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ORIGINAL ARTICLE

Role of the masseter, anterior temporalis, and sternocleidomastoid muscles in myofascial temporomandibular disorder pain: evaluation of thickness and stiffness by ultrasonography

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Abstract

Objectives This study aimed to compare the thickness and stiffness of the masseter, anterior temporalis, and sternocleidomastoid muscles of patients diagnosed with myofascial temporomandibular disorders (TMD) pain to those of a control group.
Methods This was a cross-sectional study conducted at a single center. Twenty-five patients diagnosed with myofascial TMD pain and 29 asymptomatic controls (Control Group) matched by age and sex were recruited. B-mode ultrasonography and shear wave elastography were used to measure the thickness and stiffness of the bilateral masseter, temporalis, and sternocleidomastoid muscles. All measurements were performed while resting and clenching. Patients were systematically evaluated for pain intensity and maximum mouth opening.
Results There were no differences between groups in the resting and clenching thickness of any muscles ($p > 0.05$). There were no differences in the stiffness of the measured muscles at rest and clench between the groups, except for the masseter ($p > 0.05$). Individuals with myofascial TMD pain showed higher median stiffness in the right ($p < 0.001$) and left ($p = 0.003$) masseter muscles during clenching (but not during resting) compared with controls.
Conclusions Clenching masseter stiffness was greater in individuals with myofascial TMD pain than in asymptomatic controls. These findings might help to understand the jaw biomechanics and dysfunction of individuals with myofascial TMD pain.

Keywords Anterior temporal muscle · Masseter muscle · Myofascial temporomandibular disorders pain · Shear wave elastography · Sternocleidomastoid muscle · Ultrasonography

Introduction

The masticatory system is a functional unit comprising the temporomandibular joint (TMJ), teeth, bones, muscles, and ligaments. The TMJ is connected to the neck region through muscles and ligaments, forming what is known as the cranio-cervical-mandibular system [1]. Maintaining balance in this system is critical for chewing stability, with the masseter and temporalis muscles playing central roles [2]. Research indicates that the masticatory and sternocleidomastoid (SCM) muscles are activated together during mouth opening, chewing, and lateral jaw movements, demonstrating a functional link between the jaw and cervical systems [3]. This close relationship reveals that dysfunction in one area can influence the others [4, 5]. In addition, evaluating trigger points of SCM with manual palpation is an important part of the TMJ examination [6].

Temporomandibular disorders (TMD) are a group of musculoskeletal and neuromuscular conditions that affect the TMJ and surrounding areas, impacting approximately 15% of adults, particularly those aged 20–40 years. The classification of TMD varies according to the diagnostic criteria applied, with the Updated Diagnostic Criteria for Temporomandibular Disorders (DC/TMD) being the most widely used system. Myofascial pain is classified as a type of muscle disorder within this framework [7]. Common clinical symptoms of myofascial TMD include pain, tenderness,

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stiffness in the head, face, and neck, and restricted jaw movement [6]. Additionally, overactivity, hardness, and stiffness are frequently observed in the head and neck area, particularly in the masticatory muscles [8].

Imaging techniques for evaluating the masticatory and cervical muscles include magnetic resonance imaging, computed tomography, and ultrasonography (US). US offers several advantages, such as no ionizing radiation, ease of use, patient comfort, and reproducibility [9]. Although the assessment of normative and pathological muscle thickness values using US B-mode is a well-established method, shear wave elastography (SWE) is a relatively new technique for assessing tissue stiffness in practice [10, 11]. In this context, assessing the thickness and stiffness of the masticatory and cervical muscles using US in patients with myofascial TMD pain may yield clinically significant findings [12].

Although previous studies [13–16] have examined the thickness and elasticity of masticatory muscles under both normative and pathological conditions, no research has yet evaluated the SCM muscle using the SWE method in this specific patient group. The purpose of this study was to assess the thickness and stiffness of the masseter, anterior temporalis, and SCM muscles using ultrasound in patients diagnosed with myofascial TMD pain.

