Myofascial Pain: Ultrasound Width of the Masseter Muscle

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Aims: To determine whether subjects with temporomandibular disorders (TMD) manifesting as chronic myofascial pain (MFP) involving the masseter muscle present with significantly greater masseter muscle width, as evidenced by ultrasound, compared to individuals without MFP. **Methods:** A case-control study was carried out. A total of 31 subjects presenting with MFP of the masticatory muscles involving the masseter muscle and 35 controls with TMD but no diagnosis of MFP, matched by age and sex, were included. Ultrasound was used to measure the maximum width of both masseter muscles at the intermediate point between the origin and insertion of the muscle in the light occlusal contact (LOC) position and under maximum contraction. Each side was analyzed separately. Means were compared by using single-factor analysis of variance and Mann-Whitney U test; $P < .05$ was considered to reflect statistical significance. **Results:** In the study group, the right masseter muscle had a mean ± standard deviation width of 8.6 ± 1.8 mm under LOC (controls: 8.6 ± 1.6 mm; $P = .85$) and 11.5 ± 2.1 mm under maximum contraction (controls: 11.7 ± 1.9 mm; $P = .86$). The analagous measures in the left masseter muscle were 8.6 ± 1.6 mm under LOC (controls: 8.2 ± 1.5 mm; $P = .42$) and 11.3 ± 1.8 mm under maximum contraction (controls: 11.5 ± 1.8 mm) ($P = .79$), respectively. The increase in width of the right masseter muscle was 2.9 ± 2.1 mm (controls: 3.1 ± 1.2 mm; $P = .67$) in absolute terms and 1.4 ± 0.3 mm (controls: 1.4 ± 0.2 mm; $P = .91$) in relative values (width at maximum contraction/LOC width). In the case of the left masseter muscle, the respective values were 2.8 ± 1.7 mm (controls: 3.2 ± 0.9 mm; $P = .25$) and 1.3 ± 0.2 mm (controls: 1.4 ± 0.1 mm; $P = .32$). **Conclusion:** There were no statistically significant differences in masseter muscle width between MFP subjects and control subjects under LOC conditions or maximum contraction. The increase in width under maximum contraction was likewise not significantly different between the groups. *J Oral Facial Pain Headache 2018;32:298–303. doi: 10.11607/ofph.1944*

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Parafunctional activity of the masticatory muscles is considered a risk factor for temporomandibular disorders (TMD).[1] The prospective cohort study carried out in the OPPERA project (Orofacial Pain Prospective Evaluation and Risk Assessment) detected a significant increase in the relative risk of painful TMD associated with frequent or multiple parafunctional activities.[2]

Parafunctional habits imply increased muscle activity. In this regard, there is evidence that exercises involving skeletal muscle contraction against external resistance are effective in improving muscle mass balance, as these exercises stimulate muscle protein synthesis. The result is muscle hypertrophy after chronic resistance training.[3] Muscle hypertrophy is not only induced by high-intensity contractions, as low-intensity training can result in increased muscle mass similar to that produced by high-intensity resistance training.[4] Consequently, sustained muscle contraction against resistance, as found in parafunctional habits, should result in an increase in muscle mass.

Considering parafunctional habits (increased activity of the masticatory muscles) to be a possible risk factor for myofascial pain (MFP) and assuming that chronic muscle activity against resistance causes muscle hypertrophy, the hypothesis that emerges is that individuals with chronic MFP of the masticatory muscles will have larger-size (ie, wider) muscles than people without such disorders.

The present study was designed to determine whether subjects with TMD manifesting as MFP involving the masseter muscle present significantly greater masseter muscle width, as evidenced by ultrasound, compared to individuals without MFP.

