Original Article

Sonoelastographic Evaluation of the Masseter Muscle before and after Mandibular Setback Surgery

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Abstract

Aims: The purpose of this study is to compare the thickness and elasticity of the masseter muscle before and after orthognathic surgery in patients with class III skeletal deformity and to investigate the relationship between the sonographic changes in the masseter muscle and the amount of mandibular setback. **Subjects and Methods:** The study group consisted of 14 patients with skeletal class III malocclusions who had orthognathic surgery. The control group consisted of 14 patients who had dental and skeletal class I occlusion. Muscle thickness measurements were performed with B-mode and high-frequency linear scanning probe of the ultrasound device. Elastography feature and muscle hardness ratio were obtained by applying compression and decompression on muscles at rest and during maximum contraction in the transverse plane. Patients were categorized into two groups according to the mandibular setback as <5 mm and ≥5 mm. **Results:** The masseter muscle thickness after surgery was found statistically increased bilaterally in both at rest and during contraction for the study group ($P < 0.05$). No difference was found between preoperative orthognathic measurements and postoperative measurements for elasticity index ratio measurements ($P > 0.05$). **Conclusion:** We believe that in the present study important findings have been emphasized for further research aiming to investigate the possible relationship between masticatory alterations and surgical outcomes after orthognathic surgery.

Keywords: *Elastography, mandibular setback, masseter muscle, orthognathic surgery, ultrasonography*

Introduction

The success of orthognathic surgery depends on maxillofacial function and esthetics, as well as long-term stability. The basic stability of orthognathic surgery is closely related to various factors such as the type of fixation, surgical technique, wound healing, and vascularity of the bone segments, the direction and amount of the movement. Also, the strain which results from surgery in muscle groups is an important factor.[1,2] Inadequate neuromuscular adaptation of masticatory muscles after orthognathic surgery is related to strain or muscle compression as a result of the displacement of the mandible in the sagittal/vertical or both directions.[3]

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Muscle thickness is one of the determinants of muscle functions, and many studies are showing a significant relationship between muscle thickness and maxillofacial morphology.[4,5] The thickness of the masseter muscle was measured by many imaging techniques such as ultrasonography (USG), computed tomography (CT), and magnetic resonance imaging (MRI).[4,6,7] In recent years, with the advances in the USG technique, this method has encouraged researchers to work with this

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imaging technique. USG is a preferred method due to its being repeatable, simple, inexpensive, and a noninvasive method, and most importantly, without any ionizing radiation being used.[8,9]

Sonoelastography (SE) is a relatively new technique that allows the investigation of tissue flexibility. SE determines the mechanical properties of tissue qualitatively, visually, or quantitatively.[10,11] It is used to reveal the area and presence of cancer in tissues such as breast, prostate, liver, pancreas, thyroid, cervix, and lymph nodes. Furthermore, in current research, SE has been reported to play an important role in early diagnosis, staging, and guidance for the treatment in dystrophic, myopathic, and spastic muscles.[12-14]

Major SE techniques in clinical practice are as follows: strain (compression); shear-wave; transient; and acoustic radiation elastography. The most used one is the strain elastography method.[11,15] In this method, the ultrasound probe applies force via manual rhythmic movement. The applied force causes axial displacement in the tissue, which is calculated by comparing the echoes formed before and after compression.[11]

It was aimed to compare the thickness and elasticity of the masseter muscle before and after orthognathic surgery in patients with class III skeletal deformity. Also, it was aimed to investigate the relationship between the sonographic changes in the masseter muscle and the amount of mandibular setback.

Material and Methods

The study was performed with the approval of the clinical research ethics committee of Erciyes University (protocol no 2011-KAEK 80), based on the guideline in the Declaration of Helsinki. All participants were informed of the purpose of the study and provided consent before participating.

The study was performed with the patients who had undergone orthognathic surgery in the hospital of Erciyes University Faculty of Dentistry between 2015 and 2017.

Exclusion criteria

Patients who had one or more of the following criteria were excluded:

- Patients who were operated on due to cleft lip and palate
- Patients with congenital syndromes
- Patients who had malocclusions due to trauma
- Patients who underwent distraction during orthognathic surgery
- Patients with muscle or neurological diseases
- Patients with any parafunctional habit such as finger sucking, nail-eating, or bruxism
- Patients with congenitally missing teeth
- Patients who had previous orthodontic treatment.

