Imaging Science in Dentistry 2023; 53: 355-63
https://doi.org/10.5624/isd.20230134

Ultrasonographic evaluation of the masseter muscle in patients with temporomandibular joint degeneration

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ABSTRACT

Purpose: Sonographic elastography can be used to evaluate the hardness of muscle tissue through the application of compression. Strain elastography gauges hardness through the comparison of echo sets before and after compression. This study utilized ultrasonography to measure the thickness and hardness of the masseter muscle in individuals with temporomandibular joint (TMJ) osteoarthritis.

Materials and Methods: This study included 40 patients who presented with joint pain and were diagnosed with TMJ osteoarthritis via diagnostic cone-beam computed tomography, along with 40 healthy individuals. The thickness and hardness of each individual's masseter muscle were evaluated both at rest and at maximum bite using ultrasonography. The Mann-Whitney U test and the chi-square test were employed for statistical analysis, with the significance level set at $P<0.05$.

Results: The mean thickness of the resting masseter muscle was 0.91 cm in patients with osteoarthritis, versus 1.00 cm in healthy individuals. The mean thickness of the masseter muscle at maximum bite was 1.28 cm in osteoarthritis patients and 1.36 cm in healthy individuals. The mean masseter elasticity index ratio at maximum bite was 4.51 in patients with osteoarthritis and 3.16 in healthy controls. Significant differences were observed between patients with osteoarthritis and healthy controls in both the masseter muscle thickness and the masseter elasticity index ratio, at rest and at maximum bite ($P<0.05$).

Conclusion: The thickness of the masseter muscle in patients with TMJ osteoarthritis was less than that in healthy controls. Additionally, the hardness of the masseter muscle was greater in patients with TMJ osteoarthritis. ***(Imaging Sci Dent 2023; 53: 355-63)***

KEY WORDS: Masseter Muscle; Temporomandibular Joint Disorders; Ultrasonography

Introduction

Degenerative joint disease is a condition characterized by the deterioration of joint tissue and bony changes in the condyle or articular eminence.[1] This disease primarily affects load-bearing joints such as the knees, hips, and spine, but it can also impact other joints, including the shoulder joints and the temporomandibular joint (TMJ).[2] Degenerative joint diseases are categorized into 2 groups: osteoarthrosis and osteoarthritis. Osteoarthritis is associated with the presence of pain, while osteoarthrosis is defined by the absence of pain.[1] The typical symptoms of osteoarthritis include facial and jaw pain or stiffness, pain during extended mouth opening or chewing, limited mouth opening, jaw locking, and joint sounds. The clinical manifestations of this condition include tenderness of the TMJ or the masseter muscles upon palpation; deviation or restriction in mandibular movement; pain, locking, or subluxation during movement; and joint sounds.[3]

Computed tomographic (CT) findings of TMJ osteoarthritis were first documented in the early 1980s.[4] Diagnostic CT criteria were subsequently proposed by Koyama et al.[5] While these definitions were initially designed for CT images, they hold similar value when applied to cone-beam

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Received June 19, 2023; Revised August 8, 2023; Accepted August 12, 2023

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Imaging Science in Dentistry · pISSN 2233-7822 eISSN 2233-7830

computed tomographic (CBCT) scans. CBCT is a relatively recent imaging technique that can produce high-quality diagnostic images while utilizing a lower radiation dose compared to traditional medical CT.[6]

TMJ osteoarthritis is a disease that typically progresses slowly, resulting in the degeneration of joint surfaces. In a clinical setting, patients with TMJ osteoarthritis often present with pain of varying intensity, limited jaw movement, and joint sounds such as crepitation.[7]

According to Hilton's law, pain originates from the soft tissues surrounding the impacted joint and the masseter muscles, which exist in a state of spasm due to a protective reflex. This self-preserving physiological reflex triggers the contraction of nearby muscles in response to an intraarticular injury or pathology. The reflex aids in safeguarding an injured or pathological joint, thereby protecting the joint from further damage.[7]