Materials and Methods

This study was carried out in the Department of Stomatology and Maxillofacial Surgery of Valencia University General Hospital (Valencia, Spain) following approval by the local Clinical Research Ethics Committee. A case-control design was used. A total of 31 subjects diagnosed with MFP of the masticatory muscles was included between October 2014 and January 2016, based on the following inclusion/exclusion criteria:

Inclusion Criteria

- A diagnosis of MFP (according to the Research Diagnostic Criteria for Temporomandibular Disorders [RDC/TMD]),[5] with involvement of at least one of the two masseter muscles at one of the three diagnostic points (muscle origin, body, or insertion)
- A minimum evolution of 3 months from pain onset
- At least one occlusal contact in each posterior segment (premolars and molars)

Exclusion criteria:

- History of major surgery and/or radiotherapy in the maxillofacial region
- Minor surgery in the maxillofacial region during the previous 3 months
- Organic disease of either masseter muscle (cysts, tumors, infections) detected during magnetic resonance imaging (MRI) and/or ultrasound explorations
- Systemic muscle disease
- Under 18 years of age

A total of 35 controls matched by age and gender were selected from among subjects with TMD but without a diagnosis of MFP in the orofacial region. Of these subjects, clinical manifestations consistent with disc displacement with reduction were observed in 9, disc displacement without reduction in 2, joint pain in 4, osteoarthritis in 3, multiple diagnoses in 7 (disc displacement with reduction plus arthralgia being the most common association), and no RDC/TMD diagnosis in 7 subjects (3 with nonreproducible occasional sounds, 2 with signs of joint subluxation, 1 with occasional block and sounds, and 1 with intermittent block without sounds).

After the subjects signed an informed consent document, ultrasound was used to explore the temporomandibular joints (TMJs) and masticatory muscles (masseter and temporalis) on both sides in all the MFP subjects and control subjects. All the explorations were made by the same operator (P.M.), who was specialized in musculoskeletal ultrasound and blinded to the clinical diagnosis. An Aplio 500 Premium ultrasound system with a linear probe operating in the range of 5 to 14 MHz was used (Toshiba).

With the subject in dorsal decubitus, the ultrasound probe was positioned perpendicular to the anterior margin of the masseter muscle and external surface of the mandibular ramus, between 2 and 2.5 cm above the lower mandibular margin. The subject was instructed to establish contact with the molar teeth of both arches, although without applying pressure (ie, light occlusal contact [LOC] position). Then the maximum transverse width of both masseter muscles from the internal band of the epimysium (external surface of the ascending mandibular ramus) to the external fascia at the intermediate point between the origin and insertion of the muscle was measured (Fig 1). The subject was then instructed to occlude the teeth with maximum force, and again, the width of both masseter muscles (likewise at the intermediate point between the origin and insertion of the muscle) was measured (Fig 2). The internal limit of the masseter muscle was marked by the interface between the external surface of the ascending mandibular ramus (bone) and the muscle. Both these structures exhibit clearly distinct echogenicity, and the ultrasound characteristics of the external limit of the masseter muscle are likewise different from those of the subcutaneous cellular tissue. In cases of doubt, the dynamic nature of the ultrasound exploration allows clear differentiation between those structures that contract (muscle) and those that do not (bone and subcutaneous cellular tissue).

Both sides were measured in all the study subjects and controls. In the clinical setting, the presence of painful points on the side opposite the side where MFP is diagnosed is common and was seen in 7 of the 23 subjects (30%) in the present study. Initially, the side without an MFP diagnosis was included in the study group in order to analyze and compare individuals with MFP to the corresponding control individuals, as muscle hyperactivity associated with MFP is assumed to be bilateral even if pain is only unilateral.[6–10] In addition, the study specifically included the comparison of sides with a diagnosis of MFP to the corresponding control sides.

Comparison was made of the masseter muscle width of the MFP subjects and controls under

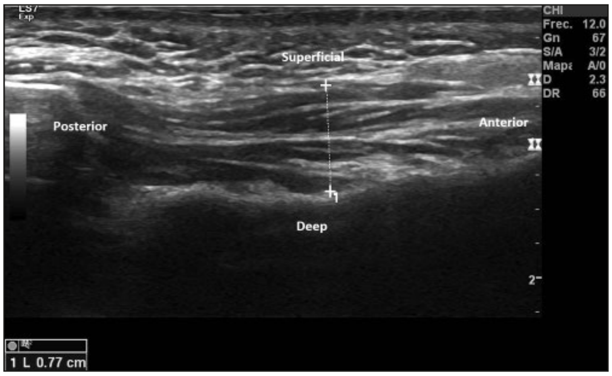

Fig 1 Masseter muscle width under light occlusal contact conditions.

