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ORIGINAL ARTICLE

Use of ultrasonography in the diagnosis of temporomandibular disorders: a prospective clinical study

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Abstract

Objectives Panoramic radiographs, computed tomography, and magnetic resonance imaging (MRI) are traditionally used for imaging temporomandibular joint (TMJ) and its pathologies. Besides these radiographic techniques, the recent use of ultrasonography (US) in diagnosing joint diseases has been introduced. However, there is no prospective clinical study examining the application of US in imaging of Temporomandibular Disorders (TMD) patients. Therefore, this study aimed to determine the features of the joint and surrounding structures in the US in TMD patients.

Methods 320 patients fulfilled the inclusion criteria, and 100 of these individuals accepted to participate in the study. This study evaluated 200 TMJ; including the right TMJ and left TMJ of 100 patients. The study was designed as a clinical single-blind observational device trial.

Results It has been seen that women are 3.54 times more likely to have muscle pain than men. It has been determined that the probability of joint pain increased as the joint space with the mouth closed increased. It has been seen that women are 3.61 times more likely to experience headaches than men.

Conclusions The US, which is becoming increasingly common in dentistry, can be used as an aid in TMD diagnoses. US will not be sufficient when it is desired to evaluate the TMJ joint area more precisely and clearly in patients who will be planned for advanced surgical intervention. Therefore, it may be necessary to refer for MRI. The values of our findings will be a reference in TMD diagnoses.

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Keywords Temporomandibular joint · Temporomandibular joint disorders · Ultrasonography

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Introduction

Temporomandibular joint dysfunction (TMD), as defined by American Academy of Orofacial Pain, is a term that includes problems caused by joints and chewing muscles, as well as all functional disorders of the chewing system [1]. This term describes muscle-joint disorders characterized by pain in the orofacial region, restriction in mouth opening, a feeling of fatigue in the masticatory muscles, and sounds in the temporomandibular joint (TMJ). TMDs are observed at least once in three quarters of the population [1]. As with all other joints, the TMJ has a passive range of motion in all directions. The average values of this range of motion are 3.4–4.4 mm. In the first stage of TMD, a narrowing of the joint space can be seen without radiologic changes in the bones. In the late stage, narrowed joint space is observed with bony changes, possibly including ankylosis [2].

Panoramic radiographs, computed tomography (CT), and magnetic resonance imaging (MRI) are traditionally used for imaging TMJ and its pathologies. Besides these radiographic techniques, the recent use of Ultrasonography (US) in diagnosing joint diseases has been introduced.

The US is an imaging method that detects echoes from different tissue surfaces by sending high-frequency sound waves to the body. In clinical practice, acoustic waves with a frequency of 2–20 MHz are applied. The ultrasound source is the probe containing a piezoelectric device. Acoustic waves received by the piezoelectric elements in the probe are converted into an electrical signal presented on the screen as a real-time black and white two-dimensional image (B mode), and echogenicity is evaluated. The area that produces strong echoes is called hyperechoic, while those with no echoes are called anechoic (no echo). Hypoechoic areas are characterized by lower echogenicity than surrounding structures, while areas with the same or similar echogenicity are called isoechoic [3]. On ultrasonography, in the anatomical structure of the TMJ, the condyle appears as a hyperechoic line, and the disc appears as a hypoechoic band just above the condyle [4]. Elastography offers the possibility to evaluate the elasticity of tissues. Color map qualitatively shows areas with higher and lower elasticity [5].

Imaging in TMDs has been extensively researched, and MRI has been considered as the gold standard. However, there is no prospective clinical study examining the application of US in imaging of TMD patients. Therefore, this study aimed to determine the features of the joint and surrounding structures (distance spacing, elastography) in the US in TMD patients. The null hypothesis was that the US is not a helpful and alternative method in diagnosing TMD.

Participants and methods

Participants

This study was performed at Istanbul University, Faculty of Dentistry, Department of Dentomaxillofacial Radiology, and the protocol was approved by the local ethics committee (26.09.2019/443). The present work was supported by the Research Fund of Istanbul University. Project No. TDK-2019-3,908. Written informed consent was obtained from each participant after a full explanation of the study. A total of 100 participants were selected consecutively from 750 TMD participants between 01.01.2020 and 01.01.2021. Only 320 participants fulfilled the inclusion criteria, and 100 of these individuals accepted to participate in the study. This study evaluated 200 TMJ; including the right TMJ and left TMJ of 100 participants. The study was designed as a clinical single-blind observational device trial.

