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Ultrasonographic evaluation of masticatory and suprahyoid muscles in obstructive sleep apnea patients treated with mandibular advancement devices; a pilot study

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Abstract

Objective This study aimed to assess the thickness and ultrasonographic pattern of the masticatory and suprahyoid muscles in OSA patients and compare the effects of mono-bloc (MB) and bibloc (BB) mandibular advancement devices (MADs) via ultrasonographic measurements.

Methods This pilot study of 20 patients with mild-to-moderate OSA who were diagnosed by full-night polysomnography (manually scored by the American Academy of Standards and Methods (AASM) manual, version 2.4) and treated randomly with mono-bloc or bibloc MAD ($n=10$). The baseline thickness and pattern (types I, II, and III) of the masticatory and suprahyoid muscles were assessed by an oral radiologist. The same procedure was repeated at the 3-month and 6-month follow-up time points for participants after appliance use.

Results Both types of MAD devices significantly increased the thickness of all muscles ($p<0.05$). The changes in ultrasonographic muscle patterns were significant only in the BB group for the SCM muscle ($p=0.006$). no other significant changes were observed in the studied ultrasonographic muscle patterns in the MB and BB devices up to 6 months ($P>0.05$). No significant differences in muscle thickness or patterns were detected between the MB and BB modalities ($P>0.05$).

Conclusion The results of the present study indicate that MAD treatments do not have contraindications based on changes in muscle thickness and ultrasonographic muscle patterns. However, the BB group showed significant changes in the SCM ultrasonographic muscle pattern. Nevertheless, further studies are required to validate these findings.

Keywords Biblock mandibular advancement device, Masticatory muscles, Monoblock mandibular advancement device, Obstructive sleep apnea, Ultrasonography

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Introduction

Obstructive sleep apnea (OSA) affects 9–38% of the population [1] and is associated with metabolic disorders, including high blood pressure, metabolic syndrome, heart failure, cognitive impairment, and increased mortality [2, 3]. Treatment options for this disorder include continuous positive airway pressure (CPAP), upper airway surgery, and mandibular advancement devices (MADs) [4, 5]. By forward movement of the mandible, the MAD dilates the upper airway, stabilizes the hyoid bone and soft palate, extends the tongue muscles, and prevents posterior rotation of the mandible [6, 7].

Two main types of MADs, mono-bloc (MB) and bibloc (BB), have gained popularity [8]. The MB is made of one fixed part that puts the mandible in a stable situation. On the other hand, the BB is made of two distinct parts that are combinable in different ways and make lateral and vertical jaw movements possible [9, 10]. MAD can cause local side effects such as jaw pain, tooth pain, temporomandibular joint click, increased saliva secretion, xerostomia, sensitive gingiva, and occlusal changes in the morning. Overbite and overjet changes have also been reported [11–13].

The masticatory muscles (i.e., masseter and temporalis) and the suprahyoid muscles (i.e., digastric) are involved in the positioning of the mandible and thus help prevent the collapse of the upper airway during sleep [14]. In OSA patients, the upper airway dilator muscles, such as the masticatory and suprahyoid muscles, often exhibit hypotonia or altered activity patterns. For example, hypotonia of the suprahyoid muscles makes the airway more resistant and therefore causes symptoms such as snoring and sleep disturbance. Additionally, inflammation and variations in masticatory muscle thickness have been noted in these patients and may exacerbate their condition [15, 16]. It is assumed that MADs directly affect the masticatory and suprahyoid muscles by altering the position of the mandible forward. MADs increase the tension in these muscles, particularly enhancing their ability to maintain airway patency during sleep.

Ultrasonography (USG) is a noninvasive, easily accessible, cost-effective, and beneficial paraclinical tool for evaluating the superficial muscles of the head and neck. The use of USGs to investigate changes in the thickness and patterns of these muscles before the onset of clinical symptoms, such as temporomandibular disorders, has been previously employed [17]. However, no sonographic studies have focused on the masticatory and suprahyoid muscles following treatment with MADs.

To our knowledge, this is the first study aimed at sonographically assessing the thickness and pattern of the masticatory and suprahyoid muscles in OSA patients treated with mono-bloc (MB) and bibloc (BB) MADs. The present study was designed to test the null hypothesis that "There is no significant difference in the changes of thickness or ultrasonographic patterns of the masticatory and suprahyoid muscles between patients treated with MB and BB mandibular advancement devices".

Methodology

Setting and ethical considerations

This pilot study included 20 patients with obstructive sleep apnea (OSA) who were referred from the sleep clinic of Imam Reza Hospital to the Prosthodontics Department of Mashhad Dental School between 2020 and 2022. All the Helsinki guidelines were followed in this study, which was approved by the ethics committee of Mashhad University of Medical Sciences with the ethics code of IR.MUMS.DENTISTRY.REC.1400.125.