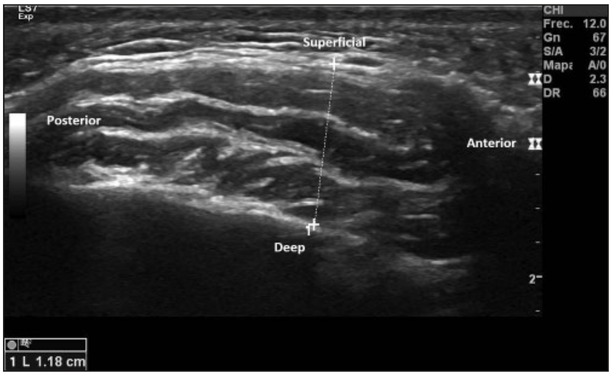

Fig 2 Masseter muscle width at maximum contraction.

Table 1 Intraclass Correlation Coefficient (ICC) Values for Successive Measurements

Muscle	n	Pearson correlation coefficient	R^2	ICC
Right masseter (LOC)	20	0.86	0.74	0.84
Right masseter (contraction)	20	0.81	0.64	0.81
Left masseter (LOC)	20	0.93	0.87	0.93
Left masseter (contraction)	20	0.81	0.66	0.92

LOC = light occlusal contact.

both LOC conditions and at maximum contraction, followed by comparison of the increase in muscle width (amplitude) at maximum contraction both in absolute terms (width at maximum contraction – LOC width) and as relative values (width at maximum contraction / LOC width; percentage of increment). Case-control comparisons were made by using single-factor analysis of variance (ANOVA) for variables with a normal distribution, and the Mann-Whitney *U* test for variables with a non-normal distribution. Normal data distribution was assessed by using the Shapiro-Wilk test. Linear correlations were used to analyze the influence of MFP subject age and the duration of the disorder on the main study variables. A statistical significance level of $P < .05$ was used in all cases.

Repeat measurements on the ultrasound images of 10 MFP subjects and 10 controls were carried out between 2 and 3 months after the first exploration with calculation of the intraclass correlation coefficient (ICC). Values of less than 0.4 were assumed to imply study suspension.[11]

The statistical analysis was performed using the SPSS version 22.0 statistical package for Microsoft Windows (IBM Corp).

Results

A total of 66 individuals were included in the study (31 MFP subjects and 35 controls). None of the MFP subjects or controls were excluded due to ultrasound-detected organic masseter muscle disease. Likewise, no subjects required exclusion a priori due to the absence of teeth in posterior segments, since the routine panoramic radiographs obtained on the first visit in all subjects with TMD excluded this possibility. The gender distribution was 8 males and 27 females in the control group and 1 male and 30 females in the study group. The mean age was 42.3 ± 17.5 years in the study group and 43.9 ± 16.9 years in the control group (F = 0.48; *P* = .49).

A total of 12 MFP subjects (38.7%) presented with MFP involving the right masseter muscle, 11 (35.5%) presented with MFP involving the left masseter muscle, and 8 (25.8%) presented with MFP involving both masseter muscles.

The first step was to calculate the ICC (required for reliability and continuation of the study) based on 10 MFP subjects and 10 controls selected at random between 2 and 3 months after the first measurement, again with blinding of the ultrasound evaluator. All the correlation coefficients were > 0.75, confirming the reliability of the measurements (Table 1).[11]

No significant differences were observed in masseter muscle width under LOC conditions or at maximum contraction between the MFP sides and corresponding control sides or between MFP subjects and controls. Indeed, all the measurements were found to be very similar in both groups, with an apparently low standard deviation (SD) (Tables 2 and 3).

