Journal of Experimental and Clinical Medicine
https://dergipark.org.tr/omujecm

Review Article

J Exp Clin Med
2021; 38(S2): 86-91
doi: 10.52142/omujecm.38.si.dent.2

Contemporary imaging modalities for temporomandibular joint: An update and review

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Received: 03.05.2020 • **Accepted/Published Online:** 04.12.2021 • **Final Version:** 19.05.2021

Abstract

There are different imaging methods used in the evaluation of bone structure, disc, ligaments and muscles that make up temporomandibular joint (TMJ). The aim of this review is given information about choice of suitable imaging methods for TMJ diseases from past to present. In the past, conventional radiographs have often been used for TMJ imaging, but nowadays magnetic resonance imaging is the gold standard for soft tissue imaging and disc position determination. Another new technology, ultrasonography can be used for disc displacement, effusion, diagnosis of intraarticular defects. Cone beam computed tomography is used for the evaluation of cortical and trabecular structure of bone components of TMJ, developmental anomalies and traumatic injuries affecting TMJ, pathological changes such as osteophyte, erosion, fractures, ankylosis, glenoid fossa-condyle relationship. Nowadays, in parallel with the developing technology, no singular imaging method is used for TMJ imaging and evaluation is performed with several imaging methods. Imaging methods should be selected by evaluating the factors such as radiation dose, contribution to diagnosis and treatment plan, easy applicability.

Keywords: cone beam computed tomography, imaging, magnetic resonance imaging, temporomandibular joint, ultrasonography

1. Introduction

Temporomandibular Joint (TMJ) is one of the most complex joints of the body that functions in chewing, swallowing and speaking functions (Okeson, 1996). In the diagnosis of TMJ disorders, clinical examination results such as anamnesis, clicking or crepitations, mandible movements should be evaluated together with radiological findings. Different imaging methods are used to examine the anatomical structures of TMJ. Some selection criteria are taken into account in determining the imaging method to be used. In view of the patient's history and clinical findings, considering the contribution of radiological examination to the diagnosis and treatment plan, preventing the patient from being exposed to unnecessary radiation dose is important in choosing the imaging method (Brooks et al., 1997).

The aim of this review is to examine the radiographs used in the imaging of bone structure, disc, ligaments and muscles of TMJ from past to present and give information about choice of suitable imaging methods for TMJ diseases.

2. Imaging for temporomandibular joint

2.1. Conventional radiography

When any pathological condition is considered after clinical evaluation of the cases, direct radiographic methods are firstly recommended by the American Academy of Pediatric Dentistry (1990) and American Academy of Oral and Maxillofacial Radiology (Brooks et al., 1997). It is easy to use and low radiation dose, visualization of many anatomical structures in a single plan, being inexpensive, detecting the developmental anomalies of TMJ and bone damage due to trauma or arthritis are the reasons of choice. In contrast, guidance for specific diagnosis of TMJ patients is limited and it is difficult to obtain direct information on the condition of the soft tissues of the joint. (Fallon et al., 2006). Transcranial, transpharyngeal and transorbital projections are used to obtain limited information about different parts of TMJ bone anatomy (Chilvarquer et al., 1988). In studies comparing transcranial radiography with MRI, transcranial radiography was recommended for initial radiological examination because of its low cost and easy applicability (Menezes et al., 2008).

2.2. Panoramic radiography

Panoramic radiographs allow condyle fractures, joint findings due to syndromes, tumors, cysts, osteomyelitis, highly degenerative changes in the condyle such as hyperplasia, hypoplasia and aplasia, as well as changes in bone structure such as osteophyte, erosion and sclerosis. Some panoramic radiography devices have special TMJ imaging programs. These radiographs, in which the image of both joints in open and closed position can be observed on a single film, are called

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mouth open-closed TMJ or lateral panoramic graph (Brooks et al., 1997; Tvrdy, 2007). Ease of use, being a non-invasive technique and ease of storage of radiographs are the advantages of this technique. However, since the joint is only visualized in a single plane, the mandibular fossa and articular eminence cannot be observed at the desired level. Cephalometric and panoramic radiographs are inadequate in determining the asymmetric relationship between the two TMJs in the sagittal plane, differences in volume and form of the condyles, variations between the incline and height of the articular eminence, and the position of condyles in the glenoid fossa (Chilvarquer et al., 1988; Katsavrias, 2003).

