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EFFECT OF EXPIRATORY MUSCLE TRAINING ON STOMATOGNATHIC SYSTEM IN PATIENTS WITH STROKE

İNMELİ HASTALARDA EKSPİRATUAR KAS EĞİTİMİNİN STOMATOGNATİK SİSTEME ETKİSİ

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ABSTRACT

Objective: The aim of this study was to assess the effect of expiratory muscle training on the stomatognathic system in patients with stroke.

Method: A total of 31 patients with stroke were included in the study: 16 patients with stroke (age=66.63±8.38, height=166.38±8.59, BMI=28.09±4.81) as the control group and 15 patients with stroke (age=65.60±7.62, height=168.20±8.78, BMI=28.95±6.92) as the study group. Temporomandibular joint range of motion and dysfunction, pressure pain threshold of masticatory muscles, facial asymmetry existence, head posture, oral hygiene, oral hygiene habit, masticatory performance, intraoral pH, deglutition, and deep neck flexor muscle endurance of the patients with stroke were assessed. Assessment methods were in order by digital caliper, the Fonseca Questionnaire, algometry, labial commissure and craniocervical angle measurement, general oral health assessment index, and questionnaire, sieve test, digital pH gauge, repetitive saliva swallow test, Eating Assessment Tool, and deep neck flexor endurance test. Patients with stroke in the study group were enrolled in an expiratory muscle training program consisting of 5 sets of 10 repetitions daily for three weeks in addition to conventional physiotherapy; the control group enrolled in the conventional physiotherapy program. Patients with stroke in the study group were called twice a week to assess their compliance with the expiratory muscle training.

Results: In intragroup comparison significant increase was found in the inferior portion of the left masseter, mandibular protrusion, and a decrease in labial commissure angle and Fonseca Questionnaire score of the control group ($p<0.05$). In the study group a significant increase was observed in mandibular depression ($p<0.05$). In intragroup comparison, both groups had similar intraoral pH, masticatory performance, craniocervical angle and neck flexor muscle endurance ($p>0.05$). While significant difference was found in lateral deviation, eating assessment inventory and labial commissure angle in intergroup comparison ($p<0.05$), other parameters were similar ($p>0.05$). Improvement in labial commissure angle was in favor of the control group ($p<0.05$).

Conclusion: Expiratory muscle training might be preferred to increase mandibular lateral deviation and improve deglutition in subacute or chronic-stage patients with stroke.

Key Words: Mastication, Deglutition, Temporomandibular Joint

ÖZ

Amaç: Bu çalışmanın amacı ekspiratuar kas eğitiminin inmeli hastaların stomatognatik sistemine etkisini incelemekti.

Yöntem: Çalışmaya kontrol grubuna 16 inmeli hasta (yaş=66.63±8.35, boy=166.38±8.59, BKİ=28.09±4.81), çalışma grubuna 15 inmeli hasta (yaş=65.60±7.62, boy=168.20±8.78, BKİ=28.95±6.42) olmak üzere toplam 31 inmeli hasta dahil edildi. İnmeli hastaların temporomandibular eklem hareket açıklığı ve disfonksiyonu, çiğneme kasları ağrı eşiği, fasiyal asimetri varlığı, baş postürü, oral hijyen ve oral hijyen alışkanlıkları, çiğneme performansı, intraoral pH, yutma ve derin boyun fleksör kasları enduransı değerlendirildi. Değerlendirme yöntemleri sırasıyla; dijital kaliper, Fonseka Anketi, algometre, labial kommissür ve kranioservikal açı ölçümü, genel oral sağlık değerlendirme indeksi ve anket, elek testi, dijital pH ölçer, tekrarlı saliva yutma testi, yeme değerlendirme envanteri ve derin boyun fleksörleri endurans testiydi. Çalışma grubundaki inmeli hastalar konvansiyonel fizyoterapi programına ek olarak üç hafta süresince, haftada her gün 5 set 10 tekrardan oluşan ekspiratuar kas eğitimi programına, kontrol grubuysa konvansiyonel fizyoterapi programına alındı. Çalışma grubundaki inmeli hastalar haftada iki gün aranarak, ekspiratuar kas eğitimi programına olan uyumları değerlendirildi.

Bulgular: Grup içi karşılaştırmada kontrol grubundaki bireylerin sol masseter inferior parçası ağrı eşiklerinde ve protrüzyon hareketinde artış, labial kommissür açılarında ve Fonseka Anketi skorlarında ise azalma gözlendi ($p<0.05$). Çalışma grubunda yer alan inmeli hastaların ise mandibular depresyonunda artış bulundu ($p<0.05$). Grup içi karşılaştırmada gruplar benzer intraoral pH, çiğneme performansı, kranioservikal açı ve derin boyun fleksörleri enduransı değerlerine sahipti ($p>0.05$). Gruplar arası karşılaştırmada ise lateral deviasyon, yeme değerlendirme envanteri ve labial kommissür açısında anlamlı fark bulunurken ($p<0.05$), diğer parametreler benzerdi ($p>0.05$). Labial kommissür açısındaki iyileşme kontrol grubu lehineydi ($p<0.05$)

Sonuç: Ekspiratuar kas eğitimi subakut ya da kronik dönem inme hastalarında mandibular lateral deviasyonun arttırılmasında ve yutmanın iyileştirilmesinde tercih edilebilir.

