Original Article

The impact of playing wind musical instruments on the masseter muscles in a West African population

Tope Emmanuel Adeyemi, Olayinka Donald Otuyemi[1], Babatunde Olamide Bamgbose[2], Suwaid Abba Muhammad[3]

Department of Child Dental Health, Faculty of Dentistry, Bayero University, Kano, Aminu Kano Teaching Hospital, [2]Department of Oral Diagnostic Science, Bayero University, Kano, Nigeria, [3]Department of Radiology, Bayero University, Kano, [1]Department of Child Dental Health, Faculty of Dentistry, Obafemi Awolowo University, Ile-Ife, Nigeria

Abstract

Aim: The morphological dimension of the masseter muscle is largely influenced by physical and habitual activities, which may impact directly on its performance. This study assessed the effects of playing wind musical instruments on the masseter muscle thickness in a male Nigerian adult population.

Materials and Methods: Equal numbers of male wind instrument players (WIP) were recruited and compared with nonwind instrument players (non-WIP) of the same age. Information on the sociodemographic characteristics, history, and type of wind instrument played was obtained. The masseter muscle thickness and fractional shortening were determined during relaxation and contraction using a linear probe of 7.5 MHz on ultrasound machine (Biosound Esaote MyLab40 Ultrasound machine; 2012; Italy, Rome). Reliability test demonstrated an excellent intrarater correlation (Cronbach's alpha; 0.98). Data were analyzed using SPSS version 17. Statistical significance was set at $P < 0.05$.

Results: The overall mean thickness of the masseter muscle at relaxation, contraction, and fractional shortening in WIP group was 9.21 ± 1.43 mm, 14.22 ± 1.95 mm, and 35.06% ± 5.07%, respectively, while 8.92 ± 1.12 mm, 13.97 ± 1.44 mm, and 36.08% ± 4.48%, respectively, in non-WIP group. No statistically significant differences were observed between the groups ($P > 0.05$). Type of instrument played, duration, and frequency of play did not significantly affect the muscle thickness except for the number of years of play. There was also a significant right/left side dichotomy in each group.

Conclusions: Playing a wind instrument showed no significant effect on the thickness of the masseter muscle, however there was a significant increase in the muscle thickness with increasing years of play of wind instruments.

Keywords: Male Nigerians, masseter muscle thickness, ultrasonography, wind instrument players

Address for correspondence: Dr. Tope Emmanuel Adeyemi, Department of Child Dental Health, Faculty of Dentistry, Bayero University, Kano, Aminu Kano Teaching Hospital, Kano, Nigeria.
E-mail: topmost007@yahoo.com

Submitted: 24-Jan-2020 **Revised:** 13-Jun-2020 **Accepted:** 25-Jul-2020 **Published:** 24-Sep-2020

INTRODUCTION

The masseter muscle constitutes an important component of the stomatognathic system which acts in harmony for the performance of different physiologic orofacial tasks

Access this article online	
Quick Response Code:	Website: www.wajradiology.org
	DOI: 10.4103/wajr.wajr_4_20

For reprints contact: reprints@medknow.com

How to cite this article: Adeyemi TE, Otuyemi OD, Bamgbose BO, Muhammad SA. The impact of playing wind musical instruments on the masseter muscles in a West African population. West Afr J Radiol 2020;27:114-20.

including speaking, chewing, tasting, swallowing, laughing, smiling, kissing, and socializing.[1,2] The role of orofacial musculature in determining facial morphology and its effects on the mandibulo-maxillary skeletal biomechanics has intrigued dental researchers for decades.[3-5] In order to properly plan orthodontic treatment, the importance of profound knowledge of the craniofacial and muscular environment cannot be overemphasized.[6]

