https://doi.org/10.5272/jimab.2019252.2563

Journal of IMAB
ISSN: 1312-773X
https://www.journal-imab-bg.org

Journal of IMAB - *Annual Proceeding (Scientific Papers).* 2019 Apr-Jun;25(2)

Review article

ULTRASOUND DIAGNOSIS OF TEMPOROMANDIBULAR JOINT IN PATIENTS WITH CRANIOMANDIBULAR DYSFUNCTIONS

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ABSTRACT:

In patients suffering from craniomandibular dysfunctions, early diagnosis of the problems and recognition of the signs and symptoms of functional pathology is of particular importance for duly managing and restoring these abnormalities to the physiological norm, thus ensuring the functional health of the masticatory system. Because of the specific location and nature of these abnormalities, the diagnosis is frequently difficult, and additional diagnostic imaging methods are required.

The aim of this review is to analyze and present the latest scientific evidence on the use of ultrasound diagnosis of the temporomandibular joint in patients with craniomandibular dysfunctions.

Material and methods: An electronic search by keywords was performed in PubMed, Google and Lilac databases from September 2018 to March 2019. The collected data were subject to critical analysis.

Results: The basic principles of application, various methods and techniques, advantages and disadvantages and the diagnostic accuracy of ultrasonography in the evaluation of joint-jaw relationships were examined. The relevant parameters for determining the norm and the various pathologies were presented.

Conclusion: Ultrasonography is a non-invasive, reliable, effective and easy-to-use method for diagnostic imaging of temporomandibular disorders in the dental office.

Keywords: ultrasound, temporomandibular joint, craniomandibular dysfunctions**,**

INTRODUCTION:

Craniomandibular dysfunctions (CMDs) is the term to denote functional pathology of the masticatory system, including clinical symptoms of masticatory muscles, temporomandibular joint (TMJ) and adjacent structures [1]. According to Dimova [2], the term "craniomandibular dysfunctions" characterizes the impaired functional interrelationship of organs and structures in the head and the shoulders, due to structural, functional, biochemical and psychological disorders of the muscle and TMJ function regulation.

With reference to the scientific literature [3, 4], CMDs are manifested by discoordination of the muscle groups, myopathies, muscular spasm, myositis, myogelosis, muscular hypertrophy and hypotrophy, primary and secondary diseases of the TMJ and alterations in the position of the articular disc. Ethiological and risk factors for the occurrence of CMDs include occlusion and articulation disorders, parafunctional activities such as bruxism and bruxomania, unhealthy habits, disturbances in the neurophysiological interrelationship of the functioning dental arches, muscles and TMJ.

A number of authors [5, 6, 7] present the most common symptoms of functional pathologies – pain and tension in masticatory muscles, "clicking", noises, pain in the TMJ, and headache. Molina et al. [8] claim that muscular hypertrophy and impaired occlusal surfaces resulting from parafunctions, such as bruxism and bruxomania may also be observed. Other authors [9, 10] consider that, although less frequently, CMDs are also characterized by signs of temporary or permanent disturbances in auditory perception, vertigo, dry mouth, reduced salivation and burning mouth syndrome.

Based on the diagnostic classification developed by Freesmeyer [11], the data from the patient's medical history and a comprehensive diagnosis through clinical, functional and manual analysis, three main diagnoses are possible:

- Occlusopathy - changes in teeth and periodontium, which are a result from impaired occlusion and/or articulation and associated with the presence of parafunctions.

- Myopathy - changes in masticatory muscles (pain, spasms, tenderness, tension) resulting from impaired function.

- Arthropathy - changes in the TMJ that can be conditionally divided into:

• compressions in a cranial direction
• distractions in a caudal direction
• dislocations of the articular condyle in a retral/a ventral direction

• structural changes of the articular disc
• structural changes of the articular condyle
• discopathies and impaired spatial relationships of the articular condyle-disc assembly, such as: anterior-medial dislocation of the disc with and without repositioning and posterior dislocation of the disc in backward excursive movements

Klatkiewicz et al. [12], declare a significant increase in the incidence of arthropathies among patients. In one study [13], it is indicated that the affected individuals are between 10% and 70% of the main population. Among children and adolescents, the prevalence varies between 16% and 68% [14].