Sample selection was based on a standardized clinical examination. The first examination evaluated if the subjects fulfilled the following inclusion criteria: (1) myofascial pain diagnosis according to the Research Diagnostic Criteria for Temporomandibular Disorder (RDC/TMD) [6], and (2) age of 18–55 years. Exclusion criteria included: (1) general inflammatory connective tissue diseases (e.g., rheumatoid arthritis), (2) psychiatric disorders, (3) tumors, (4) heart disease or pacemaker use, (5) pregnancy, (6) symptoms potentially attributable to other orofacial region diseases (e.g., toothache, neuralgia, migraine), (7) local skin infections over the masseter muscle.

Clinical examination

The same clinician performed the functional examination and was based on the official translation of DC/TMD suggested by the International RDC–TMD Consortium [6]. The clinician was an experienced prosthodontist using DC/TMD for more than 5 years and was calibrated prior to the study using DC/TMD as the gold standard. The participants were seated upright during the clinical and radiological examination. A study was performed during COVID-19 pandemics, the Infection Prevention Guidance for Dental Settings During COVID-19 Response of Ministry of Health Republic of Turkey was also followed [7]; the social distance was maintained, and gloves, protective masks, and disinfectants were used during the examination.

The clinical examination was performed following the DC/TMD form. Masticator muscle tenderness was assessed on both sides by bilateral palpation. The mandibular mobility was measured with a plastic millimeter ruler on the mandibular excursion [8]. All records were noted as millimetric integers. In the incisal relations, the overjet and overbite

Fig. 1 Probes used in the study

measurements were performed according to the FDI system with reference to tooth number 21. Participants were asked to report any pain and joint noise during muscle palpations and mandibular movements, and the answers were recorded according to a verbal scale. Using the DC/TMD Diagnostic Decision Tree form in line with all clinical examination findings, each participant was diagnosed with a pain disorder, right and left TMJ disorder.

Pain characteristics of the participants were also evaluated; the severity of the limitation of the pain experienced by the participants in their daily activities and the extent of their depression was determined. The participants' pain intensity, disability, and depression dimensions by scoring the completed pain information forms according to the AXIS II Scoring Protocol recommended by Dworkin and LeResche [8].

Radiological examination

The Siemens Healthineers—Acuson Juniper Diagnostic Ultrasound System was used for the radiological examination of the participants. The Linear (6.7 MHz) and Intraoral Probes (10.6 MHz) were used for taking US images from the participants (Fig. 1).

US images were taken by placing the probes at an angle of 60°–70° parallel to the Frankfurt plane and the ramus of the mandible. The participants were divided randomly into two groups; the linear probe was used in the first 50 participants, whereas the rest 50 participants were investigated with an intraoral probe. In both groups, left and right TMJ were investigated.

The evaluations were performed as follows:

- TMJ measurement (mouth-closed): The participants were directed to close their mouths, and then images of the right and left joint regions were obtained. The joint space between the condyle and fossa was measured.
- TMJ measurement (mouth-open): The same procedure was repeated as the participants’ mouth were open (Fig. 2). The participants were instructed to open their mouth till they felt pain (unassisted maximum mouth opening
- TMJ Stiffness measurement: With the mouth closed, the images of the right and left joint regions were taken, and the degree of stiffness (elastography) of the joint space between the condyle and fossa was measured separately for the right and left regions by comparing it with the subcutaneous fat tissue (Fig. 3).
- Masseter thickness measurement: The masseter muscle thickness was measured by taking images of the right and left muscle regions, while the mouth was closed and the participants was resting. Furthermore, the contracted muscle thickness was measured. The participants were directed to clench their teeth, and the measurement was repeated (Fig. 4).
- Masseter Stiffness measurement: The stiffness (elastography) of the masseter was measured as the muscle was in