Various authors have studied the masseter muscle for their volume by computed tomographic scan (CT scan), magnetic resonance imaging (MRI), and three dimensional (3-D) ultrasonography for the assessment of facial morphology and concluded that 3-D ultrasonography provides adequate information comparable to CT and MRI imaging of masseters.[7,8] From a criterion validity perspective, researchers have been able to demonstrate an association between ultrasound imaging measurements of muscle morphologic characteristics with both MRI and electromyography.[9,10]

Wind instrument players (WIP) form an important study group because their orofacial muscles are under constant stress. Aberrations in the functional patterns of orofacial muscles have a major impact on the dentofacial complex.[11] Quantifying the change in muscle thickness function could help us to determine the long-term impact of playing wind instrument on the dentofacial complex.[11] Without accurate information on the contraction, relaxation, and fractional shortening of the masseter muscles in wind and non-WIP, it is impossible to understand the significance of its variation on the dentofacial complex.[11]

This aim of this study was to determine and compare the thickness and fractional shortening of the masseter muscle in individuals with and without the experience of playing wind instruments, using ultrasonography, in our environment.

MATERIALS AND METHODS

The Research Ethics Committee of Aminu Kano Teaching Hospital, Kano state, Nigeria, granted the ethical approval for the conduct of this study while informed consent was obtained from individual participants.

This was a comparative cross-sectional study conducted among male Nigerians that played wind musical instruments in the case group and a control group that did not play wind musical instruments in the northern Nigerian state of Kano. The WIP group comprised fifty males that had been playing wind musical instruments for a period of 2–25 years (mean ± SD of 9.26 ± 6.21 years). The case and control groups were residing in the same environment and were also matched for age and gender. All the participants had a complete set of dentition. Individuals with disorders of the temporomandibular joint (TMJ), bruxism, previous surgery to the TMJ, trauma or fracture of the jaws, previous tooth extraction, and previous orthodontic treatment were excluded from this study.

A pilot study was carried out prior to commencement of the study using 10% of the sample size (five participants from each of the two groups) in order to establish internal consistency and calibrate one of the researchers (T.E.A). The Cronbach's alpha for intra-examiner reliability for measurement carried out after an interval of 2 weeks was 0.85.

The mean age of participants in WIP, non-WIP groups, and overall mean age were 28.00 ± 7.64, 28.10 ± 7.55, and 28.05 ± 7.56 years, respectively. There was no statistically significant difference in the mean age of the WIP and non-WIP groups ($P > 0.05$).

A questionnaire was used to obtain information regarding sociodemographics, history and type of wind instrument played, and the thickness of the masseter muscle as determined using ultrasonography.

Ultrasonographic assessment (2D) of the masseter muscle thickness was carried out at rest and during clenching in both groups as described by Agnihotri *et al*.[11] using a linear probe of 7.5MHz and ultrasound machine (Biosound Esaote MyLab40 Ultrasound machine; 2012; Italy, Rome).

The participants were positioned in the lateral decubitus position throughout the assessment period [Figure 1]. A coupling gel was applied to the area (masseter) to be assessed before commencement of the scan with the linear probe held perpendicular to the surface of the skin. Measurements were taken at the origin (at the zygomatic arch), midbelly (taken at a line joining the intertragic notch of the ear with the lateral commissure of the mouth), and insertion (outer surface of the mandibular angle) of the right and left masseter muscles at relaxation states (at gentle closure of the mouth in occlusion). The participants were required to clench their teeth maximally for 5–10 s while the masseter muscle thickness at contraction was being determined on both right and left sides. Each recording (in millimeters) was repeated thrice, and the mean values were recorded to ensure the reproducibility of the results and eliminate intra-operative error during recording of the muscle thickness. The right and left sides of the face were regarded as two different groups for calculations.