Likewise, there were no statistically significant differences in the increase in width (amplitude) of the masseter muscles between the MFP subjects and controls for either side in absolute terms (width at maximum contraction minus LOC width) or as relative

Table 2 Transverse Width of the Masseter Muscles of MFP Subjects (Considering Only Affected Side) and Control Subjects Under LOC Conditions and at Maximum Contraction

	MFP right side, mean ± SD (n = 20)	Controls right side, mean ± SD (n = 35)	MFP left side, mean ± SD (n = 19)	Controls left side, mean ± SD (n = 35)	Contrast test	*P* value
RM (LOC) (mm)	8.6 ± 1.8	8.6 ± 1.6			0.19	.85
RM (C) (mm)	11.5 ± 2.1	11.7 ± 1.9			0.18	.86
Δ Absolute RM (mm)	2.9 ± 2.1	3.1 ± 1.2			−0.43	.67
Δ Relative RM (%)	1.4 ± 0.3 (37.2)	1.4 ± 0.2 (38.0)			−0.1	.91
LM (LOC) (mm)			8.6 ± 1.6	8.2 ± 1.5	0.81	.42
LM (C) (mm)			11.3 ± 1.8	11.5 ± 1.8	0.27	.79
Δ Absolute LM (mm)			2.8 ± 1.7	3.2 ± 0.9	−1.17	.25
Δ Relative LM (%)			1.3 ± 0.2 (34.5)	1.4 ± 0.1 (40.6)	−1.24	.32

MFP = myofascial pain; RM = right masseter; LM = left masseter; LOC = light occlusal contact; C = contraction; Δ = Increase.

Table 3 Transverse Width of the Masseter Muscles of MFP Subjects (Considering Both Sides) and Controls Under LOC Conditions and at Maximum Contraction

	Width (mm)				
Muscle	MFP subjects	Controls	Contrast test	*P* value	95% CI (difference of means)
Right masseter (LOC) (mm)	8.9 ± 1.9	8.6 ± 1.6	0.77[a]	.44	−0.5, 1.2
Right masseter (C) (mm)	11.8 ± 2.2	11.7 ± 1.9	0.25[a]	.80	−0.9, 1.1
Left masseter (LOC) (mm)	8.5 ± 1.4	8.2 ± 1.5	523.0[b]	.80	−0.4, 1.0
Left masseter (C) (mm)	11.4 ± 1.8	11.5 ± 1.8	0.13[a]	.89	−0.9, 0.8
Δ in right masseter width (mm) (relative %)	2.9 ± 1.4 (32.6%)	3.1 ± 1.2 (36.0%)	517.5[b]	.75	−0.8, 1.1
Δ in left masseter width (mm) (relative %)	2.9 ± 1.7 (37.9%)	3.3 ± 0.9 (40.2%)	−0.96[a]	.34	−1.0, 0.4
Contraction/LOC width ratio of right masseter (mm)	1.3 ± 0.3	1.4 ± 1.2	447.0[b]	.22	−1.4, 0.1
Contraction/LOC width ratio of left masseter (mm)	1.3 ± 0.2	1.4 ± 0.1	−0.99[a]	.33	−1.4, 0.1

[a]Single-Factor ANOVA. [b]Mann-Whitney *U* test. Δ = Increase; LOC = light occlusal contact; C = contraction. CI = confidence interval.

values (width at maximum contraction / LOC width) (Tables 2 and 3).

The influence of age on masseter muscle width was assessed by using linear regression analysis. The Pearson correlation coefficient revealed no significant differences. The Spearman correlation coefficient based on the left masseter muscle under resting conditions likewise revealed no statistically significant differences. Linear regression analysis was also used to examine the influence of the duration of MFP (mean duration: 24.6 ± 31.6 months; range 3 to 120 months) on masseter muscle width among the MFP subjects and revealed no significant correlation (Table 4).

Table 4 Relationship Between the Duration of Myofascial Pain and Masseter Muscle Width

Muscle	Coeff β	*P* value	R^2
Right masseter (LOC)	0.01	.23	0.05
Right masseter (C)	−0.09	.63	0.01
Left masseter (LOC)	0.2	.08	0.11
Left masseter (C)	0.34	.06	0.12

Coeff β = standardized coefficient; LOC = light occlusal contact; C = contraction.

Discussion

According to the working hypothesis, the masticatory muscles of subjects with chronic MFP should be of greater width under resting conditions and with a lesser increase in width under contraction compared to the healthy controls. The present study identified no significant differences in either variable in the masseter muscles of subjects suffering MFP with involvement of these muscles.