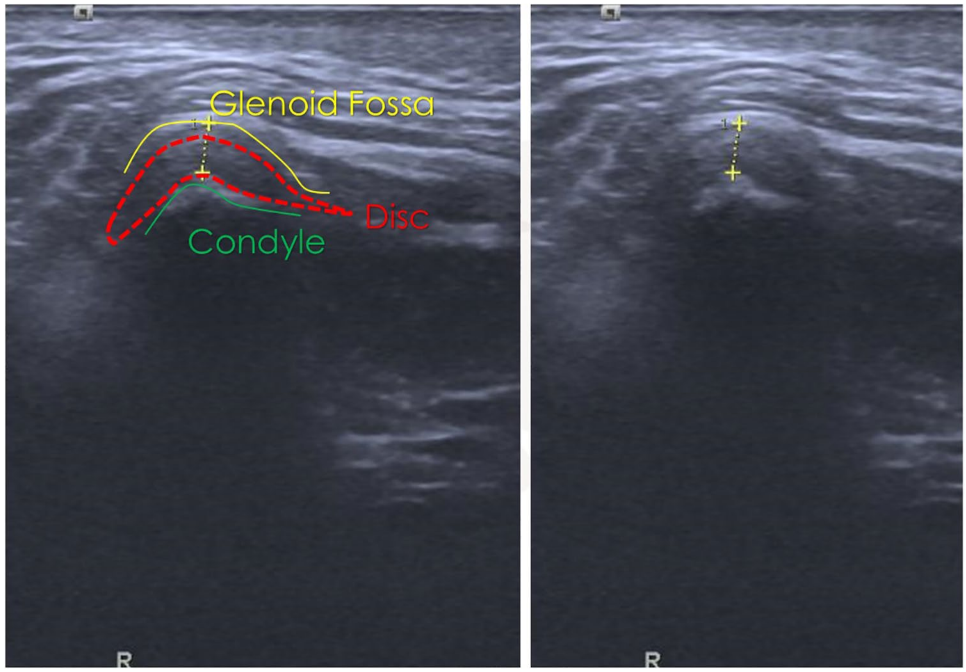

Fig. 2 TMJ anatomy in ultrasonography and measuring joint space distance

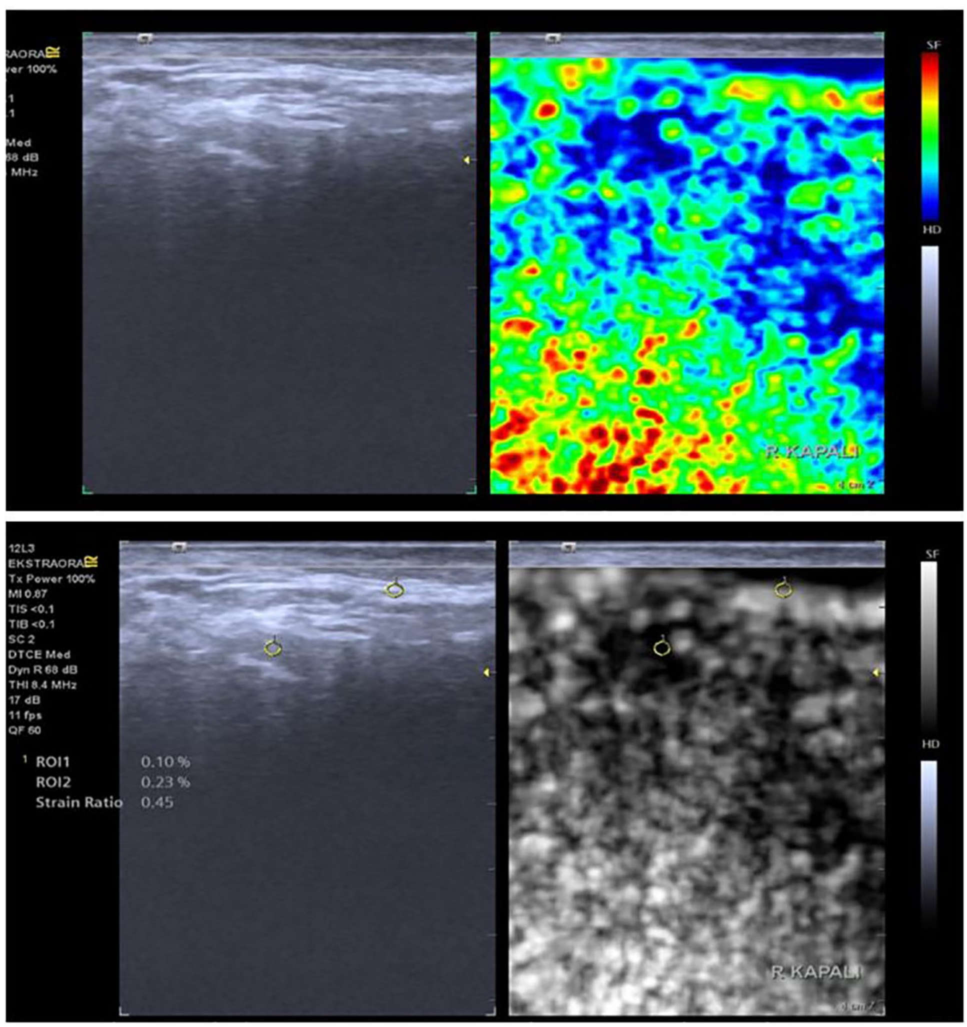

Fig. 3 Evaluation of TMJ elastography in ultrasonography

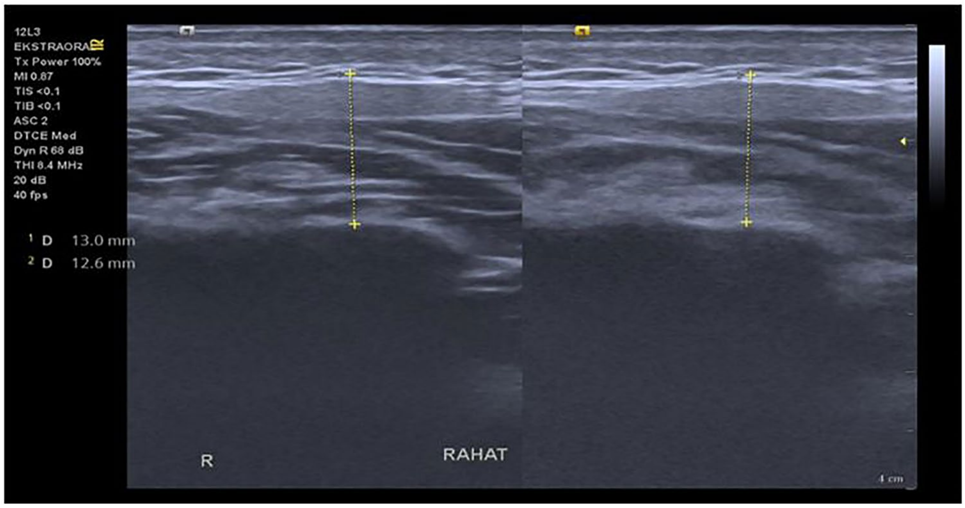

Fig. 4 Measurement of masseter muscle thickness in ultrasonography

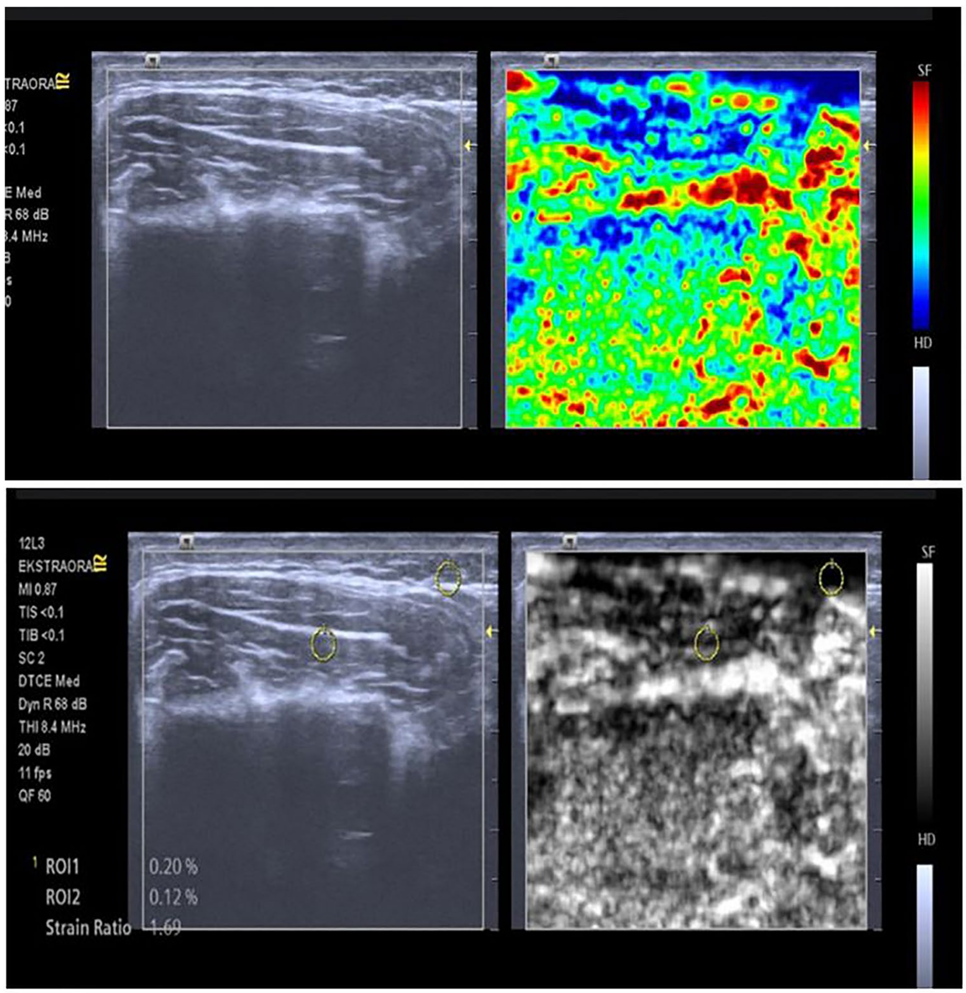

Fig. 5 Evaluation of masseter muscle elastography in ultrasonography

rest position and contracted and was compared with the skin tissue. The difference was obtained proportionally (Fig. 5).

Statistical analysis

All variables were analyzed descriptively. Descriptive statistics of continuous variables were given as mean, standard deviation, minimum and maximum. The normality of continuous variables was checked with the Kolmogorov–Smirnov test. The Mann–Whitney *U* test was used to evaluate the difference