Materials and methods

Participants

The study included 25 patients diagnosed with myofascial TMD pain (Myofascial TMD Group) and 29 age- and sex-matched individuals who presented for various dental reasons unrelated to TMD and served as asymptomatic controls (Control Group). Participants were required to have Angle Class I occlusion, no missing teeth, no history of systemic diseases or trauma, and untreated myofascial TMD pain lasting between 3 months and 5 years at least on one side. Patients were excluded if they had a history of head or neck surgery or trauma in the relevant area, connective tissue diseases, neurological or musculoskeletal conditions (other than myofascial TMD pain) that could influence measurement results, or occlusion problems [17].

This study was conducted in the Department of Oral Diagnosis and Dentomaxillofacial Radiology, Faculty of Dentistry, Dokuz Eylul. University, following ethical approval from the Dokuz Eylul University Non-Interventional Research Ethics Committee (No: 2024/16–32, Date: 08/05/2024). All procedures were carried out in accordance with the principle of the Declaration of Helsinki. Clinical and ultrasound examinations were performed after the participants signed an informed consent form.

Study design

Measurements

Sex, age, and body mass index (BMI) of all participants were recorded. BMI was calculated by dividing body weight (kg) by the square of height (m2) using the technique recommended by the World Health Organization.

Myofascial TMD pain evaluation

Patients with myofascial pain from the muscular disorders subgroup of temporomandibular disorders, based on the RDC/TMD classification [18], were selected for the study. The following symptoms were required for inclusion:

I. Pain in the jaw, temple, ear, preauricular area, or face, either at rest or during activity.
II. Pain in three or more muscle areas (such as the temporal muscle, masseter muscle, and submandibular region) when both sides of the face were examined.
III. At least one painful palpable area must be on the same side where the pain occurs

Muscle thickness measurement

All participants in the study were evaluated using a LOGIQ P9 with an XDclear ultrasound device (GE Healthcare, WI, USA) equipped with L3-12t (2–8 MHz) linear probes and a standard water-based acoustic gel. Thickness and stiffness measurements were taken for each patient on both sides during both resting and clenching phases while they were positioned supine. Muscle measurements were recorded at rest with no teeth in contact during the resting phase. Participants were instructed to close their lips, swallow saliva, inhale deeply, exhale deeply, and relax their jaws. For the clenching phase, participants were asked to apply the maximum bite force with their teeth in a centric occlusion [16].

When assessing the thickness of the masseter muscle, the midpoint of the mediolateral line along the mandibular ramus was found to be the most reliable site for measurement. The US probe was placed perpendicular to the muscle fibers at this point and aligned parallel to the long axis of the mandible halfway between the zygomatic arch and the gonial angle. This position was selected to target the thickest part of the masseter muscle near the occlusal plane. The probe was then adjusted to obtain the clearest ultrasound image. Muscle thickness was measured as the maximum distance between the inner and outer fascial