The RDC/TMD has undergone constant revision since its first introduction in 1992.[12] The classification published in 2014 includes MFP as a subcategory of myalgia.[13] The design of the present study predates the publication of this revised classification; as a result, the present study followed the RDC/TMD criteria that consider MFP as a major category comprising two subcategories (with limited opening and without limited opening).

Only two publications in the literature have been found comparing a hypothesis similar to that of the present study. One of them (Ariji et al[14]) detected statistically significant differences in masseter muscle width under resting conditions and in percentage of width increase between MFP subjects and controls.[14] Ariji et al recorded greater resting width in the MFP subjects (9.7 ± 2.5 mm vs 8.28 ± 1.73 mm) and a greater width increment in the controls (23.9% vs 38%). These results differ from those of the present study. Although these discrepant results could be due to differences in the age of the MFP subjects (28.6 ± 5.6 years in Ariji et al vs 42.3 ± 17.5 years in the present study), ethnic composition (Asian in Ariji et al vs Caucasian in the present study), or gender distribution (Ariji et al only included women), they are more likely explained by methodologic differences. In effect, one of the inclusion criteria in the present study was involvement of at least one of the two masseter muscles at some point, while Ariji et al did not state this as a requisite. Furthermore, the LOC position in the present study was defined by occlusal contact between the molars of the two dental arches without exerting pressure,[15] while Ariji et al did not specify the resting position in their study. Lastly, the analysis in the present study was made for each side separately (right and left), while Ariji et al used the value of the side with the most severe pain. Despite the above, the differences in the results obtained do not necessarily imply that the conclusions of the two studies are contradictory. The increase in width recorded by Ariji et al was not interpreted as a consequence of the increase in muscle mass secondary to widening of the fibers, but rather as an effect of the edema caused by psychological stress or prolonged muscle work.[16,17]

The second article identified in the literature reported only significant differences in right masseter muscle thickness between MFP subjects and their controls, but, unexpectedly, thickness was found to be greater in the control group (11.16 ± 1.37 mm vs 10.07 ± 1.45 mm, respectively).[18] With the exception of the dimension of the right masseter muscle under resting or LOC conditions, the results of both studies are similar. The criteria used to diagnose MFP were also similar,[5] and in contrast to Ariji et al, this second study also defined the involvement of at least one masseter muscle at some point as an inclusion criterion. The authors in turn defined the resting position as 8 to 9 mm of separation between the teeth without applying pressure from the masticatory muscles. This definition is probably more consistent with the physiologic resting position of the mandible, although it can generate important reproducibility problems that are largely avoided by using the LOC position.

Positioning of the probe represents a potential source of bias in the ultrasound exploration. Emshoff and Bertram found that the maximum width is observed in the middle portion of the masseter muscle and that measurements from various positions at one level barely differ provided the ultrasound probe is kept perpendicular to the long axis of the muscle.[15,19] Both the present study and the two studies used to compare the results made use of this ultrasound exploration procedure.

A considerable number of studies have examined the relationship between masseter muscle thickness as determined by ultrasound and facial growth pattern,[20,21] malocclusions,[22] dental condition,[23,24] and even gender.[21,25,26] These variables were not considered in the present study, since doing so would have fragmented the sample into too many subgroups, thereby adversely affecting statistical power.

Palinkas et al observed no significant differences in masseter muscle thickness between individuals with bruxism diagnosed by polysomnography and controls without bruxism.[27]

Neither the present study nor the comparator studies found in the literature performed measurements by several examiners. The ICC for explorations of this kind is therefore not known. However, the studies published by Emshoff and Bertram justify the methodology used.[15,19]

Although the results obtained do not allow rejection of the null hypothesis, some of the data obtained suggest that rejection of the alternative hypothesis cannot be ruled out entirely. In effect, with the exception of the left masseter muscle under contraction, all the values were higher in the MFP subjects than in the controls and the relative increase in muscle width under contraction was greater among the controls.