Anahtar Kelimeler: Çiğneme, Yutma, Temporomandibular Eklem

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INTRODUCTION

Stroke is defined by the World Health Organization as "caused by the interruption of the blood supply to the brain, usually because a blood vessel bursts or is blocked by a clot. This cuts off the supply of oxygen and nutrients, causing damage to the brain tissue" [1]. A variety of sensorimotor symptoms develop due to stroke [2,3].

The stomatognathic system is one of the systems affected by the stroke [4]. The stomatognathic system, consisting of the temporomandibular joint (TMJ), dental arcs, saliva glands, masticatory muscles, and cervical muscle groups, plays an active role in vital activities such as mastication, deglutition, and respiration [5]. The stomatognathic system's functionality is aided by the interrelationship between the neuromusculoskeletal and respiratory systems [5,6]. Any disruption in this dynamic interrelation triggers the cascade that results in the loss of functions of the stomatognathic system.

As mentioned above, stroke is a disease that triggers the cascade, and stomatognathic system dysfunction has developed [4]. Respiratory and orofacial dysfunction due to stroke is mainly responsible for the compromise of the stomatognathic system. Both dysfunction types cause stomatognathic system dysfunction by indirectly or directly affecting mastication and deglutition [7,8].

Orofacial dysfunction is commonly seen in post-stroke symptoms and is characterized by losses in perioral and lingual muscle strength and coordination and salivary gland function. Lack of perioral and lingual muscle strength and coordination leads to impaired mastication, diminished or impaired lip seal during mastication, and inadequate bolus transfer to the occlusal surface. Compromise in the salivary glands gives rise to impairments in the functions of the salivary glands. Considering mastication participates in the oral phase of deglutition, orofacial dysfunction may also cause impaired deglutition [7]. Similarly, respiratory dysfunction also commonly develops in patients with stroke. Respiratory dysfunction causes reductions in the contralesional diaphragm excursion, forced vital capacity, forced expiratory volume in the first second, and peak expiratory flow values [9]. Considering that peak expiratory flow is related to coughing, that comes into play in the preventing aspiration pneumonia [10].

The dynamic interrelationship between the respiratory system and the stomatognathic system has established a ground for similar and common rehabilitative approaches to the dysfunction of these systems. Expiratory muscle training (EMT), aiming to improve the dynamic coordination between the respiratory system and deglution via strengthening the expiratory muscle, is one of the therapeutic approaches that developed in this manner [8]. The respiratory system is also related to the stomatognathic system, considering deglutition is one of the functions of the stomatognathic system [6]. However, the existing literature mainly focuses on the effect of EMT on deglutition [11,12]. From this point of view, this study aims to assess and analyze the effect of EMT on the stomatognathic system.

METHOD

A power analysis with a 95% effect size and .10±.15 tolerance was performed based on a previous study [12]. It was found that each group should at least consist of 15 individuals. A total of 31 individuals were included in the study: 16 patients as the control and 15 as the study group. Due to the COVID-19 pandemic, patient participation in the control group was prioritized. Study group enrollment began after the control group's enrollment was completed.

Individuals were included in the study if their mini-mental test score was equal to 24 or above [13], their Fonseca questionnaire score was 20 points or above [14], their stroke onset period was between 3 months and 5 years, they were diagnosed with ischemic stroke, and they were 55 years of age or older. The following individuals were excluded from the study: patients who have dysphagia due to neurological or neurodegenerative diseases except for stroke, multiple stroke stories, head or neck cancer stories, abdominal or thoracic surgery stories, accompanying neurodegenerative disease or infection, lack of a lower or upper central incisor or lateral canine tooth, and lack of masticatory performance (Figure 1).

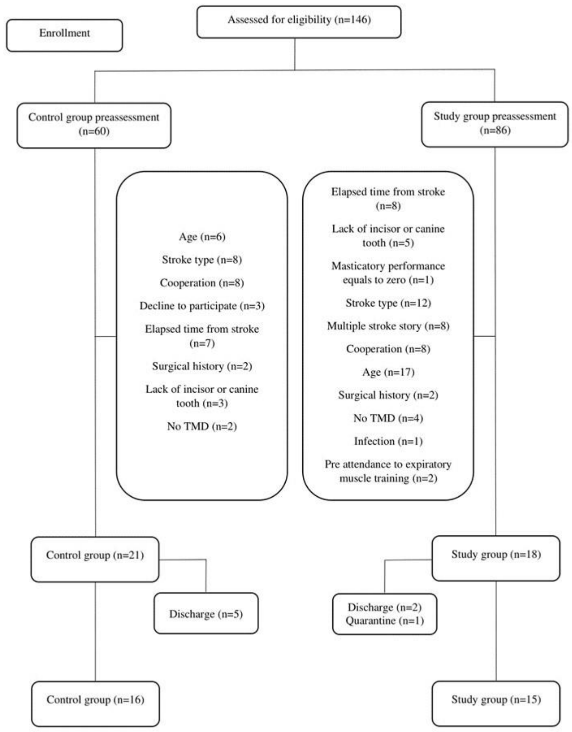

Figure 1. Study flow chart

Cognitive function, temporomandibular joint dysfunction (TMJD), TMJ range of motion, masticatory muscle pressure pain threshold, labial commissure and craniocervical angle, deglutition, masticatory performance, intraoral pH, deep neck flexor muscle endurance, and general oral health of the individuals were measured or assessed as described below.

The cognitive function of the individuals was assessed with a mini mental state examination test. The test consists of 11 items and five main areas: orientation, registration, attention and calculation, recall, and language. The total score of the test is 30 points. A total score of 24 or higher indicates no cognitive impairment [13].