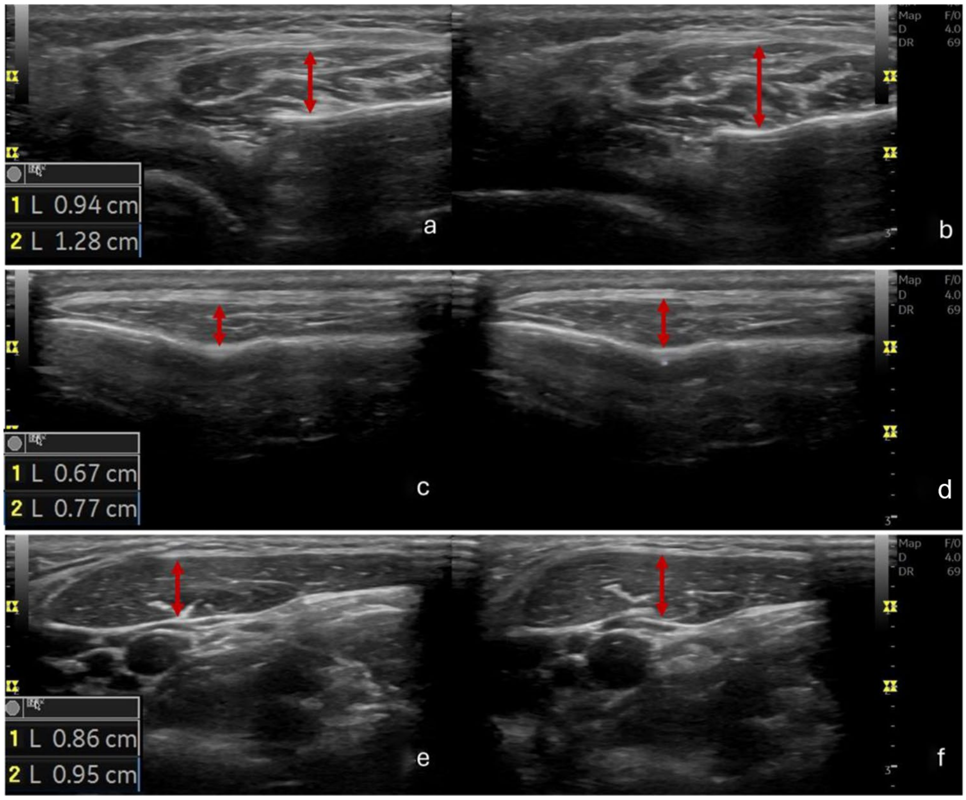

Fig. 1 Thickness measurements of the muscles in resting and during clenching. Masseter muscle in resting (**a**) and during clenching (**b**). Temporal muscle in resting (**c**) and during clenching (**d**). SCM muscle in resting (**e**) and during clenching (f)

layers. Figures 1a and b depict the masseter muscle in its resting and clenching states, respectively [16].

Due to accessibility limitations, only the anterior temporal muscle could be reliably measured. To evaluate its thickness, a linear probe was positioned between the lateral canthus and anterior hairline, beginning at the superior border of the zygomatic bone. The probe was then moved cranially parallel to the zygomatic arch until the muscle was visible. Once identified, the probe was adjusted over the muscle to obtain the optimal ultrasound image. Muscle thickness was defined as the maximum distance between the inner and outer fascial layers. Figures 1c and d illustrate the anterior temporal muscle in its resting and clenching states, respectively [16].

To measure the thickness of the SCM, the probe was positioned approximately 5 cm lateral to the trachea, with the neck in a vertical position. The muscle belly in the middle of the SCM was palpated and marked while the patient maintained this position. The probe was then adjusted to obtain the optimal ultrasonographic image of the muscle. Figures 1e and f depict the SCM in its resting and clenching states, respectively.

Muscle stiffness measurements

The transducer was positioned perpendicular to the longitudinal axis of the muscles at the widest segment within the middle portion of the muscle belly. The focal area of the masseter muscle in B-mode images was identified as the most prominent segment during clenching and resting. The probe was maneuvered along the muscle to obtain the optimal image. Then, the "Elasto" mode was activated by adjusting the examination region's width, and the SWE system was engaged. Upon activation, the screen was divided into two sections: a grayscale image on the left and an elastography image on the right. Three elastography images were captured, and a 6-mm circular region of interest (ROI) was centered on the muscle tissue. The average of these three measurements was calculated as the muscle's stiffness value. SWE measurements of the masseter, anterior temporal, and SCM muscles are presented in Figs. 2, 3, and 4, respectively.

During US elastography evaluations, the SWE technique was used to measure Young's modulus (stiffness) in kilopascals (kPa). Stiffness measurements of the bilateral masseter, anterior temporal, and SCM muscles were taken for each participant during resting and maximal clenching [16].

For the reliability study, stiffness was measured in 10 participants with myofascial TMD pain. The interrater reliability of the measurement was confirmed using the intraclass correlation coefficient (ICC1,2) with a 95% confidence interval. Stiffness was measured two times for the right side only in resting. $ICC_{1,2}$ was reported as follows: for the masseter muscle (0.964), the temporal muscle (0.972), and the SCM muscle (0.836). Therefore, our