The present study had a number of limitations. On one hand, although previous publications justify the methodology used, no inter-examiner concordance analyses were made. On the other hand, the design included individuals of both sexes, although there was only one male in the study group vs eight in the control group. No significant gender differences in masseter muscle width were observed in the study group. However, other authors have recorded gender differences.[21,28] The two comparator studies found in the literature only included women. Although there are some exceptions,[29] most studies support the hypothesis that maximum bite force decreases in individuals with MFP.[30,31] No methods were used to determine bite force and relate it to the increase in masseter muscle width. This therefore constitutes a limitation of the study that could influence the results related to maximum contraction, but would not affect the LOC measurements, which constitute a main feature of the study.

The present study contributes new information to a subject that has been investigated little to date. To the authors' knowledge, this is the first study involving standardized clinical diagnostic criteria with reproducible LOC and maximum contraction positions and an analysis of each side (MFP diagnosis vs no MFP diagnosis) independently.

The relevance of this study is related to the absence of changes in the dimensions of the masseter muscle in subjects presenting with MFP with involvement of this muscle. This suggests the need to reconsider the hypothesis of an increase in muscle mass associated with muscle hyperactivity in the context of this disease condition.

Conclusions

No statistically significant differences were found in the width of the masseter muscles between MFP subjects with involvement of these muscles and control subjects as determined by ultrasound under LOC conditions or maximum contraction.

Acknowledgments

The authors report no conflicts of interest.