The Fonseca Questionnaire was used for the assessment of TMJD. The Fonseca Questionnaire consists of ten questions. A higher total score in the questionnaire is directly proportional to the severity of the TMJD [14].

The TMJ range of motion was measured by a digital caliper. Individuals were asked to open their jaws as wide as possible for the depression motion, and then the central incisor distance was measured. Prior to lateral deviation measurement, the upper central incisor position relative to the lower central incisor was vertically marked with a biocompatible pen, and subsequently, individuals were asked to deviate their jaw as much as possible. When the deviation was achieved, a second drawing was performed. Then, the horizontal distance between the two markings was measured for one side's lateral deviation value. In protrusion motion measurement, individuals were asked to move their lower jaw as forward as possible, and then the horizontal space between the upper and lower incisors was measured [15]. The reference value for mandibular depression is 40 mm, for protrusion 6 mm, and for lateral deviation 8 mm [16].

An analogue algometer was used for pressure pain threshold measurement. The masticatory muscles' pressure pain threshold was measured bilaterally on the masseter and temporalis muscles. Four points were measured: two points in the masseter and two in the temporalis. Measurements were repeated four times for each point starting from the masseter, with a 5-second interval between each measurement and 2 minutes between the completion of the first measurement of all areas [17].

The labial commissure angle was measured to evaluate central facial paralysis. The labial commissure angle was measured by a camera (Sony SLT- A35 16.2 megapixels) that had been secured on a tripod and was 1 m away while individuals were sitting on a chair. After individuals were positioned, photographs were taken without flashlight and printed in black and white in a 15 cm x 21 cm dimension. Bilateral chelions, glabella, and gnathion were marked, and drawings that combined the markings were made on the printed photograph. After that, the angle between these two drawings was measured with a protractor. The normal labial commissure angle is 90 degrees [18].

Head posture was assessed via craniocervical angle measurement. The craniocervical angle was measured while individuals were sitting on a chair with their heads in a natural position. The spinous process of the C7 was marked with a marker, and lateral photographs were taken by a camera (Sony SLT- A35 16.2 megapixels) and printed. The angle between the two drawings was measured with a protractor subsequently. The lower the angle, the higher the forward head posture [19].

Deglutition of the individuals was assessed with the repetitive saliva swallowing test. For the repetitive saliva swallowing test, individuals were asked to repeatedly swallow their saliva for 30 seconds. While individuals were performing the test, the number of swallows was determined with the finger positioned on the individual's hyoid bone. Values equal to or lower than two require further assessment [20].

The eating assessment tool was used for deglutition assessment. The eating assessment tool consists of 10 questions with zero-to-four-point scoring answers, and the maximum score is 40 points. The higher the total score, the higher the deglutition impairment [21].

In the sieve test that assesses masticatory performance, patients were asked to chew 20 times the pre-weighted 3 g peanut and then spit the chewed substance into a half-liter beaker. This procedure was repeated five times; after this, the substance was gathered in a beaker, stirred, and subsequently sifted through a sieve with ten mesh and 1700 μm openings. After sifting, the substance passed through the sieve, and the substance piled on the sieve was transferred to a 15-ml centrifuge tube separately. Then, both centrifuge tubes were placed in the centrifuge devices and centrifuged for 3 minutes at 1500 rpm. Both centrifuge tube volumes were calculated after the centrifuge process, after which the masticatory performance was calculated. The higher the percentage, the better the masticatory performance [22].

The intraoral pH value of the saliva was measured with a digital pH gauge (ADWA-ad12). Individuals were asked not to drink anything except water from the previous evening for the intraoral pH measurement. Samples were collected later that day between 08:00 and 12:00 a.m. Prior to saliva collection, patients were asked to rinse their mouths with water, and five minutes later, sample collection started. Patients were asked to empty the saliva ten times that had been gathered at a one-minute interval, and then intraoral pH was measured [23,24]. The average intraoral pH is 6.8 [24].

The deep neck flexor muscle endurance was assessed with an endurance test. While patients were in the supine position with their knees and hips flexed, referred to as the hook-lying position. Patients were asked to retract their chins as maximally as possible, then elevate their heads one inch and sustain in this position. One hand of the assessor was placed around the patient's neck. The chronometer was started and stopped when the patient's head touched the hand of the assessor. The longer the time, the greater the muscle endurance [25].

The individuals' oral health was evaluated with the general oral health assessment index. The general oral health assessment index consists of twelve questions assessing parameters such as mastication, deglutition, and dental integrity. A higher score correlates with higher general oral health loss. The total score of the index ranges from 12 points as the minimum score to 60 points as the maximum score [26].

Patients in both groups were enrolled in a one-hour daily conventional physiotherapy program during the study period. The conventional physiotherapy program consisted of electromuscular stimulation, neurophysiologic approaches including Brunnstrom and Bobath concepts, and exercises for lower and upper limb rehabilitation using proprioceptive neurorehabilitation techniques. Patients in the study group were further enrolled in the EMT home exercise program during the study period. EMT was applied with a Philips Respironics device. Patient-specific resistance was set via the perceived exertion scale at 13-15 points [27]. Devices were handed over to patients for daily use for three weeks after the proper resistance was set. Patients were asked to perform five sets of 10 repetitions in each test with a one-minute interval [28]. EMT was performed daily for three weeks. Compliance with the training was assessed via phone calls made twice a week [29].