2.3. Arthrography

Arthrography is to obtain an indirect image of the disc by injecting radiopaque contrast agent into the lower or upper joint cavity or both joint cavities under fluoroscopic guidance. Then, images are taken with conventional radiographs or tomography. It gives information about the form, localization and function of the disc. Disc perforation, ligament of the disc, capsule tears and disc adhesions can also be visualized with this technique (Petrikowski, 2004). The greatest advantage of arthrography is that the clinician can monitor the movements of the joint during fluoroscopic examination (Katzberg, 1980). In the absence of MRI, arthrography can be used to diagnose anterior disc displacements (Tyrdy, 2007). However, it does not provide reliable information about the lateral and rotational displacement of the disc and the hard tissue cannot be evaluated well due to the radiopaque material (Isberg, 2001). The disadvantages of arthrography include being expensive, invasive, high dose radiation exposure to patients, technical training and experience, rarely observed allergy to contrast agent, risk of infection of the procedure, possibility of facial nerve paralysis due to excessive injection of local anesthetic to the condyle and condyle neck region and discomfort in the TMJ site for one or two days postoperatively (Som and Curtin, 1996).

2.4. Arthroscopy

The first arthroscopic intervention into the temporomandibular joint was made by Ohsnishi in 1975 (Sangeetha et al., 2012). This technique has been developed over time and has evolved into use for both diagnostic and therapeutic purposes (McCain, 1988). Today, arthrocentesis and arthroscopy techniques are included in the TME disorders treatment protocol as minimally invasive methods that complement each other (Nitzan et al., 1991).

Arthroscopy is indicated in cases such as disc displacement without reduction, degenerative joint diseases and synovitis (Pharaboz and Carpentier, 2009). It has been reported that it is more sensitive than MRI in the diagnosis of pathologies such as joint disc deformation or erosion, disc inflammation (Gonzalez-Garcia et al., 2008). On the other hand, it is contraindicated in cases such as ankylosis, operated joints, excessive disc resorption and tumor (Kayar, 2019).

In the literature, it has been reported that the opening of TMJ obtained by arthroscopy is greater in the comparison between arthroscopy and arthrocentesis (Israel, 1999). It has been stated that arthroscopy is a viable option before open surgery in TMJ dysfunctions that do not respond to conservative methods (Kayar, 2019).

2.5. Computed tomography (CT)

Due to the superposition of adjacent anatomical structures, imaging of joint structures that already have a complex anatomical structure can be misleading on two-dimensional radiographs (Laderia et al., 2005). Laderia et al. (2005) reported that two-dimensional panoramic radiographs were inadequate to show morphological and bone changes in TMJ and that they could not be used effectively in the diagnosis because they obscured the radiographic findings at a high rate. Computed tomography (CT) can be used to examine the three-dimensional structure of the bone components of the TMJ, TMJ anatomy, diffuse fractures and pathological changes in TMJ detailed. Since the images are taken in cross-section by CT, it is not possible for the parts outside the region of interest to be superposed. It is useful in determining TMJ pathologies such as ankylosis, neoplasms, stage of bone involvement in some arthritis, complex fractures, dislocation and ectopic bone growth (Brooks et al., 1997).

Clinical and cadaver studies have shown that CT is an appropriate method for evaluating bone morphology (Westesson et al., 1987; Tanimoto et al., 1990). However, CT is not a preferred method for examining the disc. In CT scans, the disc can be confused with the tendon of the lateral pterygoid muscle. Furthermore, the disadvantage of the technique is that the device is expensive and the scanning process is long (Christiansen et al., 1987).