Various techniques such as electromyography, CT, magnetic resonance imaging, and ultrasonography can be employed to examine the masseter muscle. Ultrasonography offers numerous advantages in comparison to other medical imaging techniques. It delivers real-time images, is portable and cost-effective, does not involve radiation, is non-invasive, and is unaffected by metal artifacts such as dental restorations.[8,9] Ultrasound elastography is based on the principle that when stress is applied to tissue, it induces changes in the tissue due to its elastic properties.[10-12] The measurement process in elastography is conducted in 3 stages. Initially, a force is applied or transmitted to the tissue. Subsequently, the tissue deforms in response to the initial stress, according to its inherent properties. Finally, the instrument is used to analyze the deformation caused by the stress.[13] Two ultrasound elastography techniques are commonly used, depending on the type of stress application and the method used to detect tissue displacement and generate the image.[14,15] The primary principle of strain elastography involves applying a compressive force to the tissue, which results in axial tissue displacement. This displacement is then calculated by comparing the echo sets from before and after compression.[16]

The purpose of this study, planned as the first of its kind in the literature, was to investigate the thickness and elasticity of the masseter muscle in patients with TMJ osteoarthritis using ultrasonography.

Materials and Methods

This study was conducted from September 2021 to December 2021 within the Department of Oral and Maxillofacial Radiology at the Faculty of Dentistry, İnönü University. The İnönü University Malatya Clinical Studies Ethics Committee granted approval for the study (Date: 08.09.2021, Decision No: 2021/172). All participants were informed of the research objectives and provided their consent prior to involvement.

The study sample comprised 40 patients who reported experiencing pain and were undergoing dental examinations at the clinic. Based on CBCT findings, these patients were identified as exhibiting bilateral TMJ osteoarthritis. Specifically, patients who exhibited bone changes on CBCT images and reported pain were classified as having TMJ osteoarthritis. Additionally, the study included 40 healthy individuals without osteoarthritis. All participants were over 18 years of age and had no more than 1 missing tooth in either half of the jaw. The study excluded patients with a history of trauma to the TMJ region, those who had undergone TMJ surgery, and those who had received or were currently undergoing orthodontic treatment. Patients with parafunctional habits such as bruxism, syndromic patients, individuals with rheumatic diseases, and male patients with beards were also excluded from the study.

A NewTom 5G CBCT device (QR s.r.l., Verona, Italy), located at the Department of Oral and Maxillofacial Radiology of the Faculty of Dentistry of İnönü University, was utilized for imaging purposes. Images were captured with the patient in the standard supine position, with a scan time of 18 seconds, an imaging area of 15 × 12 cm, an exposure time of 3.6 seconds, a peak kilovoltage of 110, a current of 1 to 20 mA, and a voxel size of $0.2\,mm^3$. In terms of patient positioning, the patient's head was arranged such that the Frankfurt plane was perpendicular to the floor. During the imaging process, the patient's head was secured in place, and the mouth was kept closed. NNT software (Cefla, Imola, Italy) was employed for image analysis. To detect degeneration, the type of bony change was determined based on sagittal images that displayed the medial part of the condyle in a mouth-closed position. The classification of bony changes proposed by Koyama et al.[5] was used to categorize degeneration. The classifications were as follows: N: no bony change, F: flattening (Fig. 1A), E: erosion with or without roughening (Fig. 1B), D: deformity (Fig. 1C), and S: deformity accompanied by erosion with or without roughening (Fig. 1D).

All patients in this study underwent examination using a LOGIQ F8 ultrasound device (General Electric Co.; Milwaukee, WI, USA) at the Department of Oral and Maxillofacial Radiology. The device, equipped with a high-frequency linear ultrasound probe (6-12 MHz), was used to measure muscle thickness on the right and left sides. These