The results in some studies [15, 16] demonstrate that the presence of occlusal prematurities may cause increased muscle activity, bruxism, sleep disturbances, increased release of adrenaline or noradrenaline, hydroxycorticosteroid, TMJ-associated complaints and decreased efficiency.

Other studies [17, 18] present evidence that CMDs may evolve into craniovertebral dysfunctions and cause depression and psycho-emotional changes with varying degrees of severity.

Craniomandibular dysfunctions are manifested in disorders affecting not only the masticatory system and the maxillofacial area but also the entire body. Therefore, the use of visual analytical methods, such as ultrasonography, is necessary for a detailed evaluation of the interrelationship of the structural components of the masticatory system, accurate diagnosis and appropriate choice of treatment by the dental practitioner [19].

OBJECTIVE:

The aim of this literature review is to present and analyze current literature evidence on the ultrasound diagnosis of the temporomandibular joint in patients with craniomandibular dysfunctions.

MATERIALS AND METHODS:

An electronic search was performed in PubMed, Google and Lilac databases from September 2018 to March 2019 by using the following keywords: ultrasound, temporomandibular/mandibular joint, craniomandibular dysfunctions and the corresponding terms in English, German, Russian and French: „ultrasound", „temporomandibular/mandibular joint", "craniomandibular dysfunctions", „Ultraschall", „Kiefergelenk", „kraniomandibuläre Fehlfunktionen", „ультразвук", „височно-нижнечелюстного сустава ", „кранио мандибуларни дисфункции", „ultrason", „articulation temporo-mandibulaire", "dysfonctionnement cranio-mandibulaire". The data from 67 finally selected publications were analyzed, summarized and presented in the main part of this review.

RESULTS:

Anatomy of the TMJ

The temporomandibular joint (TMJ) is a synovial joint that, along with masticatory muscles, enables mandibular movement in various directions, masticatory and speech functions [20]. The composition of the TMJ includes the articular disc, articular surfaces, fibrous capsule, synovial fluid, synovial membrane, ligaments and tendons. The articulating surfaces of the mandibular condyle and the mandibular fossa of the temporal bone are covered by fibrous cartilage [21]. The mandibular component is an ovoid-shaped process, 15.0 mm - 20.0 mm wide and 8.0 mm – 10.0 mm long, which may vary with age. The cranial part of the joint is completely composed of the squamous part of the temporal bone, at the posterior part of which is the articular eminence [22].

The articular disc is a biconvex, oval, avascular, fibrous cartilage, located between the two articular surfaces. The anterior part of the articular disc is 2.0 mm thick and passes into the articular capsule. The posterior part of the articular disc is 3.0 mm thick and extends into a bilaminar zone that attaches to the posterior surface of the mandibular condyle. This zone consists of an upper fibro-elastic layer that resists the sliding of the disc, when the mouth is widely opened, and a lower fibrous layer that prevents the excessive rotation of the disc over the condyle [23]. Blood vessels, nerves and elastic fibres pass through the two layers, bind to the posterior part of the articular capsule and assist the retraction of the disc then the mouth is closed. Collateral ligaments fix the disc laterally and mesially [24].

Biomechanics of the TMJ

The movements and function of TMJ are determined by the complex interaction and coordination of the condyle, articular disc, muscles and articular ligaments [21]. In healthy individuals, the thin middle portion of the articular disc is located between the mandibular condyle and the mandibular fossa of the temporal bone, in both closed and opened mouth positions.

In closed mouth position, the condyle is centered in the mandibular fossa, the articular eminence is anterior to the disc, and the disc itself is located in the superior-posterior part of the condyle [24]. According to some authors [25, 26], the anterior part of the disc should be positioned in front of the condyle, and the bilaminar zone and the posterior part should be located on *caput mandibulae*, corresponding to the 12-hour position. Other authors [27, 28] have found significant individual deviations in the position of the posterior part of the disc and the bilaminar zone. Therefore, Drace et al. [29] have suggested deviations of +30° to be considered normal.

Diagnostic imaging of the TMJ

The most commonly used methods for visual diagnosis of TMJ are computed tomography (CT), conventional radiography, arthrography, magnetic resonance imaging (MRI) and ultrasonography [30].