All the lateral cephalometric analysis and 6th-month follow-ups of the patients who had undergone orthodontic treatments by different orthodontists (academic staff in Erciyes University, Department of Orthodontics) before and after the surgery were performed by the orthodontist (KGT). All orthognathic surgeries were performed under general anesthesia by academic staff (AA, OAE, and AED) who are specialists in their field at Erciyes University Oral and Maxillofacial Surgery Hospital. Medical follow-ups of the patients in the study group were performed by a maxillofacial surgeon (AED).

Ultrasonographic measurements

Ultrasonographic imaging and measurement procedures of all individuals in the study were performed by the oral and maxillofacial radiologist (ME) who had 4 years of USG and strain SE experience. Muscle thickness measurements were performed bilaterally, simultaneously with B-mode and high-frequency linear scanning probe 7–18 Mhz (PLT-1005BT) of the ultrasound device (Aplio™ 500; Toshiba Medical Systems Corporation, Otawara, Japan). Measurements were performed as follows with reference to the method of Kiliaridis and Kalebo,[16] while the patients were in the sitting position, they were contacted from the thickest part of the masseter muscle in the palpation to the transducer skin without pressure. In order to avoid possible artifacts and oblique imaging, the probe was held perpendicular to the skin surface and the distance in the transverse section between the place where the hyperechoic linear image of the mandibular bone and the muscle facies was measured.

The measurements were repeated twice both for the contraction and rest. The mean muscle thickness was recorded. The measurements for the patients who were scheduled for orthognathic surgery were repeated at two different times before the surgery (T1) and 6 months after the surgery (T2) [Figure 1].

After activating the USG device elastography feature, the muscle hardness ratio was obtained by applying compression and decompression with approximately the same intensity and same time intervals on muscles at rest and during maximum contraction with a probe in the transverse plane. Compression-decompression intensity and time interval were followed by sinusoidal waves in USG. Two images determined by the generator in the optimum range were selected, and the measurement areas were created in the muscle and within the subcutaneous adipose tissue as the reference region. The elasticity index (EI) values measured at determined areas were proportioned by the device and was transformed into the EI ratio (EIR) = masseter EI/subcutaneous adipose tissue EI [Figure 2].

Orthodontic examinations

Lateral cephalometric measurements [Table 1] were performed on 18 × 24 cm cephalometric films obtained via cephalometric X-ray device, Planmeca Proline XC (Helsinki, Finland). The control group was formed with 14 patients who had skeletal class I occlusion since the angle of ANB is between 0 and 4 degrees according to the original cephalometric films and who were diagnosed as dental class I anterior crowding with vertical values within normal limits.

The study group consisted of 14 patients who had an ANB angle of less than 0 and who were planned to perform orthognathic surgery via mandibular setback. The cephalometric films of the control group were taken via masseter muscle thickness measurements at the beginning of treatment, and skeletal, dental, and soft-tissue measurements via the method developed by Bishara *et al*.[17] described in previous studies were recorded. Orthodontic skeletal, dental, and soft tissue change analyses of orthognathic surgery patients of the study group before surgery (T1) and after the 6th-month follow-ups (T2) were performed and recorded.

Surgical procedures

Orthognathic surgical procedures performed for patients with skeletal class III deformity are generally bilateral sagittal split ramus osteotomy (BSSRO) in mandibula and Le Fort I osteotomy in the maxilla. In the planned study, all operations were performed under general anesthesia by a team of specialists in the field of oral and maxillofacial surgery. After completion of the orthodontic treatment of patients with skeletal deformity of class III, surgical planning was performed by lateral cephalometric measurements and model surgery, and then surgical guide templates were obtained. Within the scope of the study, the patients with class III skeletal deformity group were applied BSSRO in the lower jaw as standard in order to correct these deformities and when necessary, according to the severity of skeletal deformity, Le Fort I osteotomy was applied in the upper jaw, and normal dental/skeletal jaw relationship (class I) was provided. Patients were anesthetized with nasotracheal intubation by specialist anesthesiologists. Hypotensive anesthesia technique was applied to reduce the amount of bleeding during the surgery.[18]

All patients underwent double-jaw surgery following semi-rigid fixation with mini plates and monocortical screws. None of the patients had facial asymmetry. The patients were categorized into two groups as <5 mm and ≥5 mm, and the following mandibular motion amounts after surgery were recommended: Passive jaw opening exercises 5-5-30: Five times per day; five stretches each time; each stretch held for 30 s for all patients between the 1st and 3rd months after surgery. There was no sign of relapse after 6 months of surgery.