between groups. The Kruskal–Wallis *H* test was performed for comparing more than two groups. The Spearman correlation test was applied to evaluate the relationship between the variables. Multivariate Logistic Regression Analyzes and Univariate Logistic Regression Analyzes tests were used for probability calculations. The statistical significance limit was taken as $p<0.05$.

Table 1 US data of the study population

US data	Linear probe	ıntraoral probe	*p**
Mouth closed			
Joint spacing distance	1.57 ± 0.50	1.20 ± 0.44	0.000
Joint space elastography	1.045 ± 0.69	1.49 ± 0.99	0.000
Open mouth			
Joint spacing distance	1.38 ± 0.43	1.17 ± 0.41	0.000
Joint space elastography	1.22 ± 0.86	1.60 ± 0.98	0.000
Resting			
Masseter muscle thickness	9.07 ± 2.05	8.25 ± 1.4	0.001**
Masseter muscle elastography	1.56 ± 0.82	2.15 ± 1.49	0.136
Clenching			
Masseter muscle thickness	12,50 ± 2,66	12.62 ± 2.12	0.730**
Masseter muscle elastography	1.57 ± 0.80	1.85 ± 1.06	0.064

*Kruskal–Wallis test, **ANOVA

Results

The present study included 100 participants (61 females, 39 males) with a mean age of 25.62 ± 8.10 [18–55] (females; 26.31 ± 9.323 [18–55], males; 24.54 ± 5.665 [21–47]). There was a predominance of women in the study.

A total number of 200 TMJs were analyzed; 100 TMJs evaluated with linear probe were 100 TMJs evaluated with intraoral probe and a statistically significant difference was observed between the groups with regards to joint space distance and elastography in both mouth closed and open positions (Table 1) ($p<0.05$). A statistically significant difference was also observed in resting masseter muscle thickness ($p<0.005$). The masseter muscle demonstrated less thickness in intraoral probe group than in linear probe group.