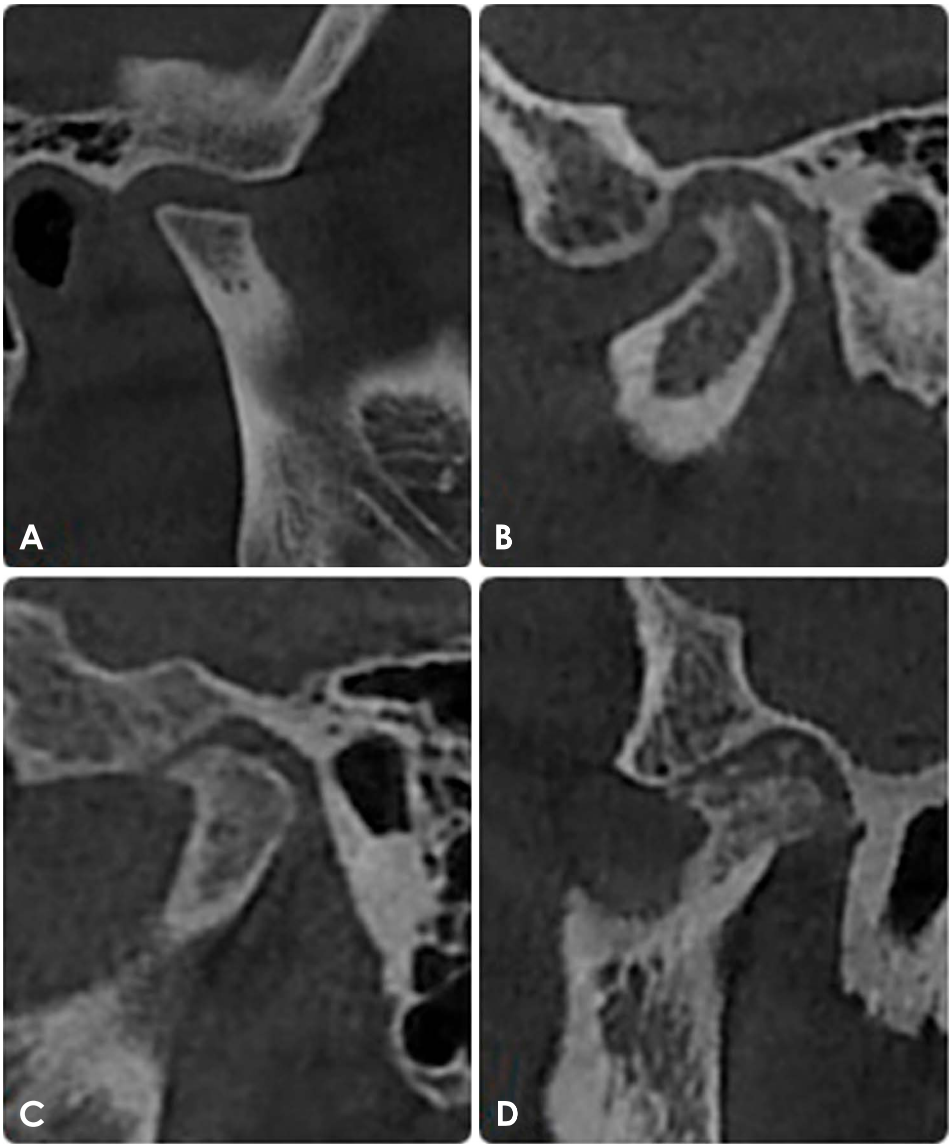

Fig. 1. Classification of bone changes. A. Flattening. B. Erosion. C. Deformity, marginal proliferation, and osteophyte formation. D. Erosion, deformity, osteophyte formation, and marginal proliferation.

measurements were taken in B-mode. The patients were positioned sitting upright, with their backs touching the chair, and their heads were not restrained.

To avoid potential artifacts, measurements were taken by positioning the probe perpendicular to the skin surface of the masseter muscle. When assessing the thickness or elasticity index (EI) of the muscle, the probe was aligned parallel to the zygomatic arch. A Konix water-based gel (Turkuaz, İstanbul, Turkey) was utilized to eliminate any air trapped between the skin and the probe. The probe, positioned transversely, was gently placed on the skin without exerting pressure, allowing measurements to be taken from the thickest part of the muscle.

To measure masseter muscle thickness, images of the muscle were captured with the patient in the resting position (Fig. 2A). Subsequently, additional images of the masseter muscle were taken at the point of maximum contraction, with the patient in the bite position (Fig. 2B). The muscle thickness was then determined from these saved images, utilizing the distance measurement capabilities of the device.

The sonographic elastography procedure was conducted using the same device and probe. The elasticity scale, located on the left side of the sonographic elastography screen, was closely monitored to ensure the application of the optimal degree of compression (Fig. 3).