Statistical analysis

The statistical analysis of the data was performed via the IBM SPSS Statistics v22.0 statistical package program. The Shapiro-Wilk test was used to determine whether the data displayed a normal distribution. Descriptive statistics of the data were expressed as (Median [minimum-maximum]) for variables that did not show the normal distribution and frequency and percentage (*n* [%]) for categorical variables. For continuous data with non-normal distribution, the Mann-Whitney U test was used for the comparison of two independent groups, and the Wilcoxon Signed-Rank test was used for intragroup comparison of time-dependent changes. Fisher's exact test was used to compare categorical data. The significance level was determined as $\alpha = 0.05$.

Results

The study group consisted of 14 patients (the mean age was 20, and they were aged between 17 and 26 years) with skeletal class III malocclusions and those who underwent orthognathic surgery. The control group consisted of 14 patients with an average age of 22 (13–27 years) who had dental and skeletal class I occlusion. The groups were distributed homogeneously in terms of age and sex.

Statistically significant differences were found among time-dependent comparisons of SNA, SNB, and ANB angle variables, and *P*-significance values for

Table 1: Comparison of orthodontic angle values before orthognathic surgery (T1) and postoperative 6th month (T2) in the study group

Orthodontic Angles	T1 (*n*=14)	T2 (*n*=14)	*P*
SNA	78.90 (72.50-84.20)	83.95 (78.60-89.00)	**0.001**
SNB	83.75 (78.30-89.50)	82.90 (78.70-88.60)	**0.017**
ANB	−5.60 (−11.40-−1.90)	1.40 (−2.60-5.80)	**0.001**
SNGoGN	31.25 (20.20-43.90)	31.25 (20.30-57.80)	0.510
Nasolabial	91.40 (60.30-117.20)	98.85 (79.20-117.60)	0.158

Data are presented as median (min-max). $P < 0.05$ values are shown in bold. T1: Before surgery; T2: 6 months after surgery; *n*: Number of individuals; *P*=0.05 significance level; SNA°=The angle between the S-N plane and the N-A plane. SNB°=Angle between the S-N plane and the N-B plane. ANB°=The angle formed by the intersection of a line extending from point A and point B of nasion. SNGoGN=Angle formed by lines S-N and Go-Gn

Table 2: Comparison of preoperative (T1) and postoperative 6th month (T2) USG measurements of the masseter muscle in the study group

Masseter thickness measurements		T1 (*n*=14)	T2 (*n*=14)	*P*
Right	Rest	9.85 (6.60-14.30)	11.05 (7.70-16.60)	**0.003**
	Clenching	12.55 (9.10-15.90)	14.35 (10.10-18.30)	**0.002**
Left	Rest	10.25 (6.60-14.40)	11.55 (8.30-16.70)	**0.013**
	Clenching	12.6 (8.00-18.50)	14.2 (8.60-17.80)	**0.044**
Strain elasticity index ratio measurements				
Right	Rest	(*n*=9)	1.18 (0.59-4.12)	0.214
		0.87 (0.44-2.27)		
	Clenching	0.53 (0.10-5.21)	0.69 (0.25-5.00)	0.674
Left	Rest	(*n*=9)	1.37 (0.49-5.69)	0.515
		0.83 (0.29-9.58)		
	Clenching	0.59 (0.14-9.31)	0.81 (0.25-6.63)	0.515

Data are presented as median (min-max). $P < 0.05$ values are shown in bold. T1: Before surgery; T2: 6 months after surgery; *n*: Number of individuals; *P*=0.05 significance level

comparison of these variables were found to be 0.001; 0.017, and 0.001, respectively. From the beginning

