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Diagnostic imaging of temporomandibular joint: A review

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Abstract
Temporomandibular joint (TMJ) dysfunction affects a large portion of the population around the world. Clinical examinations alone may not provide appropriate diagnosis in a TMJ dysfunction and therefore TMJ imaging proves to be an adjunct to clinical examination in providing the necessary information. TMJ imaging include a variety of techniques and the selection of the appropriate technique is of prime importance in obtaining the necessary information for further analysis or treatment of the patient. This paper throws light on various imaging techniques for hard and soft tissue which will help enable the clinical to choose the appropriate imaging modality for the patient.

Keywords: Temporomandibular joint, temporomandibular disorders, computed tomography, magnetic resonance imaging, ultrasonography

1. Introduction
Temporomandibular joint (TMJ) related pain is most common in general population with a very less number of patients who actually seek medical assistance. The TMJ pain may arise from abnormalities that interfere with normal form or function. Even though the more common causes of the temporomandibular joint dysfunction (TMD) are related to these causes they may also arise from pathological changes related to the TMJ. These disorders may be characterised by facial pain in the region of the TMJ/muscles of mastication, joint pains, limitation or deviation in mandibular movements or sounds during TMJ movement or function. This paper presents a general approach to diagnostic imaging of TMD.
The diagnosis of TMD requires a thorough diagnostic workup, including diagnostic imaging, before treatment is begun. The clinical signs and symptoms of other disorders of the TMJ may include swelling in and around the joint, an elevated temperature, and redness of the overlying skin.
In addition to clinical assessment there may be a necessity to assess the TMJ radiographically especially when there may be an osseous involvement, infection is suspected, there is a history of trauma or altered range of motion or changes in occlusion or if conservative treatment has failed, or symptoms are worsening. Indications for TMJ imaging can be from anything such as when conservative treatments fail to provide relief or if the symptoms worsen, altered occlusion, patients with trauma, infection or osseous abnormalities.
Different imaging modalities are used in imaging of TMJ, MRI being the most common and widely used and is even the diagnostic technique of choice.

1.1 Temporomandibular joint
TMJ is a ginglymoarthroidal joint and has a hinge like and sliding movement. The hinge movement represents the first half of the movement whereas the second half as well as the lateral and protrusive movement is represented [1].
TMJ pathology is complex and includes temporomandibular disorders, infections, tumors, traumatic lesions and growth development anomalies. The most common clinical signs of TMD are represented by pain in TMJ or ear or both, limited mouth opening and joint sounds (clicking and crepitation), locking or subluxation [2]. TMD is defined by the American Academy of Orofacial Pain (AAOP) as a complex term covering a number of clinical problems involving the masticatory muscles, the joint and the associated structures [3].
In 2014, Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD), clearly

defined the different internal derangement conditions. According to RDC/TMD, two different degrees of displacement of the disc relative to the condyle exist: disc displacement with reduction and disc displacement without reduction [4].

The Piper disc classification [5] is also useful when dealing with internal derangements

1. Normal;
2. Ligaments or cartilage damage;
3. Partial disc subluxation, with reduction; 3b) Partial disc subluxation, non-reducing;
4. Complete disc dislocation, with reduction; 4b) Complete disc dislocation, non-reducing;
5. No disc, bone to bone- adapting; 5b) No disc, bone to bone- adapted.

2. Imaging of TMJ

The primary step in diagnosis of the temporomandibular joint disorders (TMD) is clinical evaluation but special imaging modalities are needed to study the TMJ due to the complexity in its anatomy and thereby the pathology. There are various modalities of studying the TMJ which can be invasive or non-invasive. Invasive techniques such as arthrography and non-invasive such as conventional radiography, Computed Tomography (CT), Magnetic Resonance Imaging (MRI), ultrasound; each modality has its own advantage. The joint function evaluation of the TMJ has to be carefully considered while studying the TMJ which can be done by comparing the position of the condyle in the open and the closed mouth. The technique of radiographic evaluation depends on the clinical evaluation and the individual selection criteria.