For all sonographic elastography imaging procedures, the region of interest was strategically positioned to exclude the mandible as much as possible, with the aim of minimizing that structure's influence. The EI was consistently measured by the same clinician using the same device for all

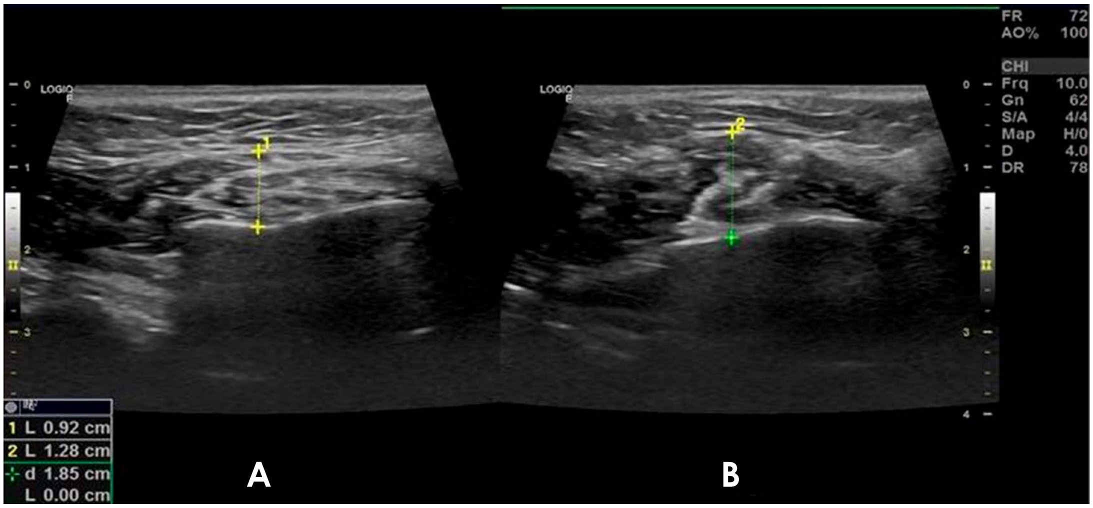

Fig. 2. A. The thickness of the masseter muscle in the resting position. B. The thickness of the masseter muscle at the maximum bite position.

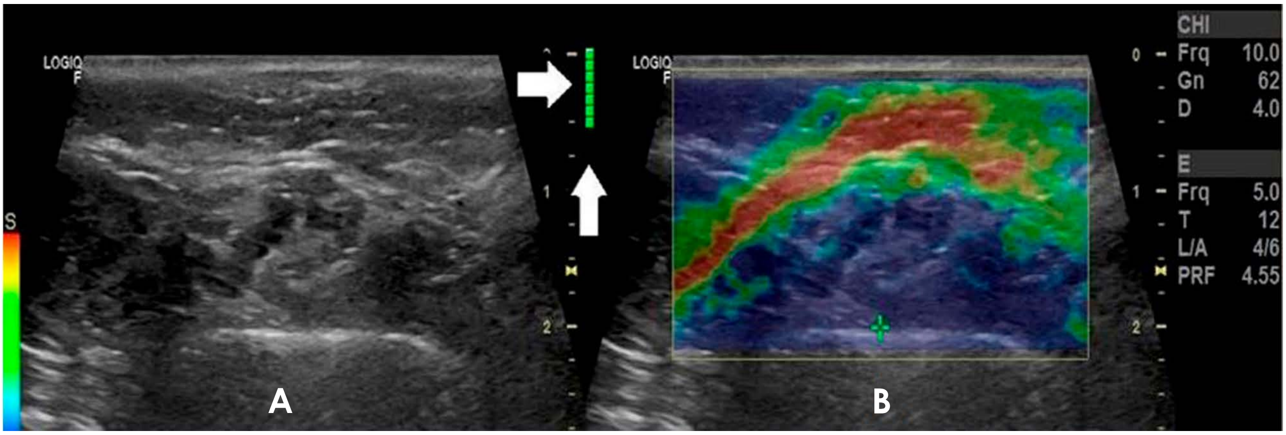

Fig. 3. A. A normal ultrasound image of the masseter muscle. B. An ultrasound elastography image of the same masseter muscle as shown in image A. The elasticity scale indicates the optimal degree of compression in the elastogram, which is entirely green (indicated by the white arrow).

participants. EI values were obtained from the masseter muscle and the subcutaneous adipose tissue of the masseter muscle, following adjustments of the region of interest to customized sizes. The EI value of the masseter muscle was then calculated. This was done by determining the ratios of the average EI of the masseter muscle at the resting and maximum contraction (bite) positions to the average EI of the subcutaneous adipose tissue of the masseter muscle (Figs. 4 and 5).