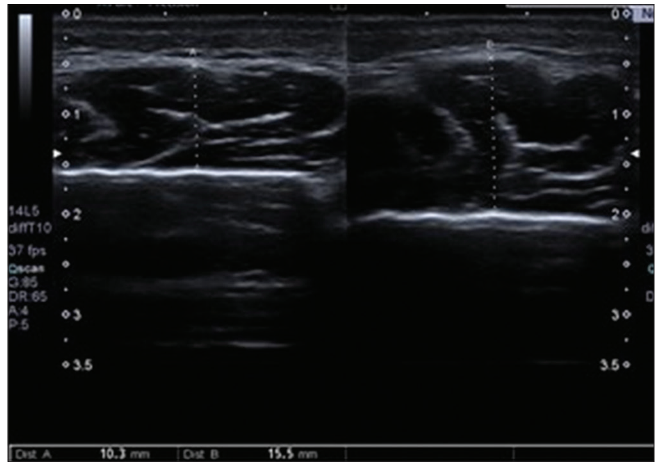

Figure 1: B-mode USG image. Thickness measurement (dashed lines) in the case of resting and maximum contraction of the masseter muscle

Table 3: In the study group, preoperative (T1) and postoperative 6th month (T2) comparisons of the thickness and elasticity values of right masseter muscle for the amount of surgical mandibular motion

Mandibular setback amount (mm)	Right masseter muscle	T1 (*n*=7)	T2 (*n*=7)	*P*
<5	Rest	9.70 (7.40-14.30)	12.30 (7.90-16.60)	**0.018**
	Clenching	13.60 (9.90-15.90)	14.90 (10.30- 18.30)	**0.028**
	Rest EIR	(*n*=5)		
		0.80 (0.44-1.17)	1.19 (0.59-3.52)	0.500
	Clenching EIR	0.72 (0.14-2.60)	0.74 (0.30-2.34)	0.893
≥5	Rest	(*n*=5)	10.90 (7.70-13.20)	0.051
		10.20 (6.60-11.70)		
	Clenching	12.30 (9.10-13.70)	13.90 (10.10- 16.10)	**0.028**
	Rest EIR	(*n*=4)	1.17 (0.69-4.12)	0.273
		1.28 (0.63-2.27)		
	Clenching EIR	0.39 (0.10-5.21)	0.64 (0.25-5.00)	0.593

$P < 0.05$ values are shown in bold. EIR=Elasticity index ratio; T1=Before surgery; T2=6 months after surgery; *n*=Number of individuals; *P*=0.05 significance level. Data are presented as median (min-max)

Table 4: In the study group, preoperative (T1) and postoperative 6th month (T2) comparisons of the thickness and elasticity values of left masseter muscle for the amount of surgical mandibular motion

Mandibular setback amount (mm)	Left masseter muscle	T1	T2	*P*
<5	Rest	(*n*=8)	(*n*=8)	0.093
		10.45 (6.60-12.20)	11.35 (9.00-14.90)	
	Clenching	12.30 (8.00-15.90)	14.70 (11.40-16.20)	**0.042**
	Rest EIR	(*n*=4)	(*n*=8)	0.144
		0.38 (0.29-1.23)	1.11 (0.49-2.92)	
	Clenching EIR	0.55 (0.26-0.79)	0.81 (0.25-6.63)	0.273
≥5	Rest	(*n*=6)	(*n*=6)	**0.046**
		10.15 (7.30-14.40)	11.75 (8.30-16.70)	
	Clenching	13.40 (8.50-18.50)	13.90 (8.60-17.80)	0.343
	Rest EIR	(*n*=5)	(*n*=6)	0.686
		0.89 (0.64-9.58)	1.76 (0.81-5.69)	
	Clenching EIR	1.96 (0.14-9.31)	0.81 (0.32-2.37)	0.225

$P < 0.05$ values are shown in bold. EIR=Elasticity index ratio; T1=Before surgery; T2=6 months after surgery; *n*=Number of individuals; *P*=0.05 significance level. Data are presented as median (min-max)

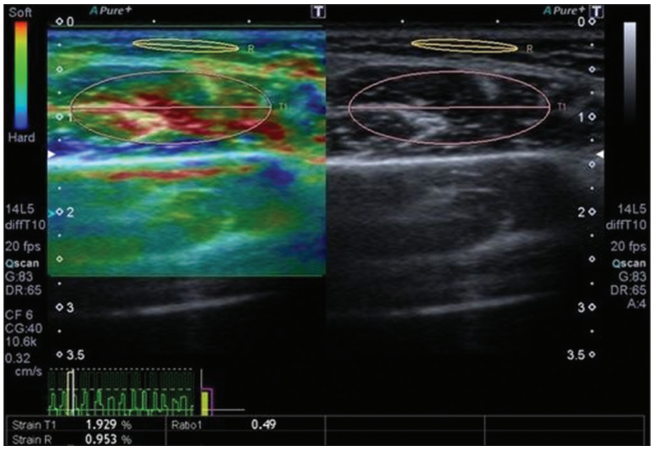

Figure 2: Sonoelastographic measurement of the masseter muscle at rest. Strain T1: Masseter muscle (pink selected area) and Strain R: Subcutaneous fat tissue (yellow selected region)