Ethical Approval

This study was approved by the Bolu Abant İzzet Baysal University Clinical Research Ethics Committee (2020/54) and conducted at the İzzet Baysal Physical Therapy and Rehabilitation Training and Research Hospital. Prior to participation, individuals were verbally informed, and written consent was obtained from the participants.

Statistical Analysis

Data analysis was performed using the SPSS 22 program. Continuous variables were illustrated as average, standard deviation, and categorical variables as number and percentage. The normal distribution of the data was evaluated with the Shapiro-Wilk test. Whether or not the parametric assumptions were achieved, the independent sample t-test or Mann-Whitney U test was used for the independent group comparison, and the paired t-test or Wilcoxon signed-rank test was used for the dependent group comparison. Differences between the categorical variables were analyzed with the chi-square test. Statistically, the significance grade was determined as $p<0.05$.

RESULTS

Both groups' physical characteristics and demographic data were homogeneous (Table 1).

Table 1. Demographic data and physical characteristics of the patients

Characteristics	Control group		Study group		t	p
	Mean	SD	Mean	SD		
Age (year)	66.63	8.35	65.60	7.62	.356	.724
Height (cm)	166.38	8.59	168.20	8.78	-.585	.563
Weight (kg)	76.82	16.65	80.91	12.19	-.777	.444
BMI (kg/cm^2)	28.09	4.81	28.95	6.42	-.424	.675
Poststroke elapsed time (month)	13.00	15.82	14.80	13.16	-.343	.734

**p<0.05 independent t test; SD: Standard deviation.*

More than half of the patients had right-side stroke in both groups. Arteria cerebri media occlusion was in the foreground for both groups. Hypertension was highly observed in both groups. Antihypertensive and anticoagulant medication was 94% for the control group; for the study group, these percentages were 93% and 100%. Patients in both groups were at least in stage 3, according to the Brunnstrom stage of stroke recovery. Nearly half of the patients in the control group and more than half of the patients in the study group were in the chronic stage of the stroke. Most of the patients in the EMT group were fully compliant with the training (Table 2).

Table 2. Intergroup comparison of premorbid diseases and stroke characteristics

Characteristics		**Control group**		**Study group**		**p**
		n	**%**	**n**	**%**	
Impaired body side	Right	9	56	8	53	.870
	Left	7	44	7	47	
Affected artery	Cerebri media	15	94	10	66	.116
	Cerebri anterior	1	6	2	13	
	Cerebri posterior	-	-	3	21	
Poststroke elapsed time	6< months	7	44	3	20	.344
	≥6 months	9	56	12	80	
Hypertension	Yes	15	94	14	93	.962
	No	1	6	1	7	
Diabetes mellitus	Yes	9	56	5	33	.200
	No	7	44	10	67	
Brunnstrom stages (Upper limb)	Stage 3	13	82	8	54	
	Stage 4	1	6	3	20	
	Stage 5	1	6	3	20	
	Stage 6	1	6	1	6	
Brunnstrom stages (Lower limb)	Stage 3	9	56	3	20	
	Stage 4	4	25	8	53	
	Stage 5	3	19	4	27	
Compliance with EMT	Fully compliant	-	-	13	87	
	Partially compliant	-	-	1	6.5	
	Poorly compliant	-	-	1	6.5	

*Chi square test; *p<0.05.*

In intragroup comparison, a significant increase in pressure pain threshold of the left masseter and mandibular protrusion, a significant decline in the Fonseca Questionnaire score, and a significant improvement in the labial commissure angle were found in the control group, and a significant increase in mandibular depression of study group (p<0.05). Other assessed stomatognathic system parameters were similar in both groups (i.e., masticatory performance, intraoral pH) (p>0.05) (Table 3).

In intergroup analysis, a significant decrease was observed in the labial commissure angle in favor of the control group and a significant decrease in the eating assessment tool in favor of the study group (p<0.05) (Table 4).

Baseline values of depression, intraoral pH, labial and craniocervical angle, deep neck flexor muscle endurance, repetitive saliva swallow test, eating assessment tool, and general oral health assessment index were significantly different (p<0.05). Other assessed stomatognathic system parameters were similar in both groups (i.e., mastication, neck muscle endurance) (p>0.05). Because the first measurement values of the groups were different, an analysis of the difference between the first and last measurements was performed. As a result of this analysis, a significant difference was found in the right and left lateral deviation range of motions in favor of the study group (p<0.05). (Table 5).

DISCUSSION

The aim of this study was to assess the effect of expiratory muscle training on the stomatognathic system in patients with stroke. This study showed that EMT is a practical approach to increase mandibular lateral deviation and improve deglutition in patients with stroke.

A variety of studies report the exercise compliance of the Turkish population. In a study by Ay et al. [30] the exercise compliance rate of elderly patients with knee osteoarthritis was reported to be 62.5%. In our study, exercise compliance of patients with stroke with the EMT was high. This difference might result from exercise type and patients' symptoms.

Postural adaptations might cause alterations in mandibular condyle position. A study by Ohmure et al. [31] points out the effect of malposture (forward head posture) on mandibular condyle position. From this point of view, we hypothesized that placement of EMT to mouth might alter the mandibular condyle position, yet our hypothesis has been rejected. Considering the post-stroke elapsed time, the anterior tilt of the head turns into chronic malposture. For this reason, EMT may have fallen short in improving chronic malposture.