In general, the EI is defined as a measure of the elasticity of a target tissue in relation to the surrounding anatomical structures.[17] In the present study, the masseter muscle was identified as the target tissue. Concurrently, the subcutaneous adipose tissue was measured and served as the reference tissue.

The measured EI values inform sonoelastography results, which are depicted as color-coded images overlaid on B-mode images. Tissues are categorized by relative hardness from the least hard to the hardest, represented in order by the colors red, yellow, green, and blue. Strain sonoelastography, as defined here, has several limitations, one of which is the known variability of EI values based on the applied compression force. Consequently, the EI values of the subcutaneous adipose tissue were employed as a reference in the present study.

The data collected in this study were analyzed using SPSS version 21 (IBM Corp., Armonk, NY, USA). To test the normality of the data distribution, the Shapiro-Wilk test was employed, considering the number of data points. Because the data were not normally distributed, the Mann-Whitney

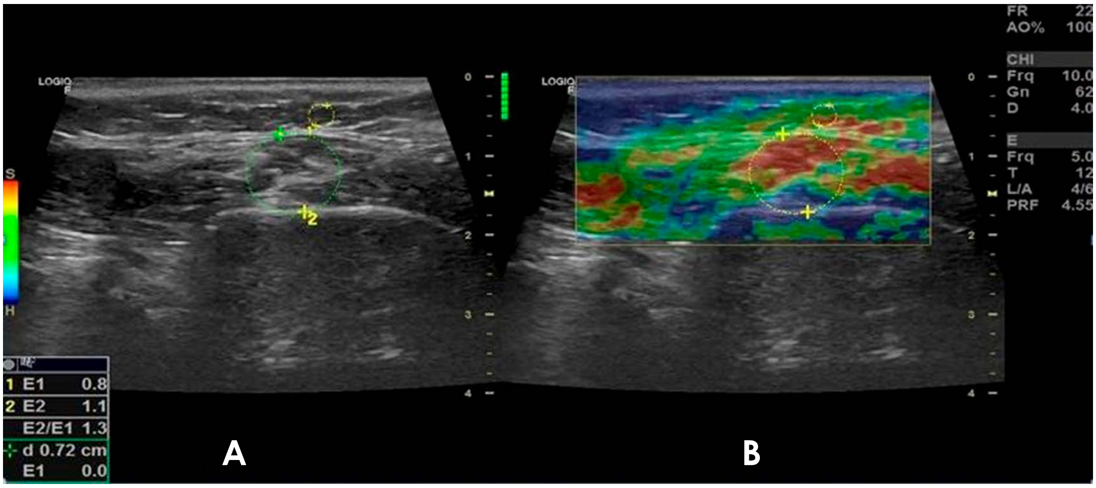

Fig. 4. The masseter muscle elasticity index (EI) value was calculated as the ratio of the average EI of the masseter muscle in the resting position to the average EI of the subcutaneous adipose tissue (indicated by the small circle) of the masseter muscle (indicated by the large circle). A. A normal ultrasound image of the masseter muscle. B. An ultrasound elastography image of the same masseter muscle as shown in image A, depicted in the resting position.