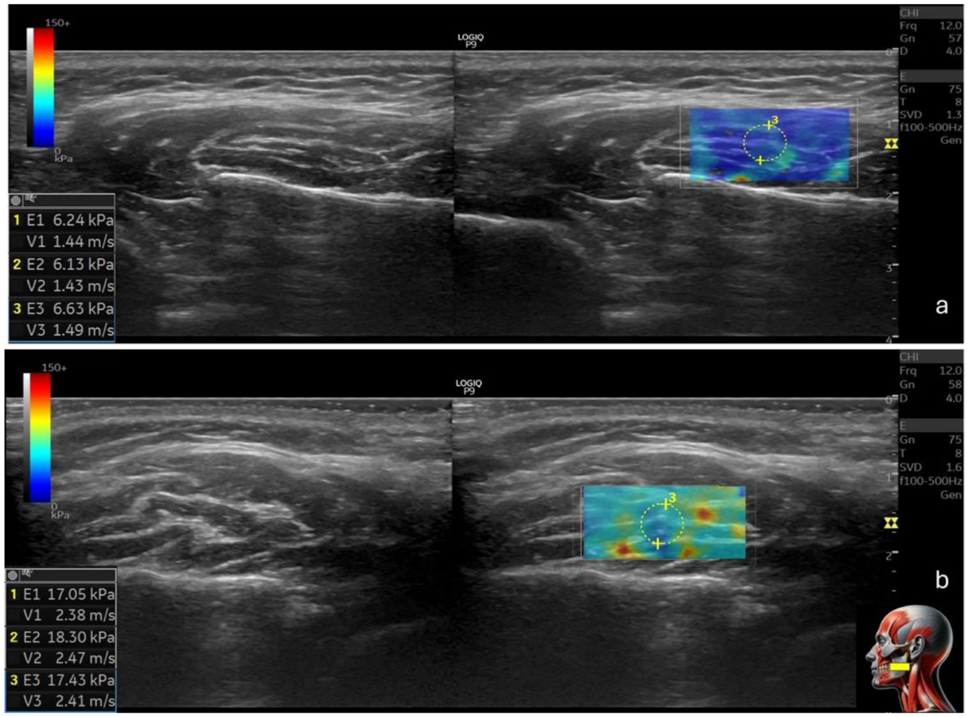

Fig. 2 SWE of the masseter muscle in the resting (**a**) and during clenching (**b**)

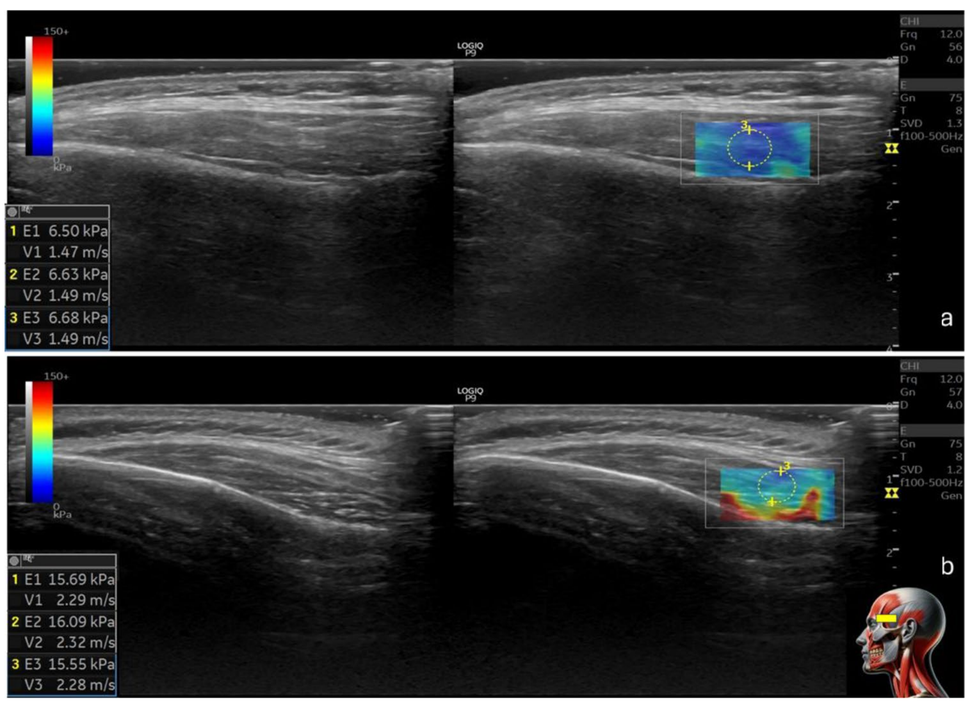

Fig. 3 SWE of the anterior temporal muscle in the resting (**a**) and during clenching (**b**)

results suggest that stiffness measurement for all three muscles in our study was reproducible. ICC values were categorized as poor for values below 0.5, moderate for values ranging from 0.5 to 0.75, good for values between 0.75 and 0.9, and excellent for values exceeding 0.9 [17].