Passive stretching improves mandibular depression range of motion [32]. The effect of passive stretching on mandibular depression was characterized by increased mandibular depression, right and left lateral deviation range of motion in the study group. Although the range of motion of the control group was below the minimum reference values except for mandibular depression, significant improvement occurred in protrusion in the three weeks of follow-up. This might be the cumulative effect of the improvement in pressure pain threshold of the inferior portion of the left masseter and masticatory performance. Increased masticatory performance and pressure pain threshold of the inferior portion of the left masseter muscle might improve the protrusion by changing the muscular activity and functional improvement in the muscle fibers that play a role in protrusion.

A significant difference was observed in the right and left lateral deviation in the intergroup comparison of pretest and posttest values. This might be caused by increased lateral pterygoid muscle strength and coordination. Bilateral activation of the lateral pterygoid is required to place the EMT device in the mouth. The lateral pterygoid muscle also participates in contralateral deviation movements [5]. From this perspective, EMT may increase the lateral deviation.

Over the 3-week follow-up, except for the pressure pain threshold of the inferior portion of the left masseter, the pressure pain threshold of the masticatory muscles of the control group was similar. We believe that the improvement in the inferior portion of the left masseter pressure pain threshold is due to a significant decrease in the total score of the Fonseca Questionnaire.

It is stated that most of the disc displacement with reduction patients had no accompanying pain, which supports our claim [33]. The pressure pain threshold of the masticatory muscles following EMT was not improved. The type of TMJD probably played a significant role in this case. Most of the patients in our study had crepitation during mandibular depression movement, characterized by disc displacement with reduction. The effect of exercise on facial muscles is reported by Uchida et al., pointing out that exercise does not only affect the targeted muscle facial mimicry as well. The finding of Uchida et al. might be the factor for the improvement in the labial commissure angle of the control group in the three weeks of follow-up [34]. We believe this improvement might be caused by the patient's physiotherapy program and the individual exercises they perform in their free time.

Table 3. Intragroup comparison of the stomatognathic system component, functions, and questionnaires

Assessed parameters		Control group				Study group			
		First measurement	Second measurement	z	p	First measurement	Second measurement	z	p
Pressure pain threshold	Right temporalis anterior (kg/cm^2)	1.86 (1.56-2.56)	1.86 (1.66-2.60)	-.456	.648	2.3 (1.9-3.06)	2.3 (2-2.76)	-.178	.859
	Left temporalis anterior (kg/cm^2)	1.83 (1.6-2.5)	1.8 (1.7-2.63)	-.306	.759	2.3 (1.9-2.96)	2.33 (2-2.66)	-.867	.386
	Right temporalis middle (kg/cm^2)	1.91 (1.7-2.73)	1.95 (1.76-2.7)	-.223	.824	2.3 (2-3.16)	2.5 (2-2.86)	-.178	.859
	Left temporalis middle (kg/cm^2)	1.9 (1.7-2.7)	1.9 (1.8-2.73)	-.584	.559	2.3 (2-3.13)	2.43 (2-2.83)	-.446	.656
	Right masseter anterior (kg/cm^2)	1.3 (1.1-1.76)	1.3 (1.2-1.83)	-1.695	.090	1.5 (1.36-1.86)	1.5 (1.2-1.66)	-1.618	.106
	Left masseter anterior (kg/cm^2)	1.3 (1.1-1.8)	1.31 (1.2-1.8)	-1.873	.061	1.5 (1.13-1.83)	1.5 (1.1-1.66)	-1.643	.1
	Right masseter inferior (kg/cm^2)	1.24 (1.1-1.66)	1.3 (1.2-1.73)	-1.202	.229	1.4 (1.3-1.8)	1.46 (1.1-1.73)	-.867	.386
	Left masseter inferior (kg/cm^2)	1.2 (1.1-1.7)	1.3 (1.1-2.1)	-2.106	**.030***	1.5 (1.13-1.7)	1.46 (1.1-1.6)	-1.281	.2
Temporomandibular joint range of motion	Depression (mm)	40.61 (31.71-55.00)	40.20 (31.44-54.88)	-.879	.379	41.42 (25.07-45.89)	42.39 (30.99-53.07)	-1.988	**.047***
	Right lateral deviation (mm)	5.54±2.49	5.61±2.15	-.338	.740	7.44±2.04	8.09±2.34	-1.698	.113†
	Left lateral deviation (mm)	4.36 (2.99-10.23)	5.11 (3.26-9.21)	-.750	.453	7.11 (3.05-14.13)	7.37 (3.86-9.25)	-1.704	.088
	Protrusion (mm)	3.85 (1.48-9.77)	4.24 (2.02-11.76)	-2.301	**.021***	5.36 (2.21-7.66)	5.68 (3.85-7.82)	-.682	.496
Saliva pH	Intraoral pH	6.66±0.4	6.63±.34	.399	.696	6.45±.28	6.54±0.30	-1.296	.216
Mastication	Masticatory performance (%)	.13±.07	.16±.1	-1.424	.175	.24±.18	0.25±0.17	-.743	.470
Central facial paralysis	Labial commissure angle(°)	92 (89-98)	90.5 (89-95)	-2.521	**.012***	91 (83.5-93)	90 (85-92)	-1.842	.065
Head posture	Craniocervical angle (°)	29.09±11.95	30.53±11.95	-.490	.631	28.93±12.54	27.07±12.57	.838	.416
Neck muscle endurance	Deep neck flexor muscle endurance (s^{-1})	27.12±11.58	27.92±10.58	-.657	.521	24.02±10.89	26.97±14.25	-1.533	.147
Deglutition	Repetitive saliva swallow test	2.5 (2-4)	3 (2-4)	-.816	.414	3 (2-6)	3 (2-6)	-1.300	.194
Temporomandibular joint dysfunction	Fonseca Questionnaire	20 (20-40)	20 (15-30)	-2.165	**.030***	25 (20-40)	25 (10-40)	-1.897	.058
Deglutition	Eating assessment tool	0 (0-5)	0 (0-5)	-1.30	.194	0 (0-6)	0 (0-4)	-1.414	.157
Oral health	General oral health assessment index	52 (34-53)	52 (34-53)	-1.00	.317	52 (46-52)	52 (46-52)	.000	1