Eligibility criteria

The patients were selected via convenience sampling. From the population of OSA patients, only those diagnosed with mild to moderate OSA based on the apnea–hypopnea index (AHI) criteria ($5 < AHI < 29.9$ times per hour) according to version 2.4 guidelines of the American Academy of Sleep Medicine (AASM), as confirmed by full-night polysomnography (PSG) results, were included [18]. These patients were candidates for Mandibular Advancement Device (MAD) therapy. This screening was assessed by an experienced sleep specialist (M. A.).

According to the AASM [19], OSA patients are classified into three groups, namely, mild, moderate, and severe. Mild OSA was diagnosed when the AHI ranged from 5 to 15 times per hour and the lowest oxygen saturation was between 85% and 90%. Moderate OSA was identified when the AHI ranged from 15 to 30 times per hour and the lowest oxygen saturation was between 65% and 85%. Severe OSA was diagnosed if the AHI exceeded 30 times per hour and if the lowest oxygen saturation was less than 65%.

In the next step of screening, patients clinically examined by an expert prosthodontist (AT. M.) according to the clinical signs and symptoms of TMD and the DC-TMD criterion [20]. Only OSA patients in this classification's healthy group (They did not meet any of the axis I criteria and had normal scores on the axis II.) were included in the study. Another inclusion criterion was that patients had full dentition and be classified as Angle Class I in terms of molar relationships.

Following the investigation of the isolated effects of MAD on the muscles, all confounding variables were minimized as much as possible. Individuals exhibiting bruxism or parafunctional habits, as well as those who consumed tobacco or alcohol, were excluded. Additionally, patients who did not cooperate or who had a history of jaw or facial trauma, temporomandibular disorders, use of anti-inflammatory medications, malignancies in

the facial region, or any prior adverse effects impacting the study variables were also omitted from the study.

Protocol

The individual matching method allocated twenty eligible patients into two treatment groups, MB and BB. The general distributions of the study variables, such as body mass index (BMI), neck circumference, age, and sex, were adjusted for them. For each two individuals with adjusted characteristics, participants were randomly assigned to either the MB or the BB treatment.

A single operator (M. H.), specializing in dental prosthetics, conducted all clinical examinations. Alginate (Chromogel Alginate, Marlic Dental, Tehran, Iran) impressions of both dental arches were taken from all patients. Subsequently, the patients' bite registration was performed at 50% of maximum protrusion and a vertical occlusal dimension of 4 mm. Customized appliances made of self-curing acrylic (AcroPars, Marlic Dental, Tehran, Iran) were prepared for the patients in the dental laboratory.

During the appliance delivery session, patients were assessed for fit and any interference with the soft tissues of the mouth and instructed on using the appliances. Patients were advised to wear the device throughout their sleep and to return if they experienced any issues or interferences. Before starting the treatment, a USG was requested for the patients, and follow-up appointments were considered for the patients 3 and 6 months after the treatment by ordering the USG to evaluate the thickness and pattern of the patients' muscles.

Ultrasound assessment

The ultrasound method for the muscles examined in the present study was based on the study by Emshoff et al. [21]. A blinded oral, maxillofacial radiologist performed all assessments with 15 years of experience and expertise in sonography (M. I.). USGs were prepared with a multifrequency linear probe of 3–12 MHz (ALPINION MEDICAL SYSTEMS Co., Ltd., Gangseo-gu, South Korea) using gel without creating pressure by placing the probe on the skin and measurements were evaluated by real-time sonography. With the order of the radiologist, All experiments were carried out in a dimly lit room, with the patient seated in an upright position in a stress-free situation and the Frankfort Horizontal plane aligned parallel to the floor. Echo gain was adjusted appropriately for each patient individually. All USGs of the patients' muscles used in the protocol included both sides of the face. All muscle thickness measurements were repeated twice with an interval of 5 min, and the final data were acquired from the average of measurements of both sides. The patients' muscle thickness was examined in the resting and contracting states. In a resting state, the position of the masticatory muscles occurs when the teeth are spaced 2 to 4 millimeters apart (resting occlusion). The suprahyoid muscles are in a relaxed position when the hyoid bone is in a neutral position, and occlusion is resting. The resting position of the SCM muscle occurs when the head is in a neutral position without lateral rotation. However, during contraction, for the masseter and temporal muscles, the jaws are closed and the dentition is occluded. The contraction of the sternocleidomastoid muscle involves rotation in both directions, while maximum mouth opening represents the contracted position for the digastric muscle.