Conventional imaging techniques can be used to study a number of pathologies, but they have limited use when it comes to studying the non-bony elements like the soft tissues and cartilages of the TMJ.

2.1 Plain radiography

Plain radiography includes transcranial projections. A disadvantage concerning conventional radiographs is the problem of superimposition of adjacent structures. Many different views such as the submentovertex, trans maxillary, trans pharyngeal, and the transcranial are used to reduce superimposition. Degenerative joint disorders are studied using plain radiography. To study the TMJ, 3D imaging plays an important role as plain radiography may not be sufficient in studying the pathology of this complex joint.

CT has been reported to be more suitable in identifying TMJ changes than conventional radiography [6].

2.2 Panaromic radiography

Panaromic radiography is a useful tool in studying the jaws and its associated structures. However only the lateral part of the condyle can be assessed on the panaromic image due to the superimposition by the base of the skull and the zygomatic arch.

The panoramic radiography does not reveal the functional status of the joint and has a relatively low specificity and sensitivity when compared with CT [3] but helps in evaluating degenerative bony changes, trauma, hyperplasia, hypoplasia, tumors or asymmetry of the condyle.

Epstein *et al*. [7] consider the clinical findings of greater relevance than panoramic images for patients with TMD. Nevertheless, some authors have suggested panoramic radiography as a good imaging modality for TMJ visualization [8]. Although morphological abnormalities of the condyle can be assessed with panoramic radiography, they do not necessarily represent a sign of TMD [9]. Variations of condylar shape are present among individuals. Moreover, changes in head position could affect the image of TMJ, simulating different bone abnormalities (flattening, osteophytes, asymmetries) [10].

2.3 Computed tomography (Ct)

CT which is a 3D imaging modality is best for assessing the osseous pathologic conditions of TMJ, it provides multi-planar reconstruction of the TMJ structures in both closed and open mouth. CT is useful to evaluate the bony elements of the TMJ as well as the adjacent soft tissues.

CT is ideal for the evaluation of fractures, degenerative changes, erosions, infection, invasion by tumour and congenital anomalies.

Degenerative changes in the joint, like surface erosions, osteophytes, remodeling, subcortical sclerosis, articular surface flattening can be evaluated using CT.

CT has been reported to be more suitable in identifying TMJ changes than conventional radiography [6]. Autopsy studies performed for the assessment of condylar abnormalities showed better results for CT than MRI [11].

CT is not used as a primary modality to study the visualisation of the soft tissue including the disc, the synovial membrane, ligaments, lateral pterygoid muscle. The disc can be visualized on CT scans only with injection of contrast media in the joint. The main disadvantage of CT, compared to other radiological methods, is the high cost and the radiation exposure.

2.4 Cone beam CT (CBCT)

The CBCT provides high-resolution multiplanar reconstruction of the TMJ and its main advantage over CT is the lower dose of radiation to the patient. The spatial resolution of CBCT is higher than that of conventional CT [3]. CBCT performs better than conventional radiography and is as good as conventional CT, allowing to depict early bony changes of TMJ [3].

Studies developed by Hintze *et al*. [12] found no significant differences between conventional tomography and CBCT in the detection of morphological TMJ changes.

A review published by Silvia Caruso *et al*. [13] pointed out the main contributions of CBCT in the field of TMJ

1. Allows the calculation of volume and surface of the condyle; improves qualitative analyses of condylar surface and allows detecting the mandibular condyle shape;
2. Improves the accuracy of linear measurements of mandibular condyle;
3. CLARIFIES that, in case of facial asymmetry, the condyles are often symmetric, while joint space can change between the two sides;
4. Clarifies the position of the condyle in the fossa.