The table shows the means between diagnostic groups for participants diagnosed with pain disorders (Table 2).

When the joint space distance was examined in the participants who participated in the study and was diagnosed with pain disorder, a statistically significant difference was observed between the diagnostic groups ($p<0.05$). It was observed that the joint space distance measured with the mouth closed was higher in people diagnosed with joint pain compared to those in all other diagnostic groups. It was observed that the joint space distance measured with the mouth open was higher in people diagnosed with muscle pain compared to those in the other group.

Table 2 Means of US data by pain disorder diagnostic groups

Pain disorders	No pain	Muscle pain	Joint pain	Headache	*p**
Mouth closed					
Joint space distance	1.29 ± 0.49	1.41 ± 0,43	1.55 ± 0.58	1.47 ± 0.47	**0.034**
Joint space elastography	1.29 ± 0.88	1.32 ± 1.10	1.37 ± 0.83	0.93 ± 0.43	0.213
Open mouth					
Joint space distance	1.20 ± 0.37	1.39 ± 0.43	1.29 ± 0.50	1.38 ± 0.51	**0.048**
Joint space elastography	1.46 ± 0.98	1.38 ± 0.82	1.36 ± 0.95	1.36 ± 1.00	0.861
Resting					
Masseter muscle thickness	8.44 ± 1.78	8.75 ± 1.81	8.75 ± 1.96	9.29 ± 1.45	0.206**
Masseter muscle elastography	2.02 ± 1.33	1.59 ± 1.09	1.82 ± 1.29	1.66 ± 0.88	0.357
Clenching					
Masseter muscle thickness	12.87 ± 2.50	11.75 ± 2.18	13.00 ± 2.19	11.85 ± 2.34	**0.024****
Masseter muscle elastography	1.85 ± 1.10	1.58 ± 0.73	1.73 ± 0.88	1.31 ± 0.52	0.148

*Kruskal–Wallis test, **ANOVA

Table 3 Multivariate logistic regression analyses

US parameters		*p** value	Odds ratio	% 95 CI	
Muscle pain	Masseter muscle thickness (resting)	0.050	1.303	1.000	1.699
	Masseter muscle thickness (clenching)	0.018	− 0.797	0.659	0.962
	Sex	0.007	3.547	1.406	8,950
Joint pain	Joint spacing distance (mouth closed)	0.025	2.563	1.127	5.831
Headache	Joint space elastography (mouth closed)	0.028	− 0.423	0.197	0.910
	Masseter muscle thickness (resting)	0.005	1.599	1.152	2.219
	Masseter muscle thickness (clenching)	0.008	− 0.733	0.583	0.922
	Masseter muscle elastography (resting)	0.038	− 0.447	0.209	0.957
	Sex	0.021	3.610	1.218	10.701

*Multivariate logistic regression analyses

Table 4 Means of US data based on TMJ disorders diagnosis groups

TMJ disorders	None	Disc displacement with reduction	Disc displacement without reduction	*p**
Mouth closed				
Joint spacing distance	1.36 ± 0.47	1.41 ± 0.50	1.50 ± 0.83	0.742
Joint space elastography	1.28 ± 0.89	1.29 ± 0.89	0.92 ± 0.59	0.303
Open mouth				
Joint spacing distance	1.29 ± 0.43	1.25 ± 0.44	1.36 ± 0.42	0.438
Joint space elastography	1.41 ± 0.95	1.43 ± 0.93	1.25 ± 0.94	0.819
Resting				
Masseter muscle thickness	8.67 ± 1.74	8.53 ± 1.58	9.75 ± 3.46	0.129**
Masseter muscle elastography	1.89 ± 1.26	1.86 ± 1.26	1.41 ± 0.64	0.656
Clenching				
Masseter muscle thickness	12.22 ± 2.1	12.84 ± 2.54	13.67 ± 2.93	0.065**
Masseter muscle elastography	1.71 ± 0.82	1.73 ± 1.10	1.56 ± 0.85	0.727

*Kruskal–Wallis test, **ANOVA

It was observed that the masseter muscle thickness in the contracted state was higher in people diagnosed with joint pain compared to other groups.