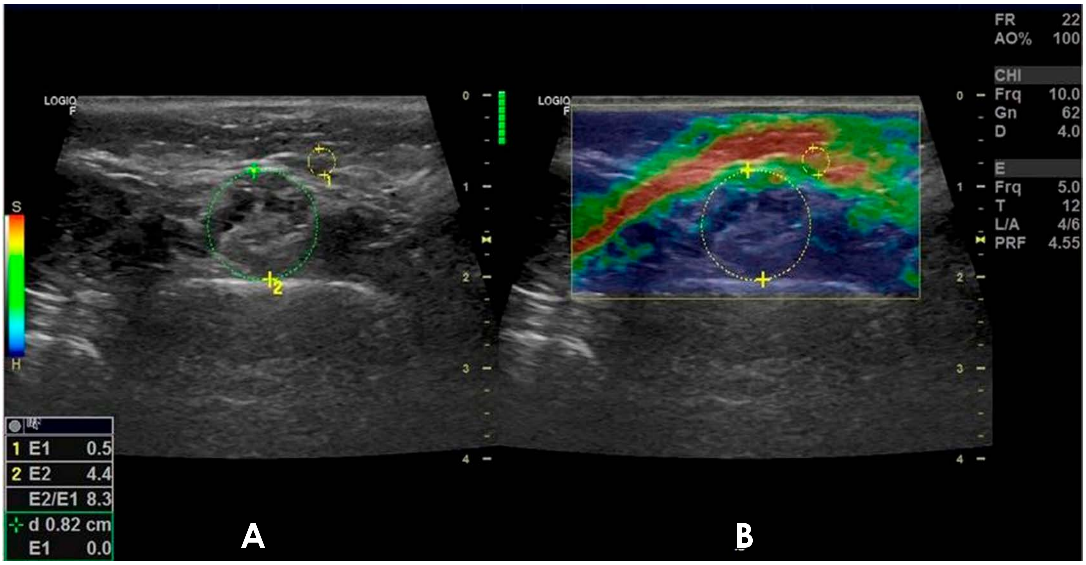

Fig. 5. The masseter muscle elasticity index (EI) value was calculated as the ratio of the average EI of the masseter muscle in the bite position to the average EI of the subcutaneous adipose tissue (indicated by the small circle) of the masseter muscle (indicated by the large circle). A. A normal ultrasound image of the masseter muscle. B. An ultrasound elastography image of the same masseter muscle as shown in image A, depicted in the bite position.

U test was applied to analyze differences between groups. Chi-square analysis was used to investigate relationships among groups of nominal variables. When interpreting the results, a significance level of 0.05 ($P<0.05$) was deemed acceptable.

Results

The study sample was composed of 80 voluntary participants, ranging in age from 18 to 60 years. Of these, 62 (77.5%) were female and 18 (22.5%) were male. The sample included 40 individuals diagnosed with osteoarthritis (the osteoarthritis group), consisting of 31 female and 9 male participants, and 40 healthy individuals (the control group), also comprising 31 female and 9 male individuals. No statistically significant difference was present in the sex distributions of the groups ($P>0.05$).

The mean age of the study population was 31.38 years.

Table 1. Thickness of the masseter muscle at rest and maximum bite

Group	Number	Rest		Maximum bite	
		Mean	Range	Mean	Range
Control	80	1.00±0.18	0.70-1.45	1.36±0.21	1.03-1.99
Osteoarthritis	80	0.91±0.17*	0.59-1.46	1.28±0.25*	0.92-2.20
Total	160	0.95±0.18	0.59-1.46	1.32±0.23	0.92-2.20

*$P<0.05$ compared with control

Table 2. Elasticity index of the masseter muscle at rest and maximum bite

Group	Number	Rest		Maximum bite	
		Mean	Range	Mean	Range
Control	80	1.49±0.18	1.0-2.8	3.16±0.95	1.4-5.6
Osteoarthritis	80	2.11±0.17*	1.2-4.2	4.51±1.85*	2.1-10.3
Total	160	1.80±0.18	1.0-4.2	3.84±1.61	1.4-10.3

*$P<0.05$ compared with control

In the osteoarthritis group, the mean age of the participants was 31.62 years (minimum, 18 years; maximum, 58 years; standard deviation, 12.42 years). In the control group, the mean participant age was 31.15 years (minimum, 19 years; maximum, 60 years; standard deviation, 9.94 years). No statistically significant difference was present between the groups regarding age distribution ($P>0.05$).

In this study, the types of bony changes in the osteoarthritis group were assigned according to the Koyama classification system.[5] A total of 80 joints from 40 patients with osteoarthritis were examined. The identified types of bony changes were as follows: type F was found in 40 joints (50.0%), type E in 12 joints (15.0%), type D in 22 joints (27.5%), and type S in 6 joints (7.5%).

Masseter muscle thickness

The resting thicknesses of the masseter muscle in the participants were measured bilaterally. The osteoarthritis group displayed a mean masseter thickness of 0.91 cm, while the control group had a mean thickness of 1.00 cm. The difference in resting masseter muscle thickness between the groups was statistically significant ($P<0.05$) (Table 1).