**p<0.05; Wilcoxon signed-rank test; Paired samples t test.*

Table 4. Intergroup comparison of baseline and final values

Assessed parameters		Control group				Study group			
		First measurement	Second measurement	z	p	First measurement	Second measurement	z	p
Pressure pain threshold	Right temporalis anterior (kg/cm^2)	1.86 (1.56-2.56)	2.3 (1.9-3.06)	3.415	**<.001***	1.86 (1.66-2.60)	2.3 (2-2.76)	3.652	**<.001***
	Left temporalis anterior (kg/cm^2)	1.83 (1.6-2.5)	2.3 (1.9-2.96)	3.433	**<.001***	1.8 (1.7-2.63)	2.33 (2-2.66)	3.568	**<.001***
	Right temporalis middle (kg/cm^2)	1.91 (1.7-2.73)	2.3 (2-3.16)	3.113	**.002***	1.95 (1.76-2.7)	2.5 (2-2.86)	3.430	**<.001***
	Left temporalis middle (kg/cm^2)	1.9 (1.7-2.7)	2.3 (2-3.13)	3.053	**.002***	1.9 (1.8-2.73)	2.43 (2-2.83)	3.445	**<.001***
	Right masseter anterior (kg/cm^2)	1.3 (1.1-1.76)	1.5 (1.36-1.86)	3,909	**<.001***	1.3 (1.2-1.83)	1.5 (1.2-1.66)	3.150	**.002***
	Left masseter anterior (kg/cm^2)	1.29±.16	1.50±16	3.495	**.002***	1.31 (1.2-1.8)	1.5 (1.1-1.66)	3.107	**.002***
	Right masseter inferior (kg/cm^2)	1.24 (1.1-1.66)	1.4 (1.3-1.8)	3.660	**<.001***	1.3 (1.2-1.73)	1.46 (1.1-1.73)	3.262	**.001***
	Left masseter inferior (kg/cm^2)	1.2 (1.1-1.7)	1.5 (1.13-1.7)	3.540	**<.001***	1.3 (1.1-2.1)	1.46 (1.1-1.6)	2.777	**.005***
Temporomandibular joint range of motion	Depression (mm)	40.61 (31.71-55)	41.42 (25.07-45.89)	.004	.968	40.20 (31.44-54.88)	42.39 (30.99-53.07)	.474	.635
	Right lateral deviation (mm)	5.54±2.49	7.44±2.04	2.318	**.028***	5.61±2.15	8.09±2.34	3.077	**.005***
	Left lateral deviation (mm)	4.36 (2.99-10.23)	7.11 (3.05-14.13)	2.412	**.016***	5.11 (3.26-9.21)	7.37 (3.86-9.25)	1.996	**.046***
	Protrusion (mm)	3.85 (1.48-9.77)	5.36 (2.21-7.66)	2.016	**.044***	4.24 (2.02-11.76)	5.68 (3.85-7.82)	2.293	**.022***
Saliva pH	Intraoral pH	6.66±0.4	6.45±.28	1.640	.112	6.63±.34	6.54±0.30	.780	.441
Mastication	Masticatory performance (%)	.13±.07	.24±.18	2.108	**.049***	.16±.1	0.25±0.17	1.823	.079
Central facial paralysis	Labial commissure angle(°)	92 (89-98)	91 (83.5-93)	1.584	.113	90.5 (89-95)	90 (85-92)	2.165	**.030***
Head posture	Craniocervical angle (°)	29.09±11.95	28.93±12.54	.036	.971	30.53±11.95	27.07±12.57	.787	.438
Neck muscle endurance	Deep neck flexor muscle endurance (s$^{-1)}$	27.12±11.58	24.02±10.89	.766	.450	27.92±10.58	26.97±14.25	.211	.834
Deglutition	Repetitive saliva swallow test	2.5 (2-4)	3 (2-6)	1.059	.290	3 (2-4)	3 (2-6)	.715	.475
Temporomandibular joint dysfunction	Fonseca Questionnaire	20 (20-40)	25 (20-40)	1.981	**.048***	20 (15-30)	25 (10-40)	1.527	.127
Deglutition	Eating assessment tool	0 (0-5)	0 (0-6)	1.653	.098	0 (0-5)	0 (0-4)	2.162	**.031***
Oral health	General oral health assessment index	52 (34-53)	52 (46-52)	.000	1	52 (34-53)	52 (46-52)	.000	1

**p<0.05; Mann Whitney U test; Paired samples t test.*

Table 5. Comparison of pretest and posttest difference

Variables	Control group	Study group	u	p
	(Mean±standard deviation)			
Masticatory performance	.06±.06	.05±.03	.702	.488
Right temporalis anterior	.09±.09	.08±.11	-.763	.445
Right temporalis middle	.08±.09	.08±.11	-.385	.700
Right masseter anterior	.06±.07	.08±.07	-.721	.471
Right masseter inferior	.07±.05	.08±.07	1	1
Left temporalis anterior	.08±.09	.09±.11	-.061	.951
Left temporalis middle	.07±.06	.10±.09	-.707	.480
Left masseter anterior	.08±.08	.06±.07	-.748	.455
Left masseter inferior	.08±.06	.05±.07	-1.422	.155
Protrusion	.75±0.63	.93±.79	-.554	.580
Right lateral deviation	.61±.53	1.24±1.00	-2.162	**.042***
Left lateral deviation	.65±.76	1.45±1.24	-2.550	**.011***
Fonseca Questionnaire	3.44±3.97	4.33±6.51	-.087	.930