T1 to the time T2 in measurements of angle, while median angle values for SNA and ANB angles display a statistically significant increase, a statistically significant decrease in the median angle values for SNB is seen. The alteration between SNGoGN and nasolabial angle measurements was not statistically significant [Table 1].

In the study group, in the comparison of the masseter muscle's preoperative (T1) and 6th postoperative month (T2) USG measurements, masseter muscle thickness after surgery was found to increase bilaterally in both at rest and during contraction, and this was statistically significant. In terms of strain EIR measurements, no difference was observed between the preoperative orthognathic measurements (T1) and the 6th postoperative month (T2) measurements [Table 2].

In the study group, *P*-significance values of the variables which have a statistically significant difference in the values of surgical mandibular motion of the masseter muscle thickness and elasticity values measured at USG in the preoperative (T1) and the 6th postoperative month (T2) comparisons are shown in Tables 3 and 4.

Discussion

USG is a reliable method for measuring muscle thickness if the person performing the ultrasound technique conforms to an imaging protocol.[6] The most obvious disadvantage of the technique for the maxillofacial region is that it allows only superficial muscles to be visualized, and the probe cannot cover the entire cross-sectional area of the muscle. Therefore, many researchers have measured the ultrasound thickness of muscles instead of the cross-sectional areas of muscles.[16,19,20] In this study, the thickness measurements of the masseter muscle, which has superficial localization, were performed according to the previously reported technique. Measurements were performed in the transverse plane from the mandibular angulus region, where the maximum thickness of muscle tissue was obtained.

The surrounding musculature around the mandible is vital for patients who underwent setback surgery in terms of long-term surgical stability. Proffit *et al.*[21] reported that problematic stability might occur after setback surgery when the gonial angle is pushed back during surgery as musculature may usually return the ramus to its original position. However, in the present study, the patients underwent setback surgery in which the sagittal position of the ramus is not altered. Although ramus and the surrounding musculature are kept in the original position in the sagittal direction, it has been shown that the thickness of the masseter muscle is significantly increased.

Rani *et al*.[22] evaluated the masseter thickness at rest and during contraction for patients with different skeletal relationships and reported the mean muscle thickness at rest and during contraction as 10.429 mm and 12.84 mm in 24 patients with class I skeletal relationship and reported statistical significance between groups. In the same study, the thickness of the masseter for the maxillary ramus and mandibular setback for the patients with class II skeletal relationship was respectively 9.92 mm and 9.02 mm at rest; 12.41 and 11.41 were also reported during contraction. In our study, the masseter thickness in the control group with class I relationship was measured separately for right and left at rest and was found to be 11.15 mm and 10.90 mm, respectively. In the maximum contraction position, it was found to be 13.70 mm and 13.70 mm for right and left, respectively. These results are consistent with the findings of Rani *et al*.[22] In our study, there was no statistical significance in comparing the muscle thickness of the study group with the control group. However, there was an increase in bilateral muscle thickness before and after the surgery and these results were found to be statistically significant. We believe that this increase in muscle tissue is associated with a decrease in the strain of muscle tissue after mandibular setback surgery. Rohila *et al*.[4] measured the thickness of the masseter muscle sonographically for the patients of three different facial morphology in standardized lateral and posteroanterior cephalometric radiographs. In conclusion, they reported that the masseter muscle thickness had a negative correlation with the vertical facial parameters but had a positive correlation with transfer craniofacial morphology. In our study, a statistically significant increase was found in the thickness of the masseter muscle and the amount of mandibular setback. Thus, these results support the findings of Rohila *et al*.[4]