Figure 1: Scanning of masseter muscle of a participant

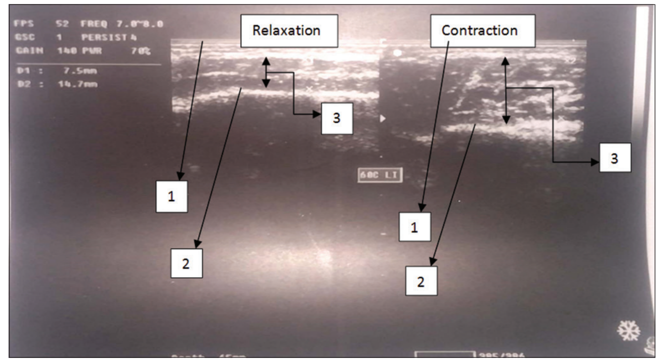

Figure 2: Ultrasound image of the masseter muscle during relaxation and contraction

With each assessment carried out by the ultrasound machine, the monitor of the machine displayed the thickness of the masseter muscle in the relaxation phase (R) and contraction phase (C) [Figure 2].

The amplitude of contraction was C– R (mm).

The fractional shortening (FS) for each muscle was derived as follows:

$$FS = \frac{\text{Amplitude of contraction } (C-R)}{\text{Thickness of contracted muscle } (C)} \times \frac{100}{1}$$

The fractional shortening was calculated in percentage (%).

The data generated were imputed into the pro forma and analyzed.

Data were processed and analyzed using Statistical Package for Social Sciences (SPSS Inc., Chicago, IL, USA) version 17. Quantitative data were summarized using measures of central tendencies (mean), dispersion (standard deviation); independent/paired *t*-tests, and analysis of variance were used to compare the means and standard deviation where required. Statistical significance level was set at $P < 0.05$.

RESULTS

Table 1 shows that the overall mean thickness of the masseter muscle during relaxation and contraction in WIPs was 9.21 ± 1.43 and 14.22 ± 1.95 mm, respectively, which was not statistically significantly higher than 8.92 ± 1.12 and 13.97 ± 1.44 mm, respectively, recorded in the non-WIP group ($P > 0.05$). The mean right, left, and overall mean fractional shortening of the masseter muscle were not significantly lower in the WIP group (35.55 ± 5.82%, 34.58 ± 5.88%, and 35.06 ± 5.07%) than the non-WIP group (36.14 ± 5.09%, 36.01 ± 5.14%, and 36.08 ± 4.48%) ($P > 0.05$).

Table 2 shows that the thickness of the masseter muscle at insertion during relaxation and contraction on the right side (8.19 ± 1.79 and 14.70 ± 2.72 mm) in WIP group was, respectively, statistically significantly higher than the left side (7.50 ± 1.80 and 13.72 ± 2.24 mm) ($P < 0.01$). Similarly, the thickness of the masseter muscle at insertion during relaxation and contraction on the right side (7.65 ± 1.46 mm and 14.25 ± 1.92 mm) in non-WIP group was, respectively, statistically significantly higher than the left side (7.19 ± 1.37 and 13.43 ± 1.95 mm) ($P < 0.01$). The fractional shortening of the right masseter muscle mid-belly (34.06% ± 7.28%) was statistically significantly higher than the left side (30.99% ± 8.46%) in WIP group ($P < 0.05$). No statistically significant differences were recorded in the fractional shortening at any anatomic point in non-WIP group ($P > 0.05$).

Table 3 shows significant differences among the overall mean thicknesses of the masseter muscle at relaxation and contraction for non-WIP (8.92 ± 1.12 and 13.97 ± 1.44 mm), those that had played wind instruments for 2–4 years (8.66 ± 1.21 and 13.56 ± 1.38 mm), those that had played wind instruments for 5–10 years (8.78 ± 1.18 and 13.60 ± 1.73 mm), and those that had played wind instruments for above 10 years (9.88 ± 1.50 and 15.11 ± 2.13 mm) ($P < 0.01$). Tukey's *post hoc* test for the overall mean thickness of the masseter muscle at relaxation revealed that the statistically significant differences were found between those that had played wind instruments for (2–4) years and (5–10) years; between those that had played wind instruments for (5–10) years and above 10 years, and between those that had played wind instruments for (2–4) years and above 10 years. Similarly, Tukey's *post hoc* test for the overall mean thickness of the masseter muscle at contraction