2.6. Cone Beam Computed Tomography (CBCT)

Due to developing technology, CBCT which works with conical X-rays has been developed for imaging of bone structures in maxillofacial region (Scarfe et al., 2006). With this technique, which provides three-dimensional imaging with reconstruction, high diagnostic quality images can be obtained with a short exposure time of 10-70 seconds and a lower radiation dose than helical computed tomography (Honda et al., 2006; Scarfe et al., 2006).

CBCT; it is used for the evaluation of condyle bone structure changes in TMJ, developmental anomalies and traumatic injuries affecting TMJ, pathological changes such as osteophyte, erosion, fractures, ankylosis, and determination of condyle position in open-closed mouth position (Krishnamoorthy et al., 2013). In addition, cortical and trabecular structure of bone components of TMJ, joint space, glenoid fossa-condyle relationship, bone changes in patients with soft tissue pathology can be used for examination (Barghan et al., 2012; Yadav et al., 2015). Studies showing that CBCT provides accurate and realistic results in linear measurements of TMJ are also available in the literature

(Hilgers et al., 2005; Zhang et al., 2012). The selection of the appropriate field of view in TMJ evaluation with CBCT is important for obtaining diagnostic images and reducing the patient dose. The right and left TMJ imaging procedure has been shown to produce a lower effective dose compared to CBCT images obtained using a large imaging area (Lukat et al., 2013).

It has been shown in the literature that the quality of the images obtained may vary due to different scanning protocols when evaluating TMJ with CBCT. Yadav et al. (2015) stated that the images obtained with 360-degree rotation were the gold standard in the evaluation of TMJ but caused the patients to take approximately twice as much as the 180-degree rotation dose. In addition, they reported that both the 180- and 360-degree gravitation protocol were approximately effective in detecting large and small erosive bone defects. Patel et al. (2014) stated that the smaller voxel dimensions are more effective in detecting condyle defects. Libirizzi et al. (2011) reported that small FOV areas should be preferred in cases where TMJ erosions are the primary objective of the assessment. However, if orthodontic treatment or orthognatic surgery is planned and there is no clinically identified TMJ disorder, they have shown that a larger FOV area should be selected instead of a small FOV. Zhang et al. (2013) reported that there was no significant difference between standard FOV (8x8x8 mm) and large FOV (150x110x80 mm) areas to differentiate condylar defects and therefore, a larger FOV area should be preferred in terms of less radiation dose in TMJ imaging, in contrast to Libirizzi et al. (2011).

Barghan et al. (2012) reported that hard tissue changes in TMJ can be detected by CBCT in inflammatory joint diseases. In another study, they showed that MRI was insufficient for imaging of osseous ankyloses detected by CBCT (Alkhader et al., 2010). It has been shown in the literature that CBCTs are effective in detecting fracture lines in the TMJ region (Palomo and Palomo, 2009; Sirin et al., 2010; Barghan et al., 2012).

In addition to all these advantages, there are some missing points about TMJ imaging of CBCTs. One of the most important deficiencies in this regard is the lack of Hounsfield Unit, and bone density cannot be measured. In addition, due to the low soft tissue contrast, it fails to evaluate the articular disc. Especially in pediatric patients, artifacts may occur due to patient movement. CBCTs may also fail to detect changes in deeper areas in patients of growing age (Alkhader et al., 2010).

2.7. Ultrasonography (US)

Ultrasonography (US) is a non-invasive, low-cost, easy-to-use imaging method performed using sound waves (Tvrdy, 2007). US may be used for disc displacements, effusion, diagnosis of intraarticular defects and evaluation of treatment results in TMJ. However, in imaging the structural changes in bone in the condyle, its specificity is lower than MRI (Manfredini et al., 2005; Bonafé et al., 2012). In US, it is possible to obtain information about narrow joint space, joint disc position, joint fluid and ligaments adhesions by using 7.5-12 MHz linear transducer in TMJ imaging (Tvrdy, 2007).