Trawitzki *et al*.[23] measured the masseter muscle thickness of 13 patients with skeletal class III deformities who underwent orthognathic surgery from 8 months to 3 years postoperatively. They compared the study group with a control group consisting of 15 volunteers with class I skeletal relationships. In conclusion, postoperative measurements of the masseter thickness were found to be statistically significant and higher than preoperative measurements. In the comparison of the postoperative treatment group with the control group, they reported that there was a statistically significant difference for both rest and contraction conditions for the right masseter and that there was a statistical difference only for the rest position for the left masseter. In our study, there was a statistical difference between all parameters in the treatment group for T1 and T2, but there was no statistically significant difference between the treatment and control groups for both T1 and T2. Therefore, while our findings support preoperative and postoperative comparisons of Trawitzki *et al*. for the patients who underwent surgery, they do not support the findings of the control and treatment groups. We think that this difference may be related to the amount of mandibular motion and type of surgery or postoperative follow-up period. Moreover, in the present study, the type of surgery and fixation were aimed to be standardized as much as possible to validate the results. In our study, muscle elasticity was examined by the SE technique of the masseter muscle, unlike Trawitzki *et al*.'s[23] study.

It has been reported that the new location of the bone is accompanied by soft tissue with surgical procedures for maxilla, and there are significant changes in the nasal tip, nasolabial angle, and upper lip area.[4,24] The present study was performed only with individuals with skeletal class III jaw relationship. In the Nasolabial angle, the relationship between the nose tip and lips displayed an increase in T1 and T2 comparisons, but this difference was not statistically significant. On the other hand, there was a statistically significant increase in SNA, SNB, and ANB angle comparisons with hard tissue measurements.

Although SE has been reported to be effective for muscle elasticity measurements, the method has some limitations as the compression force cannot be standardized, and the strain values are relative.[25,26] In the present study, the limitation of the technique cannot be eliminated because of the individual differences in the subcutaneous adipose tissue. Therefore, to reduce these problems that affect the validity of the strain values, subcutaneous adipose tissue[13,25] or "acoustic coupling agent = standoff pad" (kPa value of which is known)[26-28] are used as reference tissue. However, the pads might have lost their kPa values within three months due to dehydration.[29] In our study, since masseter elasticity measurements were completed in an approximately 1-year period, subcutaneous adipose tissue was used as reference tissue.

Ariji *et al*.[30] obtained 1.43 ± 0.30 for EIR at rest and 3.32 ± 1.01 during contraction at average strain SE in healthy volunteers. In the same study, they reported that EIR values of muscle tissue differed when "acoustic coupling agent" with different kPa (7 kPa and 40 kPa) values are used. In our study, EIR values at rest for the right and left masseter were found to be 1.15 and 1.55, respectively, while for the right and left masseter during contraction, they were found to be 0.6 and 1.04, respectively. Even though our EIR findings at rest were consistent with the findings of Ariji *et al*.,[30] EIR findings during contraction were found to be lower. Our assumption for this difference is that they used standoff pads with fixed kPa value in their EIR measurements. In our study, EIR results were found to be lower during contraction compared to the rest position. This is because the EI increase of the subcutaneous adipose tissue during contraction is higher than the EI increase of muscle tissue.

The EIR measurements in the study group in all T1 and T2 comparisons were found higher, but this difference was not statistically significant. There was no statistically significant difference between T1 and T2 in the EIR measurements of the study and control groups. The most obvious limitation of the present study was that strain elastography measurements were performed using subcutaneous adipose tissue as reference tissue. Subcutaneous adipose tissue not only indicates personal differences but also strain index (SI) value changes during muscle contraction. Thus, during contraction, even if the SI value of the masseter muscle increases, its SER value may decrease.

In conclusion, in the present study, before orthognathic surgery (T1) and 6 months after surgery (T2), SNA, SNB, and ANB angles were found to increase and this increase was found to be statistically significant. In the study group, in the comparison of preoperative orthognathic surgery (T1) and 6th postoperative month (T2) USG measurements of the masseter muscle, it was found that the masseter muscle thickness increased bilaterally in both at rest and during contraction after surgery and this was found to be statistically significant. In terms of EIR measurements which were performed using subcutaneous adipose tissue as reference tissue, no difference was observed between preoperative orthognathic surgery measurements (T1) and 6th postoperative month (T2) measurements. We have the opinion that it will be more significant for the elasticity of the masseter muscle to use kPa value with a fixed standoff pad or to use techniques that provide quantitative data such as shear-wave elastography.

We believe that the present study will have significant findings for research aiming to determine the effect of the masseter muscle on relapses after orthognathic surgery and will pioneer new research.

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Conflicts of interest

There are no conflicts of interest.

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