The use of MRI in the diagnosis of temporomandibular disorders is described in the literature as a "gold standard" [12, 24, 31, 32]. Despite its benefits, the authors point out significant disadvantages, such as the high cost of the examination, expensive equipment, inability to be used for patients with claustrophobia, pacemaker and metal prostheses.

Computed tomography of the TMJ is most commonly used to diagnose bone lesions, such as bone erosions, fractures, postoperative deformities, osteoarthritis and joint inflammation [21, 33]. There are some restrictions on soft tissue imaging, as well as minimal radiation exposure [11].

Arthrography is a high-precision method (84% - 100%) that gives comprehensive information on the condition of the articular disc and articular cartilage. A major disadvantage is a need for the introduction of a contrast medium in the area of upper-articular space, which is associated with some discomfort for the patient [34].

For the first time in 1991, Nebeith and Speculand [35] reported the application of an ultrasound device with a 3.5 MHz transducer, for a successful visualization of the TMJ and the articular disc. A year later, Stefanoff et al. [36] also reported the use of ultrasound for visualizing the TMJ. There are a number of studies [21, 24, 32, 39, 40] that suggest ultrasonography as an alternative method for diagnostic imaging of the TMJ. The basic advantages mentioned are the lower cost, compared to other methods for visual examination, lack of additional means and devices, feasible utilization in the dental office, easy-to-apply, non-invasive methodology. One of the most important features of ultrasonography is that it allows the investigator to examine the movement of the TMJ and the reposition of the articular disc in dynamics and real time. The other imaging methods provide static information of the joint elements [34].

Principles of ultrasound examination

All diagnostic ultrasound devices use reflected acoustic energy from different parts of the body [39, 40]. The ultrasound pulses produced by the scanner have a frequency of 3 MHz to 10 MHz, a duration of about 1.0 microsecond and repetition of about 1,000 times per second. Reflected pulses are received by the transducer and converted into the scanner. Part of the signals is amplified, while other signals are reduced to achieve a balanced image. The reason for this is that the echoes, derived from the deeper structures, are weaker compared to those coming from superficial structures [41].

Ultrasonography of the TMJ

The various structural components of the TMJ reflect the sound waves in a different way. Bone tissues, such as the condyle, *caput mandibulae*, articular eminence and articular fossa, reflect them as hypoechoes (low sound wave reflection) and appear black on the sonographic images. The borders of the bone structures, however, have a high sound wave reflection (hyperechoes) and are visualized as white/light lines. Soft structural elements in the area of TMJ have intermediate sound wave reflection (isoechoes) and are visualized as heterogeneous grey. These include the articular capsule, ligaments, connective tissue and muscle tissue. Like bone structures, muscle and articular capsule borders have a high sound wave reflection and are also marked with hyperechoic white lines. Empty spaces, liquids and water react as hypoechoic and appear black on the sonographic images [30].

Difficulty with ultrasound imaging in the area of TMJ is the limited access to deeply positioned structures, such as the articular disc, due to the high absorption of sound waves from the surrounding bone structures [42]. This problem, according to some authors [13, 30, 43], can be managed by further tuning and positioning of the transducer and the use of 18 MHz high-frequency devices that differentiate the tissues in more detail. The articular disc is visualized as a thin, homogeneous, hypo-isoechoic band.

Most commonly, the ultrasound examination is performed in the closed and maximally opened mouth positions [12, 36, 42]. When the mouth is closed and resting, the position of the disc is defined as normal, when the disc is located above *caput mandibulae* and between the superior-posterior end of the condyle and the inferior-posterior part of the articular eminence [30, 41]. The position of the articular disc is classified as: anteriorly dislocated without extension, when the anterior border of the disc is located in front of the condyle; mesially dislocated, when the border of the disc is mesial to the border of the condyle; laterally dislocated, when the border of the disc is lateral to the border of the condyle [36, 42, 43]. De Mello Junior et al. [24] suggest the position of the articular disc to be considered normal when its posterior part is located between the 12- and 1-hour positions on the articular surface of the mandibular condyle. The authors assume that the disc is anteriorly dislocated when the posterior part of the disc is located in front of the 12-hour position. According to other authors [44], when the articular disc is not located between the condyle and the articular fossa in the closed and maximally opened mouth positions, it is considered dislocated.

In evaluating the position of the disc in the opened mouth position, it is considered normal, when the intermediate part of the disc is located between the condyle and the articular fossa [30, 42].