The table shows the probabilities between diagnostic groups for participants diagnosed with pain disorders (Table 3).

When the values in the table were examined, it was seen that the probability of muscle pain increased as the resting masseter muscle US thickness increased, while this probability decreased as the muscle thickness in the contracted state increased. It has been seen that women are 3.54 times more likely to have muscle pain than men. It has been determined that the probability of joint pain increased as the joint space with the mouth closed increased. It was observed that the probability of headache increased as the resting muscle thickness increased, while it decreased as the other data in the table increased. It has been seen that women are 3.61 times more likely to experience headaches than men.

The table shows the means between diagnostic groups for subjects diagnosed with TMJ disorders (Table 4).

Table 5 Univariate logistic regression analyses

US parameters	*p** value	Odds ratio	95% CI	
Mouth closed				
Joint spacing distance	0.322	0.379	0.056	2.588
Joint space elastography	0.131	0.353	0.091	1.365
Open mouth				
Joint spacing distance	0.544	0.478	0.044	5.198
Joint space elastography	0.349	0.636	0.247	1.639
Resting				
Masseter muscle thickness	**0.045**	**1.821**	**1.012**	**3.275**
Masseter muscle elastography	0.114	0.406	0.133	1.241
Clenching				
Masseter muscle thickness	0.986	1.003	0.716	1.405
Masseter muscle elastography	0.762	1.164	0.435	3.114
Sex	0.507	0.642	0.173	2.383

*Univariate logistic regression analyses

When the US data of the participants diagnosed with TMJ disorder were examined, no statistically significant difference was found between the diagnostic groups ($p > 0.05$). However, considering the mean values, it was observed that the joint space distance and masseter muscle thicknesses increased towards the Disc Displacement without Reduction, but on the contrary, the elastography values decreased in proportion to sweat.

The table shows the probabilities between diagnostic groups for participants diagnosed with TMJ dysregulation (Table 5).

When the values in the table were examined, it was found that the probability of Disc Displacement without Reduction increased as the resting masseter muscle US thickness increased.

Discussion

Today, a significant increase in TMD prevalence is observed, with a rate of 10–70% in the general population and 16–68% in children and adolescents. The increasing number of TMD cases may be related to increased psychological pressure on today's society. Besides these disorders, there may be different causes for several different specific conditions. The similarity of symptoms for different disorders causes difficulties in clinical diagnosis [9].

In addition to the primary clinical examination, various methods, and techniques for diagnosing TMD. MRI is accepted as the gold standard in the evaluation of articular disc as well as soft tissues. On the other hand, CT is used to diagnose bone lesions, such as bone erosion, fractures, postoperative deformities, and deformities of the temporal bone. Bone scintigraphy is helpful for the evaluation of osteoarthritis and joint inflammation. In recent years, the US has been defined as an essential method for imaging the TMJ. [9, 10].

First, it is necessary to determine which imaging methods are suitable for TMD diagnosis. Choosing the appropriate imaging modality depends on what kind of information the referring clinician wants. Although each imaging technique has its strengths and weaknesses, information about the location of the disc may be required in most cases to diagnose TMD [11, 12].

Detailed clinical, physical and additional psychological examinations are considered the gold standard for diagnosing TMD. Clark et al. According to TMD, the only need for imaging is to generate critical information that can influence treatment decisions [13]. If the method does not generate such information, the cost–benefit ratio of the procedure is meager. However, since the clinical diagnosis of TMD is based on the patient's symptoms together with an objective assessment, researchers have reported that TMJ diseases cannot be reliably evaluated by clinical examination alone [14, 15].

Elias et al. reported in their study that the normal TMJ range was 1.4–1.6 mm on the US scans in adults [16]. In their study, Kirkhus et al. found the mean joint space distance in the US to be 1.3 ± 0.67 [0.4–3.4] with the mouth closed. He calculated the median value of the joint space distance as 0.9 on average [17]. Our study calculated the mean joint space distance 1.39 ± 0.51 [0.6–3.2] on the right and 1.38 ± 0.50 [0.7–3.2] on the left. We calculated the median value of the joint space distance as 1.3 on the right and 1.35 on the left. We saw similar results in both studies.