**p<0.05; Mann Whitney U test; Paired samples t test.*

Following EMT, the labial commissure angle was similar to the pretest value. We consider that this might be caused by the setting of the device's resistance in a patient-orientated, subjective manner. It is known that a portable expiratory pressure measurement device is used for setting the resistance of the EMT device [10].

Following the EMT, no improvement was seen in the craniocervical angle. This is because EMT did not achieve the desired effect, characterized by strengthening the muscles taking part in the malposture, specifically the anterior tilt of the head. It is mentioned that 20 minutes of steady position ends up with crepitation and recovers in double time [35]. From this point of view, the importance of timing and resistance setting of the EMT devices yields rehabilitation of the craniocervical component of the post-stroke developed malposture.

EMT is one of the preferred approaches for the rehabilitation of deglutition [11]. Following EMT, no change was observed in the repetitive saliva swallow test. This might be caused by the fact that EMT was not achieved to increase salivary synthesis by mechanical stimulation effect. It is known that mechanical stimulation results in an increased salivary flow rate [36]. Contrary to the repetitive saliva test, significant improvement was observed in the eating assessment inventory. This might be caused by the stimulation effect of the EMT device on the hyoid bone. The placement of an EMT device on the mouth resulted in hyoid elevation, according to a study by Wheeler-Hegland et al. [37].

The decline in masticatory performance following stroke was remarkable. From a shortened dental arc to orofacial dysfunction, many factors might play a role in the drastic value in the control group [38,39]. The high rate of prosthesis use and facial asymmetry in the control group might have reduced masticatory performance.

No improvement was observed in EMT aiming to improve masticatory performance by reducing the facial asymmetry rate and improving the perioral muscle strength and coordination. A similar masticatory performance was observed despite the reduction in facial asymmetry rate, pointing to the idea that the occlusal surface and dental prosthesis might be more effective on masticatory performance than the facial asymmetry rate.

It is known that mechanical stimulation results in an increased salivary flow rate [36]. From this point of view, we aimed to improve the intraoral pH by inducing mechanical stimulation by EMT. Similar intraoral pH values following EMT indicate that EMT may not be an option for intraoral pH regulation.

No improvement was observed after EMT, aiming to improve deep neck flexor muscle endurance by improving the craniocervical angle. We believe the similar craniocervical angle following the EMT is responsible for this. A negative correlation between deep neck flexor endurance and anterior tilt of the head supports our claim [40].

Limitations

The study's non-randomized nature due to the pandemic and inability to measure the maximal expiratory pressure value owing to the pandemic are the study's limitations.

CONCLUSION

Our study showed that EMT is effective when improvement was aimed in the TMJ range of motions especially for the right and left lateral deviation movements, improve deglutition, craniocervical posture, and other functions and structures of the stomatognathic system.

The effect of EMT on stomatognathic system structures and functions was assessed in detail. Although current studies exist related to the topic, our study is the first study that assesses the stomatognathic system structures and functions in a cumulatively.

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REFERENCES

1. Mackay J, Mensah GA, Mendis S, Greenlund K. The atlas of heart disease and stroke World Health Organization. 2004.
2. Mayer NH, Esquenazi A. Muscle overactivity and movement dysfunction in upper motoneuron syndrome. Phys Med Rehabil Clin N Am. 2003;14:855-883.
3. Tyson SF, Hanley M, Chillala J, Selley A, Tallis RC. Balance disability after stroke. Phys Ther. 2006;86(1):30-38.
4. Dursun Ö, Çankaya T. Assessment of temporomandibular joint dysfunction in patients with stroke. J Stroke Cerebrovasc Dis. 2018;27(8):2141-2146.
5. Okeson JP. Management of Temporomandibular Disorders and Occlusion. Missouri: Mosby/Elsevier Publishing Company; 2012.
6. Selley WG, Flack FC, Ellis RE, Brooks WA. Respiratory patterns associated with swallowing: Part 1. The normal adult pattern and changes with age. Age Ageing. 1989;18(3):168-172.
7. Dai R, Lam OLT, Lo ECM, Li LSW, Wen Y, McGrath C. Orofacial functional impairments among patients following stroke: a systematic review. Oral Dis. 2015;21(7):836-849.
8. Brooks M, McLaughlin E, Shields N. Expiratory muscle strength training improves swallowing and respiratory outcomes in people with dysphagia: a systematic review. Int J Speech Lang Pathol. 2019;21(1):89-100.
9. Khedr EM, Shinawy OE, Khedr T, Ali YAA, Awad EM. Assessment of corticodiaphragmatic pathway and pulmonary function in acute ischemic stroke patients. Eur J Neurol. 2000;7(5):509-516.
10. Kulnik ST, Birring SS, Moxham J, Rafferty GF, Kalra L. Does respiratory muscle training improve cough flow in acute stroke? Pilot randomized controlled trial. Stroke. 2015;46:447-453.
11. Hegland KW, Davenport PW, Brandimore AE, Singletary FF, Troche MS. Rehabilitation of swallowing and cough functions following stroke: an expiratory muscle strength training trial. Arch Phys Med. 2016;97(8):1345-1351.
12. Eom MJ, Chang MY, Oh DH, Kim HD, Han NM, Park JS. Effects of resistance expiratory muscle training in elderly patients with dysphagic stroke. Neurorehabil. 2017;41(4):747-725.
13. Folstein MF, Folstein SE, McHugh PR. "Mini-Mental State": A practical method for grading the cognitive state of patients for the clinician. J Psychiatr Res. 1975;12(3):189-198.