Visual analog scale (VAS)

Myofascial pain was scored by the patients on a visual analog scale (VAS) ranging from 0 (no pain at all) to 10 (worst pain imaginable) [19]. Pain intensity was assessed

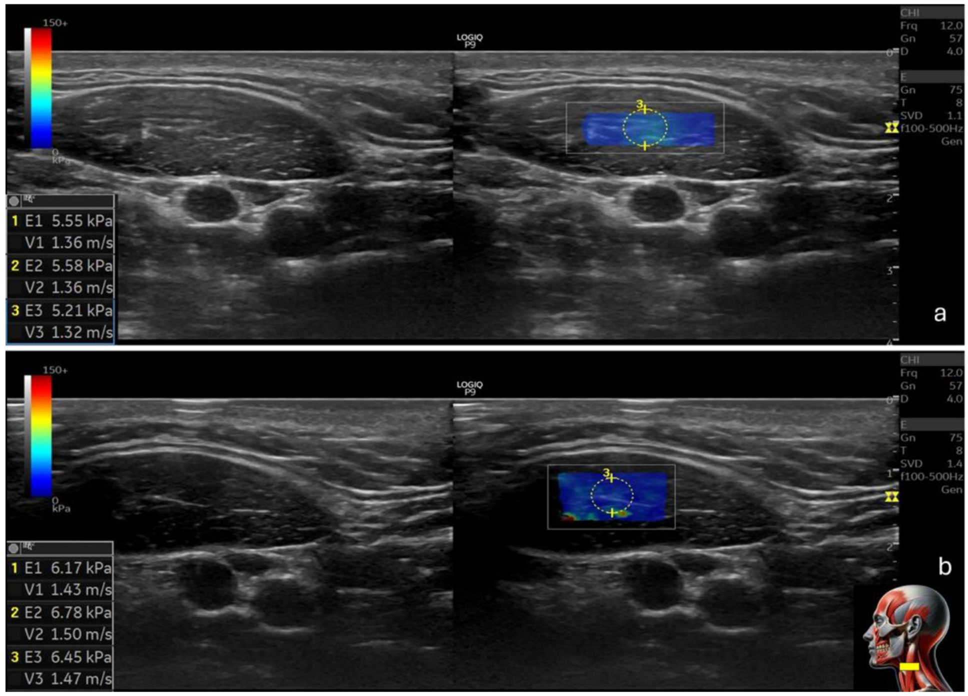

Fig. 4 SWE of the SCM muscle in the resting (**a**) and during clenching (**b**)

using the VAS at rest and during function (speaking, eating, etc.).

Maximum mouth opening

To assess maximum mouth opening, a caliper, a versatile and precise instrument used to measure point-to-point distances, was used. This instrument allows measurements to be made in increments of 0.01 mm to minimize the error range. In this study, the maximum painful mouth opening of patients was measured [21].

Statistical analysis

Data were analyzed using SPSS statistical software (version 24, SPSS Inc., Chicago). Prior to statistical analysis, "The Shapiro–Wilk Test" was used to verify the normal distribution and homogeneity of the variance. Because the majority of data were not normally distributed, nonparametric tests were used for the analysis. Results were presented in "median (minimum–maximum)" or "frequencies and percentage". Differences between groups of continuous variables was established by the "Mann–Whitney *U* Test". The intergroup difference in categorical variables was established by "Chi-Square Test". The significance level was set at $p < 0.05$.