In addition to the muscles thickness, the ultrasonographic pattern of the fibers was determined twice (with an interval of 5 min) for the patients according to the amount of observation of echogenic bands and the thickness of the echogenicity of the bands. The side with more damage determined the overall ultrasonographic muscle pattern type.

Ultrasonographic muscle pattern classification was performed in three groups following the modified method of Imanimoghaddam et al. [22].

The explanation of the ultrasonographic muscle pattern is as follows:

Type I: The muscle is normal and hyperechoic, and thick bands are easily visible via ultrasound.

Type II: the number of thick bands is decreased, and the echogenicity of the muscle is also reduced.

Type III is divided into two subgroups:

- IIIA: A sharp reduction in the number of bands is evident.
- IIIB: The bands have thoroughly disappeared.

Types II and III are considered abnormal ultrasonographic muscle patterns.

Ultrasonographic muscle patterns (types I, II, and III) and thickness were recorded (mm), and statistical analyses were performed.

The thickest part of the masseter muscle was the chosen zone for USG assessment. Near the occlusal plane, approximately in the middle of the mediolateral distance of the ramus. For the temporalis muscle, the anterior portion of this muscle was examined. A linear probe was positioned at the corner of the eyebrow, 2 centimeters above a line connecting the outer corner of the eye to the external acoustic meatus, in front of the anterior border of the hairline. The thickness of the muscle was defined as the maximum distance between the external and internal fasciae of the temporalis muscle. For the suprahyoid muscles, the transducer was positioned under the chin in the coronal plane, perpendicular to the suprahyoid muscles, approximately halfway between the mandible and the upper palpable border of the thyroid

cartilage, applying minimal pressure to ensure that the muscle structure remained unchanged. In this position, the mylohyoid and digastric muscles can be observed between the hyoid bone and the mandible. The SCM muscle was assessed beneath the mandible, adjacent to the internal jugular vein and the carotid artery, between the dorsal and ventral fasciae, at the midpoint of a line drawn from the mastoid bone to the clavicular edge (mid-neck). Some examples of patients' muscle USGs are shown in Fig. 1.

Statistical analysis

Statistical analysis of the data was performed via SPSS version 25 software (IBM, Chicago, USA). Central dispersion indices of age, BMI, and muscle thickness variables in patients using MB and BB devices before and 6