2.5 Magnetic resonance imaging (MRI)

MRI is currently considered the reference method for imaging the soft tissue structures of the TMJ (articular disc, synovial membrane, lateral pterygoid muscle) and has been pointed out as the best imaging modality in diagnosing disc displacements [3, 6]. MRI can detect the early signs of TMJ dysfunction, like thickening of anterior or posterior band, rupture of retrodiscal tissue, changes in shape of the disc, joint effusion. Images can

be obtained in all planes (sagittal, axial, coronal). In most scanning sequences, T1 weighted, T2 weighted and proton-density (PD) images are obtained. The PD images serve to visualise the disc-condyle relationship, while T2-weighted images are used in diagnosing inflammation in the joint [3]. The slice thickness is important for image quality. The most frequent used section thickness is 3 mm. Reducing the slice thickness improves the quality of the images but requires longer scanning time.

An axial localising image is used to direct the long axis of the condyle in the closed-mouth position. Sagittal images are obtained perpendicular to the long axis of the condyle, and coronal images are obtained parallel to the long axis. In MRI examination, a pathological condition is considered to be present relative to the intermediate zone of the meniscus (as a point of reference) and its interposition between the condyle and the temporal bone [3].

Normal disc position, evaluated in the sagittal plane, is with the junction of posterior band aligned approximately at 12 o'clock position relative to the condyle. Disc displacement is diagnosed when the posterior band sits in an anterior, posterior, medial or lateral position with regard to the condylar surface. In the closed-mouth position, teeth should be in contact, whereas in the opened-mouth position, the jaw should be at the widest comfortable opening.

TMJ disc pathology and lateral pterygoid muscle pathology is better assessed with MRI. Clinical evaluation of the TMJ can be nonspecific due to overlap of symptoms between internal derangement and myofascial pain dysfunction, in such cases MRI should be part of standard evaluation.

Disadvantages of the use of MRI is its cost and time consumed along with claustrophobia expressed by patients. In addition to this the presence of bony pathology or soft tissue calcification with inflammatory diseases cannot be studied on an MRI and hence in such cases CT has been preferred.

2.6 Arthrography

Arthrography is an invasive imaging technique to evaluate the TMJ. This involves injection of radiopaque contrast into the TMJ under fluoroscopic guidance, after the contrast has been injected point evaluation can be done to study the presence of disc dysfunction, perforation of disc, disc adhesion depending on the flow of contrast into the joint. This modality is rarely used today because MRI can be used to evaluate the TMJ without being invasive, and also as arthrography has shown allergic reaction or infection or pain.

2.7 Ultrasonography (USG)

A simple way to study joint effusion is the use of USG. USG is less expensive and can be easily performed and helps in evaluation of cartilage as well as disc displacement in both open and closed mouth imaging. The medial part of the disc cannot be visualised on the USG which limits the use of this modality.It is used for image-guided injections for both diagnostic and therapeutic purposes [14]. Eventhough USG is an inexpensive and non-invasive procedure its use in the evaluation of TMJ is limited. Due to overlying osseous structures, particularly in open mouth position clear images to study the TMJ may not be obtained.

Normally, the disc is situated between two hyperechoic lines represented by the mandibular condyle and the articular eminence. If the disc is displaced in the closed-mouth position, the diagnosis is disc displacement. If the disc returns to its normal position during opening, the diagnosis is disc displacement with reduction. When the disc does not return to its normal position it means that there is disc displacement without reduction [3].

In cases of degenerative changes of the TMJ, USG is still not recommended.

3. Conclusion

After clinical evaluation of the patient with the signs and symptoms, the proper and appropriate imaging modality should be selected. Currently the most widely used imaging modalities are CT and MRI. CT scan is the diagnostic study used for evaluation of osseous changes in the TMJ whereas MRI is a the standard technique used in evaluation of the disc position and disc examination due to its superior contrast resolution and ability of demonstrate the functionality of the joint. The anatomy, functioning and manifestations of various pathologies of the TMJ have to be carefully analysed and studied before selecting the appropriate radiological technique. The aim of selecting the correct imaging technique is to enhance the diagnosis and treatment of the pathology.

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