Table 1: Comparison of the masseter muscle thicknesses in wind and nonwind instrument players

Muscle thickness	WIP			Non-WIP			*t*-test	
	Mean±SD	Minimum	Maximum	Mean±SD	Minimum	Maximum	*t*	*P*
Right side relaxed (mm)								
Origin	9.74±1.75	6.40	14.10	9.54±1.66	6.30	12.80	0.59	0.556
Midbelly	10.05±1.95	5.90	15.10	9.89±1.27	7.20	13.10	0.47	0.637
Insertion	8.19±1.79	4.70	13.03	7.65±1.46	5.07	10.77	1.64	0.105
Mean	9.32±1.64	6.03	13.48	9.02±1.21	6.83	12.07	1.03	0.305
Right side contracted (mm)								
Origin	13.61±2.17	9.30	20.40	13.46±1.48	10.68	17.20	0.41	0.681
Mid-belly	15.25±2.60	10.10	23.61	14.77±1.73	11.39	19.00	1.08	0.285
Insertion	14.70±2.72	9.00	25.87	14.25±1.92	9.41	19.70	0.97	0.337
Mean	14.52±2.29	9.83	22.70	14.16±1.46	11.25	18.63	0.94	0.349
Right side fractional shortening (%)								
Origin	28.31±7.27	4.80	46.20	29.35±7.88	10.40	44.30	−0.68	0.497
Mid-belly	34.06±7.28	16.60	54.60	32.89±5.69	18.70	42.60	0.90	0.371
Insertion	44.27±7.54	18.50	61.80	46.19±7.89	32.60	60.90	−1.25	0.215
Mean	35.55±5.82	19.60	47.63	36.14±5.09	22.23	44.87	−0.54	0.587
Left side relaxed (mm)								
Origin	9.85±1.38	7.30	12.67	9.62±1.45	7.07	13.75	0.82	0.414
Mid-belly	9.94±1.88	6.69	14.12	9.63±1.60	6.40	13.67	0.89	0.374
Insertion	7.50±1.80	4.10	12.30	7.19±1.37	4.16	9.90	0.99	0.326
Mean	9.10±1.43	6.30	12.30	8.81±1.20	6.40	11.70	1.08	0.281
Left side contracted (mm)								
Origin	13.66±2.07	10.13	19.90	13.59±1.97	10.22	19.50	0.17	0.863
Mid-belly	14.40±2.09	10.80	20.35	14.31±1.86	9.23	19.00	0.22	0.827
Insertion	13.72±2.24	9.30	20.60	13.43±1.95	9.14	18.90	0.71	0.480
Mean	13.93±1.86	10.86	19.67	13.78±1.59	10.13	19.13	0.44	0.663
Left side fractional shortening (%)								
Origin	27.46±7.29	3.60	42.20	28.85±7.70	11.70	44.60	−0.93	0.355
Mid-belly	31.00±8.46	4.20	47.90	32.81±6.33	20.60	46.70	−1.22	0.226
Insertion	45.28±9.80	23.70	66.00	46.36±7.92	28.30	63.50	−0.61	0.545
Mean	34.58±5.88	20.47	45.90	36.01±5.14	24.77	47.37	−1.30	0.198
Overall mean								
Relaxation (mm)	9.21±1.43	6.38	12.80	8.92±1.12	6.62	11.34	1.14	0.259
Contraction (mm)	14.22±1.95	10.52	20.43	13.97±1.44	10.78	18.88	0.75	0.458
Fractional shortening (%)	35.06±5.07	22.40	46.13	36.08±4.48	23.83	43.57	−1.06	0.292