Methods and techniques for performing ultrasonography of the TMJ

Methods and techniques for performing ultrasonography vary among the authors. Hayashi et al. [45] claim that the patient should be seated during the examination and the transducer positioned in the transverse direction on the skin in the area of the TMJ, and moved parallel to the Camper,s plane/occlusal plane. According to the authors, the transducer is positioned against the ear tragus first and then is rotated and positioned to obtain an optimal image of the lateral part of the condyle. Diagnosis is made in both maximally opened and closed mouth positions. This method of examination has also been confirmed in other studies [44, 46]. According to other studies [31, 47], ultrasonography of the TMJ should be performed in the supine position.

Dupuy-Bonafe et al. [30] also assume that the patient should be lying, but with a laterally turned head. Prior to initiating the examination, the authors recommend the palpation of the TMJ. To obtain transversal sections of the anterior-superior part of the joint in the closed mouth position, the probe is positioned horizontally on the condyle, in front of the ear tragus and parallel to the Camper,s plane. Consecutively, the frontal part of the transducer is rotated downwards, perpendicularly to the zygomatic bone and parallel to *ramus mandibulae*, to obtain good visualization of the intra-articular space, lateral part of the condyle, articular disc and articular capsule. After examining the TMJ in the static, closed position of the mandible, the authors studied the articular iterrelationships through a series of images taken during progressive and consecutive openings of the mouth. According to Emshoff et al. [42], during the dynamic examination of the TMJ, the probe should be oriented in the same way as the surface of the articular disc, to avoid artificial changes in echogenicity. According to the authors, the scanning at 60 degrees or more against the long axis of the disc results in its non-visualization.

Braun and Hicken [37] suggest the use of a transducer smaller than the standard one - about 2.0 cm in its widest part, which allows positioning in the area of the external auditory canal. In order to achieve better images in the sagittal direction, the authors suggest that the probe should be oriented at a 25-degree inclination relative to the sagittal plane and parallel to the Frankfurt horizontal line.

Motoyoshi et al. [49] describe another way of positioning the transducer, which allows better visualization of the disc that frequently remains hidden by the temporal bone: the probe is rotated at 60 degrees to the horizontal plane, following the plane of the articular eminence, and is tilted up to 5-10 degrees relative to the perpendicular line of the sagittal plane. This implies access to the joint structures over the zygomatic process of the temporal bone.

To increase the accuracy and reproducibility of ultrasound examinations, Stefanoff et al. [38] suggest marking of the exact middle of the short lateral side of the transducer, so that the marked part can be easily positioned every time just in the middle of the ear tragus.

Diagnostic accuracy of ultrasonography of the TMJ

Diagnostic accuracy and sensitivity of ultrasound examination of the TMJ are discussed in the literature [42, 47]. A major part of the information on accuracy is obtained from comparative studies on ultrasonography, MRI and CT [44]. Despite the variations in the studies, the results are positive with regard to the reliability and accuracy of ultrasonography of the TMJ.

Jank et al. [44] suggest calculation of exact values for the accuracy, specificity and sensitivity of ultrasonography in a comparative analysis with MRI and/or CT. According to the authors, accuracy is the result of the sum of true positive and true negative, divided by the total number of examinations. Sensitivity is the result of the number of true positive, divided by the sum of a true positive plus false negative. Specificity is determined by dividing the number of true negative with the sum of a true negative plus false positive. During examinations with high-frequency ultrasonography and MRI of patients with clinically diagnosed internal disorders of the TMJ, the authors have found that when the mouth is closed, 103 out of 132 ultrasound interpretations are considered true. When the mouth is maximally opened, 102 of the images are considered reliable.

According to another study by Jank et al. [31], the accuracy of ultrasonography in cases of joint-disc dislocations was 92% in the closed-mouth and 90% in the opened-mouth position. The measured sensitivity and specificity values were 86% - 92% and 91% - 92%, respectively. In cases of degenerative disorders, the results were 94% accuracy, 94% sensitivity, and 100% specificity.