References

1. Fernandes G, Franco-Micheloni AL, Siqueira JT, Gonçalves DA, Camparis CM. Parafunctional habits are associated cumulatively to painful temporomandibular disorders in adolescents. Braz Oral Res 2016;30. pii: S1806-8324201600100214.
2. Ohrbach R, Bair E, Fillingim RB, et al. Clinical orofacial characteristics associated with risk of first-onset TMD: The OPPERA prospective cohort study. J Pain 2013;14(suppl):T33–T50.
3. Phillips SM, Tipton KD, Aarsland A, Wolf SE, Wolfe RR. Mixed muscle protein synthesis and breakdown after resistance exercise in humans. Am J Physiol 1997;273:E99–E107.
4. Burd NA, Mitchell CJ, Churchward-Venne TA, Phillips SM. Bigger weights may not beget bigger muscles: Evidence from acute muscle protein synthetic responses after resistance exercise. Appl Physiol Nutr Metab 2012;37:551–554.
5. Dworkin SF, LeResche L. Research Diagnostic Criteria for Temporomandibular Disorders: Review, criteria, examinations and specifications, critique. J Craniomandib Disord 1992;6:301–355.
6. Shochat T, Gavish A, Arons E, et al. Validation of the BiteStrip screener for sleep bruxism. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;104:e32–e39.
7. Okkerse W, Brebels A, Spaepen AJ, et al. A new method for semi-automatic analysis of surface EMG in patients with oral parafunctions. Cranio 2004;22:241–249.
8. Kato T, Masuda Y, Yoshida A, Morimoto T. Masseter EMG activity during sleep and sleep bruxism. Arch Ital Biol 2011;149:478–491.
9. Jadidi F, Nørregaard O, Baad-Hansen L, Arendt-Nielsen L, Svensson P. Assessment of sleep parameters during contingent electrical stimulation in subjects with jaw muscle activity during sleep: A polysomnographic study. Eur J Oral Sci 2011;119:211–218.
10. Goiato MC, Zuim PRJ, Moreno A, et al. Does pain in the masseter and anterior temporal muscles influence maximal bite force? Arch Oral Biol 2017;83:1–6.
11. Prieto L, Lamarca R, Casado A. Assessment of the reliability of clinical findings: The intraclass correlation coefficient [in Spanish]. Med Clin (Barc) 1998;110:142–145.
12. Anderson GC, Gonzalez YM, Ohrbach R, et al. The Research Diagnostic Criteria for Temporomandibular Disorders. VI: Future directions. J Orofac Pain 2010;24:79–88.
13. Schiffman E, Ohrbach R, Truelove E, et al. Diagnostic Criteria for Temporomandibular Disorders (DC/TMD) for clinical and research applications: Recommendations of the International RDC/TMD Consortium Network and Orofacial Pain Special Interest Group. J Oral Facial Pain Headache 2014;28:6–27.
14. Ariji Y, Sakuma S, Izumi M, et al. Ultrasonographic features of the masseter muscle in female patients with temporomandibular disorder associated with myofascial pain. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2004;98:337–341.
15. Emshoff R, Emshoff I, Rudisch A, Bertram S. Reliability and temporal variation of masseter muscle thickness measurements utilizing ultrasonography. J Oral Rehabil 2003;30:1168–1172.
16. Bakke M, Thomsen CE, Vilmann A, Soneda K, Farella M, Møller E. Ultrasonographic assessment of the swelling of the human masseter muscle after static and dynamic activity. Arch Oral Biol 1996;41:133–140.
17. Ariji Y, Sakuma S, Kimura Y, et al. Colour Doppler sonographic analysis of blood-flow velocity in the human facial artery and changes in masseter muscle thickness during low-level static contraction. Arch Oral Biol 2001;46:1059–1064.
18. Imanimoghaddam M, Davachi B, Madani AS, Nemati S. Ultrasonographic findings of masseter muscle in females with temporomandibular disorders. J Craniofac Surg 2013;24:e108–e112.
19. Bertram S, Bodner G, Rudisch A, Brandlmaier I, Emshoff R. Effect of scanning level and muscle condition on ultrasonographic cross-sectional measurements of the anterior masseter muscle. J Oral Rehabil 2003;30:430–435.
20. Lione R, Franchi L, Noviello A, Bollero P, Fanucci E, Cozza P. Three-dimensional evaluation of masseter muscle in different vertical facial patterns: A cross-sectional study in growing children. Ultrason Imaging 2013;35:307–317.
21. Biondi K, Lorusso P, Fastuca R, et al. Evaluation of masseter muscle in different vertical skeletal patterns in growing patients. Eur J Paediatr Dent 2016;17:47–52.
22. Kiliaridis S, Mahboubi PH, Raadsheer MC, Katsaros C. Ultrasonographic thickness of the masseter muscle in growing individuals with unilateral crossbite. Angle Orthod 2007;77:607–611.
23. Bhoyar PS, Godbole SR, Thombare RU, Pakhan AJ. Effect of complete edentulism on masseter muscle thickness and changes after complete denture rehabilitation: An ultrasonographic study. J Investig Clin Dent 2012;3:45–50.
24. Müller F, Hernandez M, Grütter L, Aracil-Kessler L, Weingart D, Schimmel M. Masseter muscle thickness, chewing efficiency and bite force in edentulous patients with fixed and removable implant-supported prostheses: A cross-sectional multicenter study. Clin Oral Implants Res 2012;23:144–150.
25. Close PJ, Stokes MJ, L'Estrange PR, Rowell J. Ultrasonography of masseter muscle size in normal young adults. J Oral Rehabil 1995;22:129–134.
26. Tircoveluri S, Singh JR, Rayapudi N, Karra A, Begum M, Challa P. Correlation of masseter muscle thickness and intermolar width—An ultrasonography study. J Int Oral Health 2013;5:28–34.
27. Palinkas M, Bataglion C, de Luca Canto G, et al. Impact of sleep bruxism on masseter and temporalis muscles and bite force. Cranio 2016;34:309–315.
28. Strini PJ, Strini PJ, Barbosa Tde S, Gavião MB. Assessment of thickness and function of masticatory and cervical muscles in adults with and without temporomandibular disorders. Arch Oral Biol 2013;58:1100–1108.
29. Pereira-Cenci T, Pereira LJ, Cenci MS, Bonachela WC, Del Bel Cury AA. Maximal bite force and its association with temporomandibular disorders. Braz Dent J 2007;18:65–68.
30. Kogawa EM, Calderon PS, Lauris JR, Araujo CR, Conti PC. Evaluation of maximal bite force in temporomandibular disorders patients. J Oral Rehabil 2006;33:559–565.
31. Xu L, Fan S, Cai B, Fang Z, Jiang X. Influence of sustained submaximal clenching fatigue test on electromyographic activity and maximum voluntary bite forces in healthy subjects and patients with temporomandibular disorders. J Oral Rehabil 2017;44:340–346.