Uysal et al. (2002) showed that perfect agreement between MRI and US in the diagnosis of TMJ internal derangements, and MRI and US can be used to define the disk and its position, as well as the presence of TMJ internal derangements. Emshoff et al. (2002) stated that the accuracy of prospective interpretation of high-resolution US of internal derangement, disk displacement with reduction, and disk displacement without reduction was 95%, 92%, and 90%, respectively. Additonally they found that there was one false-positive finding was found for internal derangement. Manfredini et al. (2003) reported that US showed a good diagnostic capability to detect TMJ intra-articular effusion and disc displacement when compared to a standardized clinical assessment. Also it can be suggested that US could represent a promising imaging technique in the study of temporomandibular joint.

The main disadvantage of US is that the position of the joint disc cannot be clearly determined. As the sound waves strike the hard tissues in front of them and show abnormal deviations, it is quite difficult to identify the joint disc located between the two hard tissues (Hayashi et al., 2001). However, multiplanar examination is not possible and, major deficiency of TMJ sonography is the inability to visualize the medial part of the joint (Aksoy and Orhan, 2010). Sensitivity of US was found to be significantly lower than MRI in open and closed imaging of the mouth (Bonafé et al., 2012).

2.8. Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) is a noninvasive technique in which images are obtained using magnetic field and radiofrequency waves. Due to the high level of soft tissue contrast obtained by MRI, supporting structures of TMJ, masticatory muscles, joint disc shape, position and pathologies in the disc are evaluated. It also gives an idea about synovial fluid quality (Nogami et al., 2013; Shi et al., 2014). MRI is useful in cases where imaging techniques based on ionizing radiation such as panoramic radiography and CT are insufficient in dentistry (Şatır and Yılmaz, 2020). MRI has been an option for the evaluation of TMJ disc displacement cases. Due to the absence of radiation and the high details of soft tissue images, MRI has become superior to other imaging modalities (Liu et al., 2017). At the same time, open-closed mouth position images by evaluating the position of the disc with the joint, to provide valuable information about the condition of the joint, soft tissues and hard tissues can be evaluated, providing three-dimensional and multi-sectional imaging, tissue characterization, sortable as advantages of the method (Kondoh et al., 1998; Nebbe et al., 1998).

MRI is a gold standard in soft tissue imaging and disc position determination (Klatkiewicz et al., 2018). Yang et al. (2017) reported that MRI was very useful in the evaluation of anterior disc displacement, whereas Kaimal et al. (2018) reported that MRI was more successful in the specificity of

TMJ diseases compared to panoramic radiographs. Many studies of the position of the disc have shown a high correlation between MRI-acquired images and the anatomical studies of TMJ (Hansson et al., 1989; Tasaki and Westesson, 1993). Hansson et al. (1989) studies showed that 85% of the disc position, 77% of the disc configuration and 100% bone abnormalities were determined by MRI, and Tasaki et al. (1993) showed that 95% accuracy in evaluation of disc position and disc configuration and 93% accuracy in detecting changes in bone structure.

The disadvantages of the method are; disc perforations cannot be obtained as well as arthrography, the bone structure of the joint does not provide accurate information for the evaluation of CT, early degenerative lesions cannot be detected. In addition, it cannot be used in people with cardiac pacemakers, ferromagnetic foreign bodies in vital tissues, metal heart valve prostheses, pain simulator wires implanted for pain control, fear of confined spaces, difficulty in standing, and patients with poor cooperation (Tasaki and Westesson, 1993).

3. Conclusion

There are different imaging methods used in the evaluation of bone structure, disc, ligaments and muscles that make up TMJ. Conventional X-ray methods, CT and CBCT are preferred for the evaluation of bone components of TMJ. MRI is the preferred imaging modality for the evaluation of disc, ligaments and muscles in the TMJ structure. US, which is a widely used imaging method in dentistry, can be used for disc displacement, effusion, diagnosis of intraarticular defects and evaluation of treatment results. Nowadays, in parallel with the developing technology, a single imaging method is not used for TMJ imaging and evaluation is performed with several imaging methods. Imaging methods should be selected by evaluating the factors such as radiation dose, contribution to diagnosis and treatment plan, easy applicability, and treatment planning and follow-up of TMJ disorders.

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