$P<0.05$ - *Statistically significant; $P<0.01$ - **Highly statistically significant; $P>0.05$ - Not statistically significant. WIP – Wind instrument player; SD – Standard deviation

Table 2: Comparison between the right and left masseter muscle thickness in wind and nonwind instrument players

Masseter muscle thickness	WIP				Non-WIP			
	Right, mean±SD	Left, mean±SD	*t*	*P*	Right, mean±SD	Left, mean±SD	*t*	*P*
Relaxation (mm)								
Origin	9.74±1.75	9.85±1.38	−0.51	0.609	9.54±1.66	9.61±1.45	−0.39	0.700
Mid-belly	10.05±1.95	9.94±1.88	0.47	0.641	9.89±1.27	9.63±1.60	1.34	0.188
Insertion	8.19±1.79	7.50±1.80	3.37	0.001**	7.65±1.46	7.19±1.37	2.97	0.005**
Mean	9.32±1.64	9.10±1.43	1.39	0.172	9.03±1.21	8.81±1.20	1.80	0.079
Contraction (mm)								
Origin	13.61±2.17	13.66±2.07	−0.20	0.846	13.46±1.48	13.59±1.97	−0.62	0.540
Mid-belly	15.25±2.60	14.40±2.09	3.04	0.004**	14.77±1.73	14.31±1.86	2.63	0.011*
Insertion	14.70±2.72	13.72±2.24	3.51	0.001**	14.25±1.92	13.43±1.95	3.31	0.002**
Mean	14.52±2.29	13.93±1.86	2.86	0.006**	14.16±1.46	13.78±1.59	2.82	0.007**
Fractional shortening (%)								
Origin	28.31±7.27	27.46±7.29	0.74	0.465	29.35±7.88	28.85±7.70	0.36	0.719
Mid-belly	34.06±7.28	30.99±8.46	2.42	0.020*	32.89±5.69	32.81±6.33	0.08	0.936
Insertion	44.27±7.54	45.28±9.79	−0.75	0.455	46.19±7.89	46.36±7.91	−0.16	0.876
Mean	35.55±5.82	34.58±5.88	1.17	0.247	36.14±5.09	36.01±5.14	0.19	0.847

$P<0.05$ - *Statistically significant; $P<0.01$ - **Highly statistically significant; $P>0.05$ - Not statistically significant. WIP – Wind instrument player; SD – Standard deviation

revealed significant differences between those that had played wind instruments for (2–4) years and (5–10) years; between those that had played wind instruments for (5–10) years and above 10 years; and between those that had played wind instruments for (2–4) years and above 10 years of play.

Table 3: Comparison of the overall mean masseter muscle thickness and fractional shortening of wind instrument player and nonwind instrument player groups according to instrument played, number of years, frequency, and duration of play

Characteristics of the wind instrument players	Overall relaxation thickness				Overall contraction thickness				Overall fractional shortening			
	Mean±SD (mm)	*F*	df	*P*	Mean±SD (mm)	*F*	df	*P*	Mean±SD (%)	*F*	df	*P*
Type of instrument played												
Non-WIP (control group)	8.92±1.12	1.26	2	0.289	13.97±1.44	0.99	2	0.374	36.08±4.48	0.60	2	0.549
Class A (trumpet and trombone)	9.31±1.44				14.37±2.05				34.96±4.92			
Class B (clarinet and saxophone)	8.81±1.39				13.64±1.46				35.48±5.87			
Number of years of playing instrument												
Non-WIP (control group)	8.92±1.12	4.06	3	0.009**	13.97±1.44	3.71	3	0.014*	36.08±4.48	0.77	3	0.513
2-4 years	8.66±1.21				13.56±1.38				36.09±5.45			
5-10 years	8.78±1.18				13.60±1.73				35.27±4.81			
Above 10 years	9.88±1.50				15.11±2.13				34.27±5.14			
Frequency of playing instrument												
Non-WIP (control group)	8.92±1.12	0.90	2	0.519	13.97±1.44	0.41	2	0.895	36.08±4.48	1.40	2	0.251
Regularly (daily/weekly)	9.23±1.36				14.34±2.01				35.44±4.61			
Occasionally (monthly/3 monthly)	9.12±1.85				13.61±1.61				33.06±7.06			
Duration of playing instrument												
Non-WIP (control group)	8.92±1.12	0.70	5	0.628	13.97±1.44	0.57	5	0.720	36.08±4.48	1.59	5	0.170
1 h	9.40±1.53				14.00±1.72				32.94±5.51			
2 h	8.87±1.12				14.06±1.90				35.71±5.34			
3 h	9.73±1.97				15.23±3.07				35.75±3.07			
4 h	8.74±2.32				13.90±1.71				37.43±9.14			
>5 h	9.04±1.18				14.39±2.07				36.94±2.51			