Melchiorre et al., in their study of 68 children and adolescents with an average age of 11, calculated that the average joint distance was less than 1.4 mm [18].

In their study with 30 participants, Kumar et al. found the TMJ interval distance of 0.04 mm with mouth closed and 0.11 mm with mouth open in the US scans in adults with temporomandibular dysfunction [19]. Our study found the joint space distance in the US as closed mouth 1.39 mm on the right and 1.38 mm on the left. We found it 1.27 mm on the right and 1.28 mm on the left in the open mouth. We obtained quite different results from these studies in the literature.

In their study of 23 patients, Uysal et al. diagnosed 34.4% of Disc Displacement with Reduction, 37.5% of Disc Displacement without Reduction, and 28.12% of healthy discs [20]. In their study of 74 patients, Talmaceanu et al. were diagnosed as 43.24% healthy disc, 30.41% Disc Displacement with Reduction, and 20.27% Disc Displacement without Reduction. [21]. Our study diagnosed 52% of healthy disc, 5% of Disc Displacement without Reduction, and 43% of Disc Displacement with Reduction for right TMJ. We diagnosed 51% healthy disc, 5% Disc Displacement without Reduction for left TMJ, and 44% Disc Displacement with Reduction. When the clinical diagnoses were examined, we saw that the rates of people diagnosed with Disc Displacement with Reduction and healthy disc among these studies in the literature were relatively high, but we had meager rates for the diagnosis of Disc Displacement without Reduction.

In general, two possible reasons for increased masseter muscle thickness are considered. First, an increase in muscle fiber filament and fiber diameter causes thickening when a muscle contracts. Another possible cause is increased edema in the muscle [22].

According to Franks, the temporal muscle usually takes an active role in fast, short movements but in long-term contractions, such as masseter muscle bruxism. This event is one of the reasons for the high incidence of masseter muscle tenderness [23].

Although CT and MRI are used to view the normal anatomy and pathology of the masseter muscle, thanks to significant advances in diagnostic imaging technology, real-time US is an accurate method for measuring muscle thickness as it is considered an easy and repetitive, non-invasive, and inexpensive procedure. Based on this information, US was used for masseter muscle thickness measurements in our study [24].

Telkar et al. found the mean US thickness of the resting masseter muscle to be 8.71 ± 0.44 [7.90–9.40] mm in their study of 47 patients [25]. In our study, we calculated the resting US thickness of the right masseter muscle as 8.71 ± 1.91 [5.2–17.30] mm, and the left masseter muscle as i8.62 ± 1.69 [4.7–13.30] mm. We found that the finding we obtained in our study was quite similar to the literature.

Nabeih and Speculand first performed US imaging of the TMJ and disc in 1991 with a 3.5 MHz transducer. In 1992, Stefanoff et al. reported successful results by evaluating the TMJ disc with a 5 MHz transducer in asymptomatic participants [26, 27]. After these preliminary studies, several publications have shown the sensitivity, specificity, and accuracy in imaging the TMJ condyle–disc position. Most studies have emphasized the diagnostic value of US compared to MRI findings [28, 29].

Although the specificity, sensitivity, and accuracy in the diagnosis of disc displacement are lower than MRI and CT, it has been suggested that it is a valuable method for examinations performed in large groups. In the presence of intracapsular irregularity, it was reported that MRI and US were in good agreement in determining the disc position [20].

The most significant advantage of the US is that it helps the diagnosis of TMJ intracapsular irregularities at a much lower cost than MRI. In this sense, studies on the US's potential use and diagnostic capacity are increasing [14].

Conclusion

The US, which is becoming increasingly common in dentistry, can be used as an aid in TMD diagnoses. US will not be sufficient when it is desired to evaluate the TMJ joint area more precisely and clearly in patients who will be planned for advanced surgical intervention. Therefore, it may be necessary to refer for MRI. The values of our findings will be a reference in TMD diagnoses.

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Declarations

Conflict of interest There is no conflict of interest.

Ethics approval The protocol was approved by the local ethics committee (26.09.2019/443).

Informed consent Informed consent was obtained from all patients for being included in the study.

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