A study by Hayashi et al. [45] has confirmed the accuracy of ultrasonography in detecting internal TMJ abnormalities in early school-age asymptomatic children. For the purposes of the study, the children were subject to ultrasound, MRI and CT examinations. For verification and comparative analysis of the data, the distance between the articular capsule and the lateral surface of the condyle was used. The results have shown 92% accuracy, 83% sensitivity, and 96% specificity of the ultrasound examination.

A study by Emshoff et al. [42] among 64 patients (128 TMJs) has demonstrated that dynamic high-resolution ultrasonography, performed during the maximum jaw movement range, can detect up to 93% of the cases of internal TMJ abnormality, up to 82% of the cases of disc dislocation with reduction, and up to 83% of the cases of disc dislocation without reduction. Only one false positive finding of an internal abnormality was registered. According to the authors, the accuracy of high-resolution ultrasonography varies within 90% - 95%.

Byahatti et al. [48] report, that ultrasonography is a non-invasive diagnostic method that can be a source of valuable information for patients with internal TMJ abnormalities. According to the authors, the accuracy of examination is greater, when assessing the relationships in the closed-mouth position. Study data have shown 64% sensitivity, 88% specificity, 84% positive prognostic value, 71% negative prognostic value, and 76% accuracy. In support of these data is the study of Tu et al. [46], which, following meta-analysis, has found that visual ultrasound diagnosis is characterized by 72% - 83% sensitivity and 85% - 90% specificity. The possibility to observe the relationships in dynamics is pointed out as a major advantage.

With reference to Dupuy-Bonafe et al. [30], despite the comparatively lower sensitivity of ultrasound examination compared to MRI, it is characterized by high specificity of 96.6%. When evaluating 98 temporomandibular joints, only 2 of the interpretations were found to be false positive and 31 to be a false negative. The reason for this, according to the authors, is that the analysis of relationships in the opened-mouth position may be compromised in some patients, due to the obstruction/overlap of the articular disc image by the bone structures. It is, therefore, recommended that ultrasound diagnosis be performed in the closed-mouth position.

Talmaceanu et al. [50] take into account the difficulties that may arise in the ultrasound diagnosis of TMJ but indicate that, with the appropriate positioning of the transducer and continuous training in the interpretation of sonographic images, this method can be extremely valuable, even for the diagnosis of minor joint-disc dislocations. In a study of 74 patients with evidence of TMDs, compared to MRI, the authors have found that the ultrasonography of the TMJ is characterized by 93.1% sensitivity, 87.88% specificity, 90.32% accuracy, 87.1% positive predictive value, and 93.5% negative predictive value in the diagnosis of disc dislocations.

DISCUSSION:

Ultrasonography is a non-invasive, reliable, effective and easy-to-use method for diagnostic imaging of temporomandibular disorders in the dental office. The use of ultrasonography can be a source of additional information and is crucial for the dental practitioner's evaluation of joint-jaw relationships, the detection of abnormalities and diseases, their follow-up and subsequent treatment. Despite the lack of standardization, ultrasound examinations are characterized by high accuracy, sensitivity, specificity and are successfully applied in cases of a difficult clinical diagnosis. Parameters for determination of the norm and various pathologies have been established. Unlike other visual assessment methods, ultrasonography provides the ability to monitor the TMJ structures in dynamics, without evidence of any adverse effect or contraindication.

CONCLUSION:

The widespread prevalence of craniomandibular dysfunctions among general population requires an active focusing the attention of dental practitioners on the timely prevention and treatment of these abnormalities. Ultrasonography is an inexpensive and widely available method for excellent visualization of tissues and structures in real time. The following-up of TMJ alterations in dynamics is a significant advantage for making an accurate diagnosis, selecting an effective treatment method and adequate assessment of recovery processes. All this may greatly enhance the quality of the dental practitioner's work and treatment outcome of functional pathologies of the masticatory system.

Acknowledgements:

Òhe current data are part of the development of scientific project No. 8330/ 22.11.2018, funded by the Medical University of Sofia, Bulgaria.

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Please cite this article as: Dimova-Gabrovska M, Dimitrova D, Yordanov B, Apostolov N, Peev T. Ultrasound Diagnosis of Temporomandibular Joint in Patients with Craniomandibular Dysfunctions. *J of IMAB.* 2019 Apr-Jun;25(2):2563-2569.
DOI: https://doi.org/10.5272/jimab.2019252.2563

Received: 26/01/2019; Published online: 11/06/2019

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