A priori sample size calculation was based on our pilot study comparing masseter muscle stiffness in 10 participants with myofascial TMD pain (mean age = 22.70 ± 3.72 years) and 10 asymptomatic controls (mean age = 23.60 ± 4.14 years). The minimum required sample size was established via G*Power (version 3.1.9.4, Düsseldorf University, Germany) as 6 participants per group for 80% power, with an alpha error of 0.05 and an effect size of 1.899 (the right masseter muscle was taken as a reference), and 26 participants per group for 85% power, with an alpha error of 0.05 and an effect size of 0.793 (the left masseter muscle was taken as a reference).

After data collection, post-hoc power was calculated using G*Power 3.1.9.4. The study's effect size was 0.849 (left:0.741) based on the means and standard deviations of right clenching masseter stiffness in both groups. Our sample size provided 84.64% (left:80.573) power with an effect size and alpha of 0.05.

Results

A total of 54 participants were included in the study: 29 asymptomatic controls and 25 patients with myofascial TMD pain. Of the participants with myofascial TMD pain, 26% reported pain on one side only [right side: n = 1 (%4) and left side: n = 5 (%20)], and 76% (n = 19) of the participants reported pain on both sides. The age, sex, and BMI of the two groups were comparable. Maximum mouth opening was significantly reduced in the patient group compared with the asymptomatic controls ($p < 0.001$). Similarly, bilateral resting and clenching VAS (pain intensity) values were significantly higher in the patient group compared with the controls ($p < 0.001$) (Table 1). No significant difference was

Table 1 Demographic and clinical characteristics of groups

	Myofascial TMD Group (n = 25)	Control Group (n = 29)	P value
Age (years)	25 (18–35)	22.0 (20.0–31.0)	0.093
Height (m)	1.67 (1.57–1.84)	1.65 (1.56–1.92)	0.515
Weight (kg)	57 (47–100)	57.0 (39–110)	0.602
Body mass index (kg/m^2)	20.5 (17.0–30.0)	0.89 (0.66–1.33)	0.696
Gender			
Male/Female	3 (12%) /22 (88%)	9 (31%) / 20 (69%)	0.093[a]
Maximum Mouth Opening	41 (28.0–55.0)	46 (38.0–55.0)	**< 0.001***
Pain intensity R, resting (VAS)	3 (0–9)	0	**< 0.001***
Pain intensity R, function (VAS)	5 (0–10)	0	**< 0.001***
Pain intensity L, resting (VAS)	3 (0–9)	0	**< 0.001***
Pain intensity L, function (VAS)	5 (0–10)	0	**< 0.001***

Mann Whitney *U* Test. [a]Chi-Square Test. VAS: Visual Analog Scale

Values were expressed as median (min–max) or number of subjects (%)

Table 2 Comparison of muscle thickness values of asymptomatic control and myofascial TMD group

	Myofascial TMD Group (n = 25)	Control Group (n = 29)	P value
Anterior Temporalis R, resting (cm)	0.8 (0.55–0.98)	0.79 (0.64–1.22)	0.670
Anterior Temporalis R, clenching (cm)	0.93 (0.63–1.25)	0.93 (0.71–1.33)	0.639
Anterior Temporalis L, resting (cm)	0.8 (0.52–1.11)	0.8 (0.6–1.08)	0.903
Anterior Temporalis L, clenching (cm)	0.91 (0.7–1.25)	0.89 (0.66–1.33)	0.349
Masseter R, resting (cm)	1.45 (1.03–1.84)	1.38 (0.76–8.81)	0.532
Masseter R, clenching (cm)	1.79 (1.41–2.13)	1.7 (1.19–2.08)	0.077
Masseter L, resting (cm)	1.43 (0.91–1.87)	1.27 (0.97–1.87)	0.290
Masseter L, clenching (cm)	1.65 (1.18–2.2)	1.62 (1.18–2.9)	0.487
SCM R, resting (cm)	0.84 (0.27–1.24)	0.9 (0.58–1.21)	0.116
SCM R, clenching (cm)	0.98 (0.74–1,39)	0.92 (0.65–1.4)	0.664
SCM L, resting (cm)	0.84 (0.66–1.16)	0.88 (0.66–1.61)	0.395
SCM L, clenching (cm)	0.95 (0.72–1.35)	0.95 (0.69–1.24)	0.683

Mann Whitney *U* Test. Values are expressed as median (min–max). SCM: Sternocleidomastoid

observed in the muscle thickness values for all three muscles between the asymptomatic control and myofascial TMD groups (Table 2). Muscle stiffness during clenching of the bilateral masseter muscles significantly differed between the two groups, whereas no significant difference was observed at rest. Additionally, no significant difference in muscle stiffness was found in the anterior temporalis or SCM muscles between the two groups, either during rest or during clenching ($p < 0.05$) (Table 3).