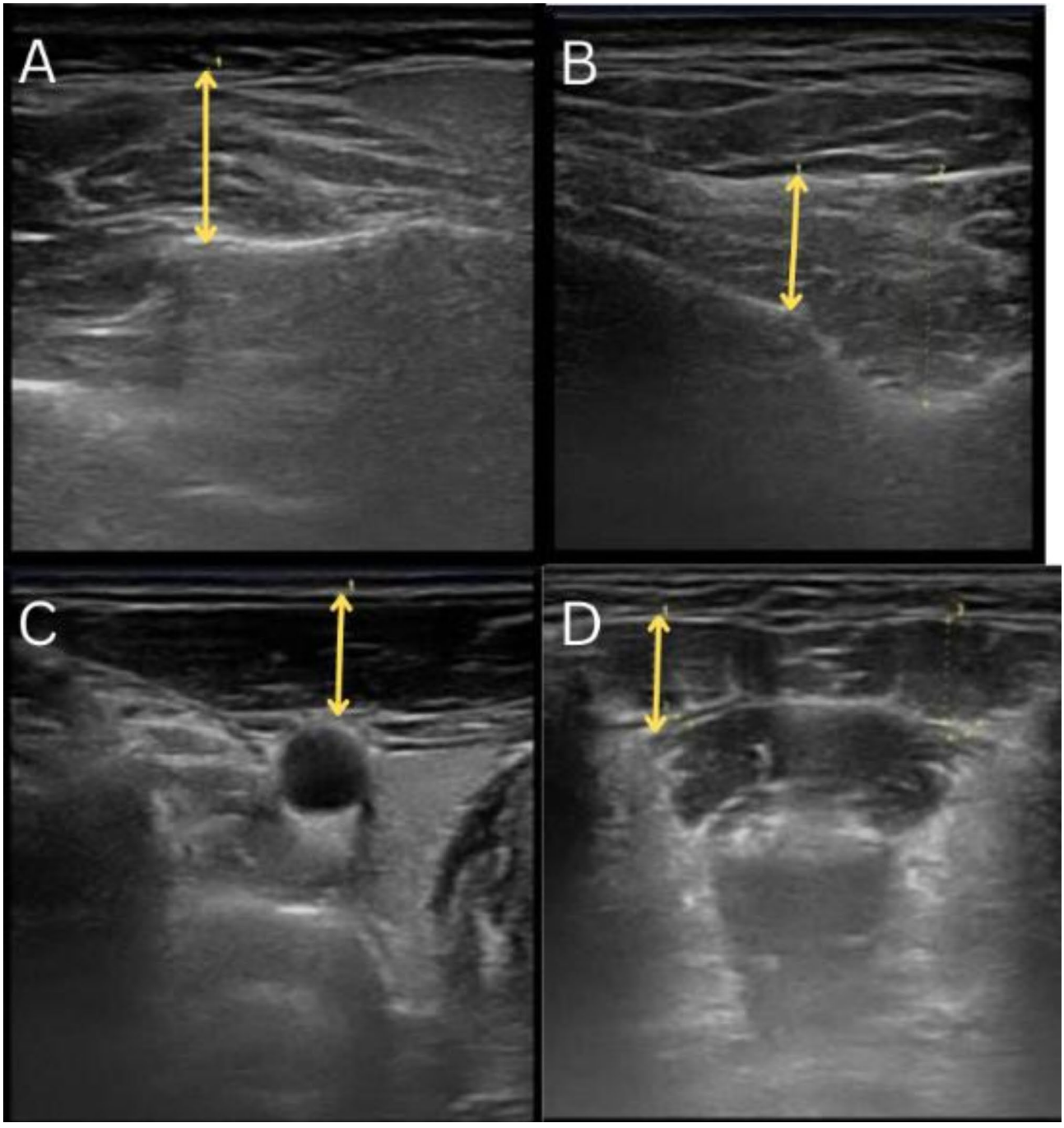

Fig. 1 USGs showing the masseter (**A**), temporal (**B**), SCM (**C**), and digastric muscles (**D**). The yellow lines in the images show the muscle thickness measurements (mm)

Table 1 Demographic information

Variable		Groups		*P* value
		mono-bloc	bibloc	
Age, mean ± SD		34.90 ± 7.92	36.70 ± 8.27	0.631[1]
BMI, mean ± SD		24.04 ± 4.02	26.13 ± 4.71	0.302[2]
Gender, n (%)	Male	5 (50%)	5 (50%)	1.0[3]
	Female	5 (50%)	5 (50%)	

1. Mann–Whitney U test

2. Student's t-test

3. Chi-square

Table 2 Mean muscle thickness by group and time interval

Groups		Time		
		Baseline	3 months	6 months
Masseter, mean ± SD	MB	1.24 ± 0.20	1.36 ± 0.24	1.40 ± 0.27
	BB	1.40 ± 0.16	1.48 ± 0.19	1.53 ± 0.22
Temporal, mean ± SD	MB	0.87 ± 0.15	0.91 ± 0.20	0.95 ± 0.20
	BB	0.82 ± 0.14	0.86 ± 0.14	0.88 ± 0.17
SCM, mean ± SD	MB	0.89 ± 0.18	0.87 ± 0.25	0.97 ± 0.21
	BB	0.79 ± 0.07	0.82 ± 0.07	0.85 ± 0.09
Digastric, mean ± SD	MB	0.26 ± 0.08	0.35 ± 0.08	0.41 ± 0.11
	BB	0.31 ± 0.17	0.39 ± 0.17	0.45 ± 0.17

months after treatment were calculated and reported. Additionally, the frequency of sex and different ultrasonographic muscle patterns in patients in the two groups at different times were calculated and reported. The normality of muscle thickness data distribution across time and groups was assessed using the Shapiro-Wilk test, revealing non-normal distributions for some variables in specific groups ($P < 0.05$). Age between groups was analyzed using the Mann-Whitney U test, BMI with the Student's t-test, and sex distribution via the chi-square test. Changes in muscle thickness over time within each appliance were evaluated using repeated measures ANOVA, while between-device comparisons at specific time points employed the student's t-test. The Mann-Whitney U test assessed muscle pattern frequencies between groups. Changes in muscle thickness, and ultrasonic patterns between groups were compared using the Mann-Whitney U test. The type I error of the study was 5%, and significance was considered below 0.05. (P value < 0.05).

Results

The patients in this study included 10 men and 10 women with an age of 35.80 ± 7.94 years and a range of 22–57 years. The patients' BMI was 25.09 ± 4.39, and the BMI ranged from 18.73 to 31.43.

The intervening variables of age, BMI, and sex were examined in the groups (monobloc and bicloc devices), and according to the Table 1, the intervening variables of age, BMI, and sex did not significantly differ from each other (Table 1).

Table 2 shows the mean muscle thickness across the different groups and time points. The greatest mean muscle thickness was observed in the masseter muscle of the BB group at the 6-month follow-up (1.53 ± 0.22). In contrast, the lowest mean muscle thickness was noted in the digastric muscle of the MB group at baseline (0.26 ± 0.08) (Table 2).