The maximum thickness of the masseter muscle in the bite position was measured bilaterally in all participants. The osteoarthritis group exhibited a mean masseter thickness of 1.28 cm, while the control group displayed a mean masseter thickness of 1.36 cm. The difference between the groups in the maximum masseter thickness when biting was statistically significant ($P<0.05$) (Table 1).

Masseter muscle elasticity

The mean masseter EI values at rest were determined to be 2.11±0.61 in the osteoarthritis group and 1.49±0.40 in the control group. A statistically significant difference was observed between the resting masseter EI values of these groups ($P<0.05$) (Table 2).

The mean maximum EI values for the masseter muscle in the bite position were 4.51±1.85 in the osteoarthritis group and 3.16±0.95 in the control group. A statistically significant difference was observed between groups in the maximum masseter EI value when biting ($P<0.05$) (Table 2).

Discussion

The imaging of the TMJ presents a substantial challenge due to the small size of its bone components and the superpositions caused by the base of the skull. Consequently, plain radiographs often fail to provide a clear view of the joint.[6] Various imaging methods have been employed in diagnosing TMJ osteoarthritis, but issues such as superpositions, high radiation doses, and lengthy scan times pose considerable limitations. These unfavorable circumstances have contributed to the growing preference for CBCT in TMJ imaging. CBCT, a relatively new imaging technique, can generate high-quality diagnostic images using a lower radiation dose than traditional medical CT.[6] In this context, magnetic resonance imaging is typically inferior to CT due to its limited spatial resolution for detailed imaging of the condyle and the magnetic sensitivity of the bone.[6] In the present study, CBCT was utilized to identify TMJ osteoarthritis because it clearly reveals bony changes without superpositions, offers a shorter imaging time, and involves a comparatively low radiation dose.

TMJ osteoarthritis is more commonly observed in women than in men.[18,19] In the present research, 77.5% of the patients with osteoarthritis were women, while 22.5% were men. LeResche has reported that the prevalence of pain in the temporomandibular region is approximately twice as high in women as in men.[18] The elevated prevalence of this condition in women could be attributed to the activation of certain immunological responses in the TMJ. Additionally, the hormonal influences of estrogen and prolactin may exacerbate the degeneration of cartilage and the articular eminence.[5]

Koyama et al. utilized helical CT to investigate condylar bony changes in 516 patients.[5] They identified bony changes in 617 of the 1032 joints examined. In their classification, they found a high prevalence of type E and type D changes, while type F changes were less common. Dos Anjos Pontual et al. used CBCT to study bony changes in the TMJs of 319 patients.[20] They classified condylar morphology and examined the bone for osteophytes, flattening, sclerosis, erosion, and pseudocysts. Their study results indicated that flattening and osteophytes, both degenerative bony changes, were most commonly found. In the present study, the most frequently encountered changes were of type F (flattening).

Several previous studies have been conducted to investigate the thickness of the masseter muscle. Ruf et al.[21] examined equal numbers of male and female participants using electromyography, ultrasonography, and facial photography. Their findings indicated that the masseter muscles were thinner in female participants who had a smaller facial width and wider mandibular planes. In another study, Şatıroğlu et al.[22] used ultrasonography to measure the thickness of the masseter muscle and explored its correlation with facial morphology and body mass index. They found that individuals with a longer facial pattern had thinner masseter muscles, as observed in both resting and maximum biting states. Furthermore, they revealed a correlation between the thickness of the masseter muscle and body mass index across all participants.

In a study conducted by Ariji et al.,[23] ultrasonography was used to measure the masseter muscle thickness in 25 female patients with temporomandibular disorders (TMDs) at both resting and maximum biting states. The data revealed that patients with TMDs had thicker masseter muscles than healthy individuals. This increase in thickness was attributed to the accumulation of edema within the masseter muscles of patients with these disorders.

In the present study, the thickness of the masseter muscle in patients with osteoarthritis, both at rest and at maximum bite, was less than that in healthy controls. This is likely due to muscular atrophy, which is associated with the diminished chewing function seen in osteoarthritis. However, this study did not incorporate variables such as facial morphology and body mass index. Therefore, more comprehensive studies are required to investigate the impact of osteoarthritis on the thickness of the masseter muscle.