Discussion

In this study, unlike the literature, the SCM muscle was also evaluated in patients with myofascial TMD pain, and significant results were obtained. First, the thickness and stiffness values of the SCM muscle in the patient population were determined. Second, it was revealed that maximum mouth opening, and bilateral resting and clenching VAS values were significantly different in the patient group. Finally, we found that the SWE values of the bilateral masseter muscle increased during clench in the patient group, but the thickness did not change significantly.

In the literature, the masseter muscle thickness values [22] in the resting and clenching states in age groups similar to our study and in the healthy population are compatible with previous studies. Additionally, the muscle stiffness values in our control group were consistent with findings from other studies [14, 16, 20, 23, 24]. Fathy et al. [25] found that TMD patients with myofascial pain had high masseter muscle thickness in a resting state. Contrary to previous findings, no significant difference in muscle thickness was detected in the patient group in the present study. This difference may be attributed to the fact that the patient group in our

Table 3 Comparison of muscle stiffness values of asymptomatic control and myofascial TMD group

	Myofascial TMD Group (n = 25)	Control Group (n = 29)	P value
Anterior Temporalis R, resting (kPa)	7.17 (4.86–20.22)	6.96 (4.47–13.24)	0.499
Anterior Temporalis R, clenching (kPa)	17.11 (7.95–32.58)	14.37 (1.54–25.85)	0.242
Anterior Temporalis L, resting (kPa)	7.31 (5.36–13.61)	6.87 (4.35–14.39)	0.729
Anterior Temporalis L, clenching (kPa)	17.26 (10.59–30,84)	14.14 (9.34–26.18)	0.187
Masseter R, resting (kPa)	7.74 (5.23–17.14)	7.43 (4.77–11.64)	0.527
Masseter R, clenching (kPa)	21.03 (15.22–37.35)	17.91(10.92–34.68)	**< 0.001****
Masseter L, resting (kPa)	8.05 (3.78–12.46)	7.08 (4.81–11,48)	0.286
Masseter L, clenching (kPa)	20.69 (12.75–36.29)	16.19 (8,8–31.98)	**0.003****
SCM R, resting (kPa)	5.82 (4.22–10.44)	6.44 (4.43–9.67)	0.168
SCM R, clenching (kPa)	8.09 (4.63–14.81)	7.53 (4.9–13.94)	0.965
SCM L, resting (kPa)	6.3 (2.4–8.69)	5.75 (3.38–9.35)	0.835
SCM L, clenching (kPa)	7.68 (3.66–11.8)	6.5 (4.16–16.63)	0.129

Mann Whitney *U* Test. *p < .05, **p < .01. Bold indicates significant values

Values are expressed as median (min–max). SCM: Sternocleidomastoid

study was young and had a relatively early stage of TMD. Takashima et al. evaluated masseter muscle stiffness in patients with masticatory myofascial pain [17]. They found that the masseter muscle SWE values in the resting state in the patient group differed from those in our study. It has been reported that the measurement of the masseter muscle can vary depending on the patient's position, such as supine or sitting [15]. In the study by Takashami et al. [17], patients were evaluated in the sitting position, whereas in our study, evaluation was conducted in the supine position. This difference in positioning may explain the observed variation in the results between the two studies. In the same study, a significant increase in masseter muscle stiffness was observed in the patient group. Additionally, the authors reported a positive correlation between muscle stiffness and pain and a negative correlation between stiffness and maximum mouth opening. Similarly, in our study, we found a positive correlation between masseter muscle stiffness and pain severity, as well as a negative correlation between stiffness and maximum mouth opening.