$P<0.05$ - *Statistically significant; $P<0.01$ - **Highly statistically significant; $P>0.05$ - Not statistically significant. WIP – Wind instrument player; SD – Standard deviation

There were no statistically significant differences in the overall mean fractional shortening of the masseter muscle across all categories ($P > 0.05$).

DISCUSSION

The primary objective of this study was to assess the impact of long-term playing of wind musical instruments on the changes in the thickness of masseter muscles in a Nigerian population. There is no previously published report of assessment and comparison of masseter muscle thicknesses in wind and non-WIP groups in this environment.

This study population comprised equal number of male participants in both the wind and non-WIP groups and were matched for age in order to ensure valid comparisons and to reduce any confounders that could occur as age and sex have been known to affect the parameter assessed.[12]

The thickness of the masseter muscle is a direct indication and measure of its activity.[13] Disorders of the TMJ, bruxism, previous surgery to the TMJ, trauma or fracture of the jaws, and previous tooth extraction are known to affect the activities of the masseter muscles, thus affecting their thicknesses. Therefore, individuals with such conditions/statuses were excluded from this study to prevent alteration of the findings.

In this study, the overall mean thickness of the masseter muscle at relaxed and contracted states in the entire assessed population was lower than those obtained in some studies[14-19] and slightly higher than those in other studies.[7,20] The overall mean thickness at relaxation was lower while the contraction thickness was higher than that obtained by Soyoye *et al*.[21,22] These variations in the thickness of the masseter muscle across different populations may be associated with racial perspectives and the relative indulgence in masticatory activities that may have led to the attendant adaptive increase or decrease in size. It may also be due to the size and orientation of the muscle fibers. The thickness of the relaxed and contracted masseter muscle at the origin, mid-belly, and insertion on both the right and left sides was higher in the WIP group than the non-WIP group. The differences were not significant, which is similar to what was reported by Gotouda *et al*.[23] in their study on the influence of playing wind instruments on the activity of masticatory muscles. The higher thickness of the relaxed and contracted masseter muscle in the WIP compared to non-WIP group supports the fact that muscles under constant stress develop hypertrophy and are thicker. The disparity between the values in relaxed and clenched states in this study population can be explained by the contraction and subsequent thickening of the masseter muscle fibers that culminated to the observed significantly higher thickness in clenched states.[15] The thickness of the masseter muscle during relaxation and contraction was higher on the right side than the left side in both groups except at the origin in both groups where higher values were recorded on the left compared to the right. The increased thickness of the masseter muscle on the right side may be due to indulgence in parafunctional habits or habitual chewing with the right side, thus leading to hypertrophy of the masseter muscles on the affected side (right side) as seen in other studies.[24,25] Generally, there was highly significant progressive increase in the thickness of relaxed and contracted masseter muscles as the number of years of playing wind instrument increased. This implies that as the number of years of playing wind instrument increased, the thickness of both the relaxed and contracted masseter muscles also increased, which is probably due to the hypertrophic changes that develop due to constant use of the muscles during play of wind instruments. Other studies also suggest that the thickness of the masseter muscle increases with age, which may also explain the increase in thickness of the masseter muscle as the number of years of playing increases.[15,26] The different overall mean thicknesses of the masseter muscle recorded according to the type of instrument played, frequency, and duration of playing wind instrument were all not statistically significant and may have been due to chance. However, it should be noted that there was a higher overall mean thickness of the masseter muscle during relaxation and contraction in regular players compared to non-WIP and occasional players, which is likely because the muscles in regular players were more constantly being subjected to activity, thus led to higher hypertrophy and therefore more thickness.