Muscle hardness can be defined as the resistance encountered when perpendicular pressure is applied to the muscle.[24] Although muscle hardness may be associated with muscle tone or stiffness, the definitions of these terms remain a topic of debate. Muscle tone and stiffness are often defined as the rate of change in the muscle's length along its long axis, contingent on the change in force.[25,26] Muscle hardness, which can be assessed through palpation, can be succinctly defined as the muscle's resistance to perpendicular pressure.[24]

Due to its simplicity, manual palpation is often the preferred method for measuring muscle hardness in clinical practice. However, this subjective assessment relies heavily on the examiner's experience and training. The specific characteristics of this measurement, particularly when assessing the hardness of the masseter muscles, remain largely unexplored. Additionally, the clinical value of evaluating spinal hardness through manual palpation has been questioned due to its low reliability.[27,28]

To address these limitations, 2 objective techniques have been suggested for measuring muscle hardness. These commonly used methods involve mechanical devices that gauge tissue displacement, such as hardness testers[24] and ultrasonographic imaging.[29] The hardness or tenderness of skeletal muscle, measurable using commercially available hardness testing devices, is known to serve as an effective index for evaluating patients with myalgia in orthopedics or sports medicine.[29] Furthermore, based on measurements taken with a hardness testing device, the thickness of the masseter muscle has been shown to tend to be greater in cases of temporomandibular disorder accompanied by myofascial pain.[30] However, a hardness tester can only measure specific points, and its results may not represent the overall change in the muscle. Additionally, these devices fall short in determining variations in muscle hardness due to differing amounts of adipose tissue and discrepancies in measurement regions among patients.[31] In this regard, sonoelastography outperforms hardness testers, as it can depict a wide area of the target muscle and display an elasticity map superimposed on a B-mode image.[32]

Ultrasonographic imaging is widely used to evaluate the elasticity characteristics of tissues.[30,33] Sonographic elastography enables the visualization of tension distribution within a tissue, represented as a color-coded elasticity map.[34] While it is effective in diagnosing a range of diseases, certain drawbacks have been identified. One of the most notable disadvantages is the lack of standardization in compressive forces that result from freehand operation. This factor could potentially affect the reliability of intraobserver and interobserver rates.[35]

The existing literature contains a limited number of studies on the elastography of both normal and pathological muscles. In this study, the EI ratio of the masseter muscle was defined as the ratio of the muscle's EI value to the EI of its underlying subcutaneous adipose tissue. This method may be beneficial when comparing values obtained from different tests conducted on the same individual, as the elasticity values of subcutaneous fat can vary between individuals. However, it may not be suitable for comparing values across different individuals or for determining the mean value of a specific group.[36,37]

Ariji et al.[30] conducted a study on the masseter muscles of 35 healthy individuals and 8 patients with TMDs who were experiencing myofascial pain. They utilized sonoelastography to examine the muscles and a hardness tester to determine muscle hardness values. Their findings revealed that the EIs of the masseter, as measured using strain elastography, were higher in TMD patients with myofascial pain compared to the healthy control group. Furthermore, these EIs demonstrated a strong correlation with the values obtained directly from the muscle hardness testing device.

Takashima et al.[31] used shear wave elastography to evaluate the masseter muscles of patients with myofascial pain. The participants were categorized into 3 groups: patients with myofascial pain, patients with myofascial pain accompanied by restricted opening, and healthy control participants. The study indicated that the masseter muscles in patients with myofascial pain, as well as those with myofascial pain and restricted opening, were approximately twice as hard as the muscles of the healthy controls.

In the existing literature, no study has yet been conducted that explores the masseter EIs of patients with osteoarthritis using sonographic elastography. The findings of the present study indicate that the masseter EI values of the patients with osteoarthritis were significantly elevated compared to those of the healthy controls in both resting and maximum biting scenarios. This outcome is likely attributable to protective muscle spasms.

An increase in the hardness values of the masseter muscle was observed, along with a decrease in the thickness values of the same muscle, in patients with TMJ osteoarthritis. Thus, ultrasonography, which does not involve ionizing radiation, could serve as a supportive and beneficial diagnostic method for patients with TMJ osteoarthritis.

Conflicts of Interest: None

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