Chen et al. [26] studied the stiffness of the masticatory muscles in patients with orofacial pain. They found that pain was linked to increased stiffness in the masseter muscle and noted a trend toward greater stiffness on the painful side of the temporalis muscle. However, no significant correlation was observed between pain ratings and stiffness. In our study, we also observed a significant increase in masseter stiffness and higher VAS scores in patients with myofascial TMD pain, but as in the literature, we found no link between pain and stiffness.

There are limited studies in the literature that used US and SWE to assess the temporalis and SCM muscles. In the study by Koruyucu et al. [16] where they evaluated the temporalis muscle in a healthy population, the thickness was similar to that observed in our study; however, there was a difference in SWE values. This difference may be attributed to the broader age range of the population they examined. Arıkan et al. [27] evaluated differences in masseter and temporalis muscle thickness in patients with various TMD subgroups. Consistent with the findings of our study, the authors found that the thickness of the masseter and temporalis muscles was similar at rest and during clenching in both the TMD subgroups and the control group.

No studies in the literature evaluated the elasticity of the SCM muscle in patients with TMD using SWE. Herman et al. [28] reported a SWE value of 9.9 ± 4.1 kPa for the SCM in a population of 128 healthy volunteers with a wide age range, which differs from our findings. This discrepancy may be attributed to the evaluation of a larger population with a broader age range. However, some studies have provided reference SWE values for the healthy population and assessed SCM elasticity in patients with TMD using a myotonometer [29, 30]. Lee et al. [28] observed a decrease in masseter and SCM muscle thickness in patients with TMD, which is in contrast with the findings of our study. However, similar to our results, the authors reported an increase in masseter and SCM muscle stiffness and a significant reduction in maximum mouth opening. They studied a large sample of patients with nonspecific TMD in their study, which may account for the differences in muscle thickness results.

Our findings have some potential limitations, which must be considered when interpreting the results. First, our sample consisted of young adults between 18 and 35 years. Second, no cut-off value regarding pain intensity was set as an inclusion criteria. Therefore, misclassification based on pain intensity may have affected our results. A previous study indicated that VAS scores ≤ 3.4 cm were best described as mild pain, 3.5–7.4 as moderate pain, and ≥ 7.5 as severe pain for patients with chronic musculoskeletal pain [31]. The majority of participants in this study reported mild to moderate pain. Third, the study included participants with both unilateral and bilateral symptoms. A subclassification analysis was not performed according to the side of pain. Participants with older age and moderate to high-intensity pain-related impairment would be critical determining factors to include in future studies. Additionally, future research can be conducted using a sitting position, which enhances the postural activity of SCM while maintaining the head-supported posture with a larger sample size.

Despite these limitations, this is the first study to evaluate the stiffness and thickness of SCM, anterior temporal, and masseter muscles in patients with myofascial TMD pain. Other studies in the literature mainly focus on the masseter muscle in this population. [12, 15, 17] In this study, many muscles were evaluated together and may contribute to clinical practice more, and the findings could help close the knowledge gap for further studies.

Conclusion

This study shows no change in the thickness of the SCM, masseter, and anterior temporal muscles in patients with myofascial TMD pain. However, increased stiffness was observed only in the masseter muscle during clenching. The findings suggest that participants reporting mild to moderate levels of pain intensity may show an increase in stiffness before an increase in muscle thickness. Stiffness assessment using SWE should be included in clinical practice from the earliest stages of this musculoskeletal problem. Although the SCM muscle was not affected in this study, the muscles around the neck may also be affected in participants with more severe TMJ functional impairment. Therefore, further studies investigating changes in muscle architecture and stiffness in this population should assess not only the level of TMJ but also the neck region.

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Declarations

Conflict of interest The authors have no potential conflict of interests to declare.

Ethics approval and consent to participate This study was conducted in the Department of Oral Diagnosis and Dentomaxillofacial Radiology, Faculty of Dentistry, Dokuz Eylul University, following ethical approval from the Dokuz Eylul University Non-Interventional Research Ethics Committee (No: 2024/16–32, Date: 08/05/2024). All procedures were carried out in accordance with the principle of the Declaration of Helsinki. Clinical and ultrasound examinations were performed after the participants signed an informed consent form.

Consent for publication All authors gave final approval for publication.

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