The functional status of a muscle is dependent on the fractional shortening, which is the distance moved by a contracting muscle and it is the amplitude of contraction divided by the thickness of the contracted muscle.[13] The fractional shortening of the masseter muscle at all the anatomic sites except the right mid-belly were consistently smaller in the WIP group than the non-WIP group; but the differences were also not significant. The higher thickness of the relaxed and contracted masseter muscle and the lower fractional shortening calculated in the WIP group supports the established fact that muscles under constant stress develop hypertrophy, and a hypertrophied muscle requires less shortening (less effort and reduced functional status) to obtain a certain contraction amplitude, as demonstrated by Rajaram *et al*.[27] and Agnihotri *et al*.[11] The literature does not have any reference study that compared the fractional shortening of the orofacial muscles in WIP and nonWIP. In this study, there was generally a decrease in the fractional shortening of the masseter muscle as the number of years of playing wind instrument increased. Though this was not significant, it however indicates a reduction in functional status of the masseter muscle as the number years of playing wind instruments increased and as well aging process, which is consistent with other studies.[15,26] The mean fractional shortening of the masseter muscle recorded according to the type of instrument played, frequency and duration of playing wind instrument were all not significant and may have been due to chance.

One limitation of this study is that the findings cannot be generalized to both males and females because it was conducted only among males. Because this is a pioneer study on the masseter muscles of WIP in this environment, it will be premature to give a final verdict on the degree of functional effects on the masseter muscle. A very longterm followup study is recommended to support and substantiate the results of this study.

CONCLUSIONS

1. Thickness of the masseter muscle was higher during relaxation and contraction in WIP than in non-WIP group and converse was the case for the fractional shortening, however the differences were not significant
2. There was a significant right/left side dichotomy in the thickness of the masseter muscle in WIP and non-WIP groups
3. A significant increase in the thickness of the masseter muscle occurred with increase in the number of years of playing wind instruments unlike the fractional shortening which decreased.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

REFERENCES

1. The glossary of prosthodontic terms. J Prosthet Dent 1999;81:39-110.
2. Kossioni AE, Dontas AS. The stomatognathic system in the elderly. Useful information for the medical practitioner. Clin Interv Aging 2007;2:591-7.
3. Ingervall B. Variation of the range of movement of the mandible in relation of facial morphology in children. Scand J Dent Res 1970;78:533-43.
4. Jacobs RM. Muscle equilibrium: Fact or fancy. Angle Orthod 1969;39:11-21.
5. Subtelny JD, Malocclusion, orthodontic corrections and orofacial muscle adaptation. Angle Orthod 1970;40:170-201.
6. Vreeke M, Langenbach GE, Korfage JA, Zentner A, Grünheid T. The masticatory system under varying functional load. Part 1: Structural adaptation of rabbit jaw muscles to reduced masticatory load. Eur J Orthod 2011;33:359-64.
7. Benington PC, Gardener JE, Hunt NP. Masseter muscle volume measured using ultrasonography and its relationship with facial morphology. Eur J Orthod 1999;21:659-70.
8. Hell A, Walters F, Schreiber S, Blaise H, Bielke G, Meindl S, *et al*. Three dimensional ultrasonography in Maxillo-Facial Surgery-A new diagnostic tool. Int J Oral Maxfac Surg 1993;22:173-7.
9. Hodges PW, Pengel LH, Herbert RD, Gandevia SC. Measurement