Figure 2 provides a clearer understanding of the changes in the mean thickness of the masseter, temporal, SCM, and digastric muscles over time intervals. As shown in the figure, all muscles exhibited an increase in mean thickness over time. Notably, in the SCM muscle within the MB group, a decrease in muscle thickness was observed between baseline and the 3-month follow-up, which is remarkable (Fig. 2).

The effects of time, group, and the interaction effect of time and group on the mean muscle thickness were determined through repeated-measures ANOVA, as indicated in Table 3. The results revealed no significant difference in muscle thickness between the MB and BB groups ($P > 0.05$). Moreover, no significant interaction effect between time and group was observed ($P > 0.05$). However, time significantly affected the mean muscle thickness ($P < 0.05$) (Table 3).

A more detailed post-hock test revealed a significant difference in the masseter muscle at the 3- and 6-month follow-ups compared with the baseline ($P < 0.001$); however, no difference was observed between the 3- and 6-month follow-ups ($P = 0.091$).

Concerning the temporal muscle, the comparisons of the mean thickness of the muscle were similar to those of

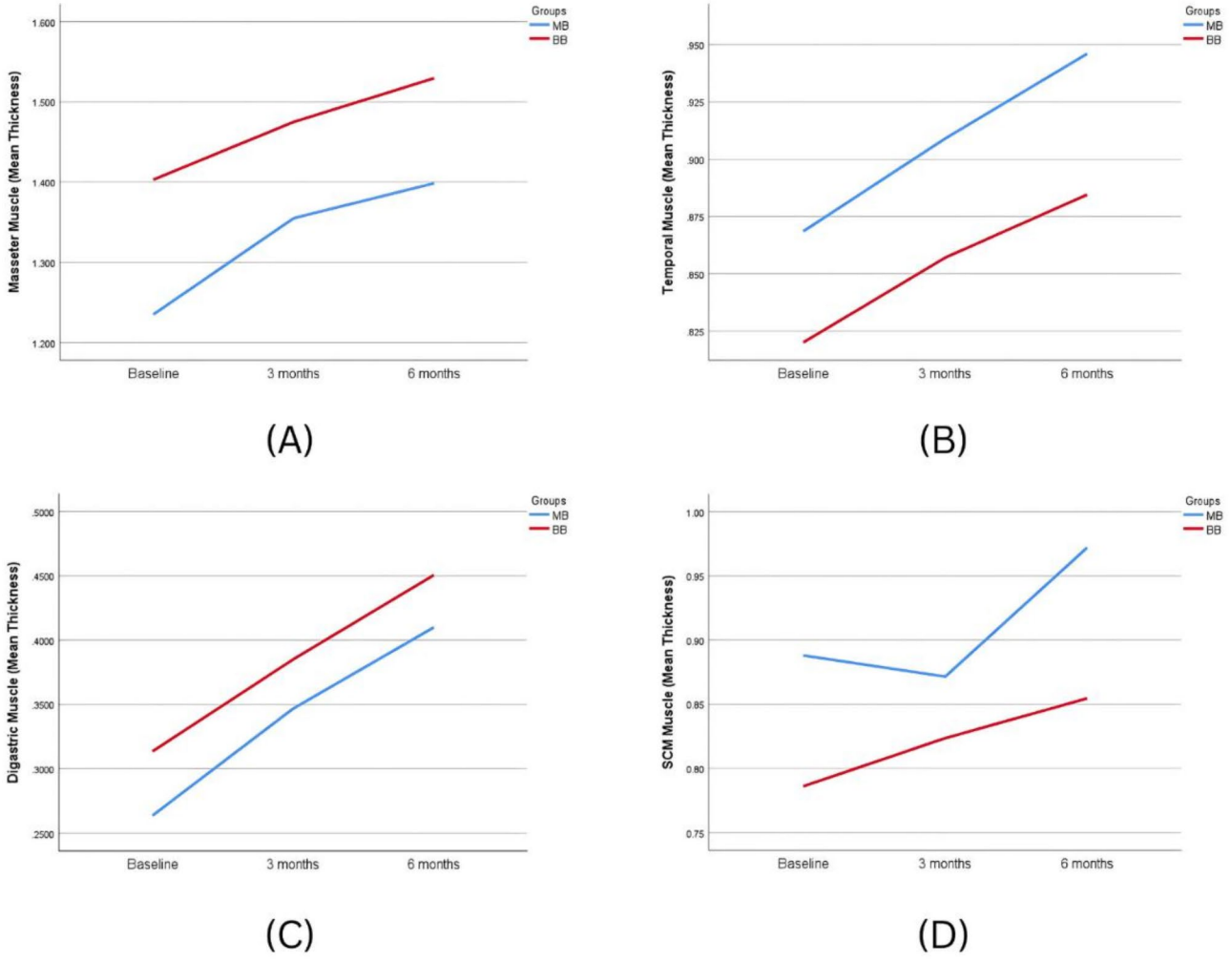

Fig. 2 Changes in mean muscle thickness: (A) Masseter; (B) Temporal; (C) Digastric; (D) SCM at baseline and follow-up time intervals

