of CBCT in contrast with CT is that Lower image contrast, higher image noise, no precise estimation of Hounsfield units possible and Image artifacts generated by patient motion or metallic objects. However, both CT and CBCT Still not reliable for evaluation of soft tissues and TMJ disc assessment. So other imaging modalities should be considered. (İlgüy D 2014)

3-Imaging of soft tissue structures of TMJ

3.1-Arthrography

This technique is recommended for assessing the soft-tissue elements of the TMJ, particularly location, function, and structure of the disc, in patients who exhibit symptoms of an internal derangement. A radiopaque contrast agent is injected into one or both joint spaces under fluoroscopic guidance, and plain films or tomograms are obtained. It being the only method allows visibility of small disc perforations or adhesions.(Larheim TAJOS1995)

3.2-Ultrasonography

It's non-invasive, broadly available, and relatively inexpensive tool for evaluation of TMJ in a dynamic manner. When compared to other diagnostic imaging modalities, ultrasonography has many benefits, including its widespread availability, lack of harmful consequences (including in pregnant women and children), high image quality, real-time imaging, and inexpensive.

US examination is useful in diagnosis of disc displacement and effusion. the normal articular disc appears as a hypoechoic, inverted c-shape structure, situated superior to the hyperechoic condyle·

One difficulty of US is the possibility to obtain clear images, especially in the opened-mouth position, due to the overlying osseous structures.

Another Limitation of US is that the medial part of the disc cannot be visualized.The diagnostic value of high-

resolution US is strictly dependent on the examiner's skills and on the equipment used. Therefore, there is a continuous need for trained and experienced radiologists in this field. (Nabeih Y 1991)

3.3-Magnetic resonance imaging (MRI)

It has been suggested that MRI is the best imaging modality for evaluation of disc displacements and is now the gold standard for imaging the TMJ's soft tissue features (articular disc, synovial membrane, lateral pterygoid muscle).Several key features should be evaluated while interpreting the MRI of TMJ derangement, including the position and morphology of the disc, the morphology and signal of the mandibular condyle and the presence of joint effusion. (Kersey ML,2003)

MRI is increasingly used for TMJ imaging and has largely replaced invasive arthrography, since it offers three major advantages: (1) It does not require the use of ionizing radiation, (2) it provides excellent images for the soft tissue components of the TMJ and allows direct visualization of inflammatory changes and the presence of effusion, and (3) it can be acquired in any desired plane.

Disadvantages include potential for artifact generation from field distortions caused by ferromagnetic metallic objects, prostheses, orthodontic brackets and implants, and the inability to image patients However, with implanted cardiac pacemakers or aneurysm clips in the brain, as well as claustrophobic patients. Magnets with lower field strengths are usually used for such units, resulting in lower signal-to-noise ratios. (Harris CA2006 Faris OP2006 , Olsrud J2005)

Recent MRI Advances

Dynamic Real-Time MRI

Dynamic or real-time MRI allows the rapid and continuous data acquisition followed by image reconstruction and visualization, ideally without noticeable delay. Such imaging is expected to largely facilitate the diagnosis of internal derangement, because the positional changes of TMJ are particularly complex during movement. The main disadvantage of this technique is that it is complicated in reconstruction and require special computation hardware.(Uecker M 2012)

4. Functional Imaging

All of the techniques of image generation discussed before fall under the category of structural imaging modalities. Functional imaging modalities provide information on the functional integrity of the area of interest. Applications of functional imaging in TMJ imaging are very limited. Examples include evaluation of functional changes following orthopedic treatment, pre-splint and post-splint therapy imaging, condylar hyperplasia, necrosis of the condyle, chronic craniofacial pain refractory to treatment, craniofacial osteomyelitis, invasion of solid tumor, and so on. (Güner D 2003, DHersek N 2002 Dimonte M 2004)

Thus, functional imaging is used in combination with morphological imaging in cases where information is required to determine the presence of primary or secondary lesions in the TMJ. These methods include scintigraphy, single photon emission computed tomography (SPECT), and positron emission tomography (PET), among others. (Nuebler-Moritz M 1995 ,Seabold JE1995)

Conclusion

The choice of imaging technique is typically determined by the specific diagnostic objectives, which involves the assessment of cortical integrity, disc position, meniscal perforation, joint dynamics, and changes in condylar position.

Disclosure

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