of muscle contraction with ultrasound imaging. Muscle Nerve 2003;27:682-92.
10. Kiesel KB, Uhl TL, Underwood FB, Rodd DW, Nitz AJ. Measurement of lumbar multifidus muscle contraction with rehabilitative ultrasound imaging. Man Ther 2007;12:161-6.
11. Agnihotri A, Magu S, Dutta S. M-mode echomyography: Functional assessment of the effects of thumb-sucking habit on masticatory and circumoral musculature. Oral Radiol 2010;26:71-6.
12. Thilander B. Dentoalveolar development in subjects with normal occlusion. A longitudinal study between the ages of 5 and 31 years. Eur J Orthod 2009;31:109-20.
13. Kiliaridis S, Georgiakaki I, Katsaros C. Masseter muscle thickness and maxillary dental arch width. Eur J Orthod 2003;25:259-63.
14. Harneet K, Tulika T, Priyank R, Anju G, Anup K. Influence of masseter muscle thickness on buccal corridor space and craniofacial morphology: A correlative study. J Indian Orthod Soc 2016;50:207-14.
15. Ogugua A, Clinton O, Edwin O, Ukoha U, Albert N, Chinwe E. Assessment of masseter muscle thickness in an adult Nigerian population: An ultrasound based study. Int J Biomed Res 2012;3:143-6.
16. Satirogolu F, Arun T, Isik F. Comparative data on using, facial morphology and muscle thickness orthodontics, ultrasonography. Eur J Orthod 2005;27:562-7.
17. Kubota M, Nakano H, Sanjo I, Satoh K, Sanjo T, Kamegai T, *et al*. Maxillofacial morphology and masseter muscle thickness in adults. Eur J Orthod 1998;20:535-42.
18. Park KM, Choi E, Kwak EJ, Kim S, Park W, Jeong JS, *et al*. The relationship between masseter muscle thickness measured by ultrasonography and facial profile in young Korean adults. Imaging Sci Dent 2018;48:213-21.
19. Yamaguchi K, Tohara H, Hara K, Nakane A, Kajisa E, Yoshimi K, *et al*. Relationship of aging, skeletal muscle mass, and tooth loss with masseter muscle thickness. BMC Geriatr 2018;18:67.
20. Ruf S, Pancherz H, Kirschbaum M. Facial morphology, size and activity of the masseter muscle. Fortschritte Kieferothopidiae 1994;23:219-27.
21. Soyoye O, Otuyemi O, Kolawole K, Ayoola O. Relationship between masseter muscle thickness and overbite values in a Nigerian population. Brazilian J Oral Sci 2017;16:1-10.
22. Soyoye OA, Otuyemi OD, Kolawole KA, Ayoola OO. Relationship between masseter muscle thickness and maxillofacial morphology in pre-orthodontic treatment patients. Int Orthod 2018;16:698-711.
23. Gotouda A, Yamaguchi T, Okada K, Matsuki T, Gotouda S, Inoue N. Influence of playing wind instruments on activity of masticatory muscles. J Oral Rehabil 2007;34:645-51.
24. Black MJ, Schloss MD. Masseteric muscle hypertrophy. J Otolaryngol 1985;14:203-5.
25. Arzul L, Corre P, Khonsari RH, Mercier JM, Piot B. Asymmetric hypertrophy of the masticatory muscles. Ann Chir Plast Esthet 2012;57:286-91.
26. Newton JP, Abel EW, Robertson EM, Yemm R. Changes in human masseter and medial pterygoid muscles with age: A study by computed tomography. Gerodontics 1987;3:151-4.
27. Rajaram P, Naidu M, Rao S, Venogopal S. M- mode echomyography: A new technique for the functional assessment of striated muscles. Indian J Radiol Imag 2002;12:537-41.