Table 3 Effects of time, group, and the interaction effect of time * group on the mean muscle thickness

Variables	Time effect		Groups effect		Interaction of Time × Group	
	F	*P*[1]	F	*P*	F	*P*
Masseter	18.53	**< 0.001**	2.30	0.147	0.54	0.588
Temporal	5.98	**0.012**	0.58	0.456	0.05	0.902
SCM	4.44	**0.019**	1.89	0.186	0.87	0.429
Digastric	66.58	**< 0.001**	52	0.478	0.12	0.884

1. Repeated-measures ANOVA

the masseter. There was a significant difference at the 3- and 6-month follow-ups compared with the baseline values ($P = 0.034$ and $P = 0.014$, respectively). No significant difference was observed between the 3- and 6-month follow-ups ($P = 0.083$).

With respect to the SCM muscle, only the 6-month follow-up significantly differed from the other time points (compared with the 3-month follow-up and baseline, $P = 0.018$ and $P = 0.012$, respectively). No significant difference was observed between the 3-month follow-up and baseline values ($P = 0.736$).

The change in the thickness of the digastric muscle was significantly different after treatment compared with before treatment ($P < 0.001$), and a significant difference was also observed at 6 months after treatment compared with 3 months ($P < 0.001$).

The comparison of muscle thickness changes at baseline and at the 6-month follow-up is shown in Table 4. There was no significant difference in any of the muscles ($P > 0.05$); however, the greatest change was related to the masseter muscle. In this muscle, at baseline and at the

Table 4 Comparison of changes in muscle thickness between the MB and BB groups

Δ Thickness	Groups		*P* value
	MB	BB	
Masseter, mean ± SD	-0.16 ± 0.13	-0.13 ± 0.11	0.5[1]
Temporal, mean ± SD	-0.08 ± 0.10	-0.06 ± 0.13	0.796[2]
SCM, mean ± SD	-0.08 ± 0.15	-0.07 ± 0.08	0.739[2]
Digastric, mean ± SD	-0.15 ± 0.08	-0.14 ± 0.04	0.757[1]

1. Independent T test
2. Mann–Whitney U test

Table 5 Comparison of the frequency distributions of patterns in the masseter, Temporal, SCM, and digastric muscles by group over time

variable		Pattern				*P* value1
		I	II	IIIA	IIIB	
Masseter, n (%)						
MB	Baseline	2 (20%)	8 (80%)	0 (0%)	0 (0%)	0.565
	3 months	2 (20%)	8 (80%)	0 (0%)	0 (0%)	
	6 months	4 (40%)	2 (20%)	2 (20%)	2 (20%)	
BB	Baseline	2 (20%)	8 (80%)	0 (0%)	0 (0%)	0.629
	3 months	0 (0%)	10 (100%)	0 (0%)	0 (0%)	
	6 months	5 (50%)	2 (20%)	1 (10%)	2 (20%)	
Temporal, n (%)						
MB	Baseline	2 (20%)	8 (80%)	0 (0%)	0 (0%)	0.311
	3 months	2 (20%)	8 (80%)	0 (0%)	0 (0%)	
	6 months	1 (10%)	9 (90%)	0 (0%)	0 (0%)	
BB	Baseline	4 (40%)	6 (60%)	0 (0%)	0 (0%)	0.247
	3 months	3 (30%)	3 (30%)	3 (30%)	1 (10%)	
	6 months	3 (30%)	5 (50%)	2 (20%)	0 (0%)	
SCM, n (%)						
MB	Baseline	3 (30%)	7 (70%)	0 (0%)	0 (0%)	0.066
	3 months	2 (20%)	8 (80%)	0 (0%)	0 (0%)	
	6 months	10 (100%)	0 (0%)	0 (0%)	0 (0%)	
BB	Baseline	10 (100%)	0 (0%)	0 (0%)	0 (0%)	**0.006**
	3 months	1 (10%)	4 (40%)	4 (40%)	1 (10%)	
	6 months	0 (0%)	5 (50%)	5 (50%)	0 (0%)	
Digastric, n (%)						
MB	Baseline	3 (30%)	7 (70%)	0 (0%)	0 (0%)	0.692
	3 months	3 (30%)	7 (70%)	0 (0%)	0 (0%)	
	6 months	1 (10%)	9 (90%)	0 (0%)	0 (0%)	
BB	Baseline	2 (20%)	8 (80%)	0 (0%)	0 (0%)	0.097
	3 months	4 (40%)	4 (40%)	0 (0%)	2 (20%)	
	6 months	2 (20%)	6 (60%)	1 (10%)	1 (10%)	

1. Mann–Whitney U test

3-month follow-up, it was 0.03 mm less in the BB group than in the MB group (Table 4).

Table 5 compares the frequency distributions of the masseter, temporal, SCM, and digastric patterns by group over time (Table 5).

In the time-dependent evaluation, in the MB and BB groups, there was no significant difference in pattern distribution over time in the masseter, temporal, or digastric muscles ($P > 0.05$), but in the SCM muscle group in the BB group, there was a significant difference in pattern distribution over time ($P = 0.006$). In a two-by-two comparison, only the pattern at the 6-month follow-up was significantly different from that at baseline ($P = 0.034$).

In the group-dependent evaluation, the comparison of the frequency distributions of the muscle patterns at each time interval (Table 5) revealed that there was no significant difference ($P > 0.05$) between the MB and BB groups in all muscles.

Additionally, Table 6 presents a comparison of changes in muscle pattern distribution between baseline and the six-month follow-up. No significant differences were

Table 6 Comparison of changes in muscle patterns between the MB and BB groups

Δ Muscle pattern	Group		*P* value[1]
	MB	BB	
Masseter, mean ± SD	-0.40 ± 1.07	-0.20 ± 1.48	0.579
Temporal, mean ± SD	-0.40 ± 0.84	-0.10 ± 0.57	0.481
SCM, mean ± SD	-0.80 ± 1.23	-0.70 ± 0.67	> 0.99
Digastric, mean ± SD	-0.30 ± 1.34	-0.49 ± 0.70	0.529

1. Mann–Whitney U test

noted across any muscle groups. Nevertheless, the most notable change was observed in the temporal muscle, where the BB group exhibited a decrease of 0.3 units in comparison with the MB group from baseline to six months posttreatment (Table 6).

Discussion

In recent decades, MAD has been widely used to treat OSA [23]. Evaluating the effects of different sleep disorder treatments on muscles requires ultrasound examinations and clinical evaluation, as OSA is a common problem in society. The ultrasound method was used in this study to examine the patients' muscles following MAD use. Based on the results of the present study, the null hypothesis was not rejected, and no significant differences in changes of muscle thickness or ultrasonographic patterns between the MB and BB groups were observed. Although the muscular pattern of the SCM in the BB group showed a notable change over time, the overall hypothesis remains accepted. Muscle thickness in both groups increased over time in the present study, and no significant superiority was observed between the appliances.

There were no studies similar to the present study conditions in the literature either in terms of muscle thickness or ultrasonographic muscle pattern. However, factors such as genetics, environment, facial height morphology, BMI, age, and sex influence muscle thickness [24]; however, in the present study, the two groups of patients were individually matched in terms of age, sex, and BMI, and as a result, the role of these factors was controlled. Additionally, some individual differences, for example, increased use of muscles on one side in patients, can affect muscle thickness. Another influential factor in muscle thickness is muscle inflammation and edema, which has been mentioned in studies [25].

The mechanism of MB and BB devices is the same in terms of advancing the mandible and reducing the collapse of the upper airway, but they differ in terms of the mouth opening pattern [26, 27]. Research has indicated that the use of an MB appliance is more efficient than the use of a BB appliance is superior in terms of patient compliance [28]. Although the mechanical effects of mandibular advancement on the airway have not yet been precisely determined, the mandible's forward movement resulting from oral appliances appears to improve airway ability, particularly in the retroglossal space, by decreasing pressure in the upper airway. Additionally, forward movements of the mandible increase the retroglossal space and the posterior bone space [29].

According to the present study results, the ultrasonographic muscle patterns of the patients in the two MB and BB groups did not significantly differ during any follow-up period. Insufficient evidence from the literature reveals a knowledge gap, indicating the importance of further investigations in the future. In the study by Imanimoghaddam et al. [22], significant differences in the masseter muscle pattern were noted in the USG of patients with myofascial pain and the control group, which was not consistent with the present study, although these two studies differed in terms of the investigated patient group.

A systematic review of 22 studies conducted by Serra-Torres et al. [30] to investigate the effectiveness of MADs for the treatment of OSA suggested that MADs are known to increase the airway area and prevent respiratory tract collapse during sleep. This is achieved by advancing the soft palate, tongue, and hyoid bone while activating the masseter and submental muscles to prevent closure of the airway.

Ultrasound provides repeatable information about muscle function; for this reason, in a study by Lione et al. [31], USGs were used to evaluate the effect of bite blocks on the masseter muscle in orthodontic patients (8–12 years old). The difference between the control and experimental groups was that the muscle thickness in the control group (not subjected to the bite block) was significantly greater than that in the experimental group ($P < 0.001$). In this sense, it is not consistent with the present study. The reasons for the difference can be mentioned in the comparison with the control group, which was not a control group in the present study. Additionally, the age range of the patients according to the growth age of the patients and orthodontic treatments are all practical and make a complete comparison of these two studies difficult.

The standard treatment for obstructive sleep apnea, the CPAP machine, is expensive, and approximately 40% of patients cannot tolerate the treatment. Moreover, the therapeutic effects of surgical methods are less than 50%

[32], and not enough evidence exists concerning the effectiveness of this treatment in older individuals [33]. Compared with the CPAP machine, MADs offer advantages such as being portable, autonomous, and inexpensive, but some patients may find them uncomfortable with their use at night [34]. Patients should receive necessary information about the side effects of these devices, including increased saliva production, xerostomia, and possible damage to teeth or discomfort of the TMJ, at the beginning of treatment with oral appliances.

The results of the current study demonstrated that muscle thickness increased over time in both groups. In line with the idea that the action of MADs by changing the position and increasing muscle thickness could create an inflammatory condition for the muscles, however, there is currently no strong evidence to support this claim [34–36]. Concerning MADs, the frequency of complications has been reported in different ways, which emphasizes the differences in the types of intraoral devices used. However, the side effects of these devices are usually temporary and occur within the first two months of use [34, 35]. MAD appliance physiological adaptation in patients after 6 months was reported in a study by Alessandri-Bonetti et al. [36]. The pressure pain threshold (PPT) in OSA patients treated with MAD was not significantly different from that in the control group after 6 months. Although the patients' PPTs in the first 15 days of MAD use were significantly different between the groups, after six months, this discomfort disappeared. In a long-term study of 142 OSA patients treated with MADs, Vuorjoki-Ranta et al. [37]. After 2 years of consecutive use of MADs, the most reported problems are sore teeth and masticatory muscle soreness. Furthermore, in the presence of a foreign body in the palate, jaw activity at night may be reduced due to changes in oral tactile stimuli, reduced mouth volume, and space required for the tongue [38, 39]. The use of intraoral devices may also lead to cognitive awareness, as patients may become aware of the position or possible complications of jaw movements [40].

Examining TMJ morphological changes is one of the concerns of using MAD for OSA patients. In the study of Zhou et al. [41], magnetic resonance imaging (MRI) was used to investigate changes in the temporomandibular joint, electrical changes in mandible movements and the masticatory muscle surface in OSA patients who were treated with MAD. Patients were evaluated via MR images before and after 18 months. Additionally, electrical changes in mandible movements and masticatory muscle surfaces in patients before and 6 months after treatment with MAD appliances were investigated. In 20 patients who were examined, there were changes in the position angle of the joint disc and other variables compared with the results before treatment, all of which were not significant. Even though the thickness of the muscles was not examined in this study and the TMJ anatomical considerations were examined, the authors stated that the long-term use of MAD is safe for OSA patients and that, in this sense, temporomandibular disorders do not arise in patients.

Notably, this study has several limitations, such as the relatively small sample size of patients recruited from a single center. Therefore, further studies with larger sample sizes and more diverse population centers are necessary to corroborate the findings. Additionally, even though the follow-up duration of patients was investigated for up to 6 months, conducting studies with longer-term examinations should be on the agenda of future studies.

Conclusion

Despite the increase in muscle thickness observed in both groups over time, the present study findings suggest that MAD treatment leads to a measurable biomechanical adaptation in the masticatory and suprahyoid muscles, likely due to prolonged advancement of the mandible. The absence of significant unfavorable ultrasonographic changes in muscle pattern supports the safety profile of MADs for the OSA management and no contraindications for long-term usage. However, the clinical implications of the observed changes in the SCM pattern within the BB group warrant further investigation, and additional studies are necessary to corroborate this evidence.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13005-025-00509-6.

Supplementary Material 1
Supplementary Material 2
Supplementary Material 3
Supplementary Material 4
Supplementary Material 5
Supplementary Material 6
Supplementary Material 7
Supplementary Material 8

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Author contributions

M.H., A.M., and A.T.M. conducted initial investigations, literature searches, and conceptualization of the study. M.A. supervised the project implementation and contributed significantly to the study methodology. M.I. and M.H. performed the study evaluations. R.S. and A.K. drafted the initial manuscript.

M.H., A.K., H.A., and L.A. collaborated in data collection. All co-authors reviewed the manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
The study was approved by the ethics committee of Mashhad University of Medical Sciences, which follows the ethics code IR.MUMS.DENTISTRY.REC.1400.125.

Consent for publication
Not applicable. The publication does not contain details, images relating to an individual person.

Competing interests
The authors declare no competing interests.

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