14. Da Fonseca DM, Bonfante G, Valle AL, De Freitas SFT. Diagnostico pela anamnese da disfunçao craniomandibular. Rev Gauch de Odontol. 1994;4(1):23-32.
15. Walker N, Bohannon RW, Cameron D. Discriminant validity of temporomandibular joint range of motion measurements obtained with a ruler. J Orthop Sport Phys. 2000;30(8):484-492.
16. Dawson PE. Functional Occlusion: From TMJ to Smile Design. St Louis: CV Mosby; 2007.
17. Farella M, Michelotti A, Steenks MH, Romeo R, Cimino R, Bosman F. The diagnostic value of pressure algometry in myofascial pain of the jaw muscles. J Oral Rehab. 2000;27(1):9-14.
18. Tessitore A, Magna LA, Paschoal JR. Angular measurement for determining muscle tonus in facial paralysis. Pro Fono. 2010;22(2):119-124.
19. Castien R, Blankenstein A, Van Der Wint D, Heymans MW, Dekker J. The working mechanism of manual therapy in participants with chronic tension-type headache. J Orthop Sport Phys. 2013;43(10):693-699.
20. Oguchi K, Saitoh E, Baba M, Kusudo S, Tanaka T, Onogi K. Repetitive saliva swallowing test (RSST) as a screening test of functional dysphagia (2) validity of RSST. Jpn J Rehabil Med. 2000;37:383-388.
21. Belafsky PC, Mouadeb DA, Rees CJ, et al. Validity and reliability of the eating assessment tool (EAT-10). Ann Otol Rhinol Laryngol. 2008;117(12):919-924.
22. Kapur KK, Soman S, Yurkstas A. Test foods for measuring masticatory performance of denture wearers. J Prosthet Dent. 1964;14(3):483-491.
23. Baliga S, Muglikar S, Kale R. Salivary pH: A diagnostic biomarker. J Indian Soc Periodontol. 2013;17(4):461-465.
24. Ediriweera DS, Dilina N, Saparamadu V, et al. Aspirin is associated with low oral pH levels and antacid helps to increase oral pH. BMC Res Notes. 2018;11:137.
25. Harris KD, Heer DM, Roy TC, Santos DM, Whitman JM, Wainner RS. Reliability of a measurement of neck flexor muscle endurance. Phys Ther. 2005;85(2):1349-1355.
26. Atchison KA, Dolan TA. Development of the geriatric oral health assessment index. J Dent Educ. 1990;54(11):680-687.
27. Borg GA. Psychophysical bases of perceived exertion. Med Sci Sports Exerc. 1982;14:377-381.
28. Marco E, Ramírez-Sarmiento AL, Coloma A, et al. High-intensity vs. sham inspiratory muscle training in patients with chronic heart failure: a prospective randomized trial. Eur J Heart Fail. 2013;15:892-901.
29. Guclu MB, Arıkan H, Savcı S, et al. Effects of inspiratory muscle training in patients with heart failure. Resp Med. 2011;105:1671-1681.
30. Ay S, Evcik D, Kutsal YG, et al. Compliance to home-based exercise therapy in elderly patients with knee osteoarthritis. Turk J Phys Med Rehab. 2016;62(4):323-328.
31. Ohmure H, Miyawaki S, Nagata J, Ikeda K, Yamasaki K, Al-Kalaly A. Influence of forward head posture on condylar position. J Oral Rehabil. 2008;35:795-800.
32. Kraaijenfa S, Molen L, Tinteren H, Hilgers F, Smeele L. Treatment of myogenic temporomandibular disorder: a prospective randomized clinical trial, comparing a mechanical stretching device (TheraBite) with standard physical therapy exercise. Cranio. 2014;32(3):208-216.
33. Poluha RL, Canales GD, Costa YM, Grossmann E, Bonjardim LR, Conti PCR. Temporomandibular joint disc displacement with reduction: a review of mechanisms and clinical presentation. J Appl Oral Sci. 2019;27:e20180433.
34. Uchida MC, Carvalho R, Tessutti VD, et al. Identification of muscle fatigue by tracking facial expressions. Plos One. 2018;18:1-11.
35. McGill SM, Brown S. Creep response of the lumbar spine to prolonged full flexion. Clin Biomech. 1992;7:43-46.
36. Setiawan S, Haroen ER, Hadidjah D. The difference in saliva pH before and after brushing with fluoride containing toothpaste and without toothpaste. Padjajaran J Dent. 2008;20(3):139-142.
37. Wheeler-Hegland KM, Rosenbek JC, Sapienza CM. Submental sEMG and hyoid movement during Mendelsohn maneuver, effortful swallow, and expiratory muscle strength training. J Speech Lang Hear Res. 2008;51(5):1072-1087.
38. Schimmel M, Ono T, Lam OLT, Müller F. Oro-facial impairment in stroke patients. J Oral Rehab. 2017;44:313-326.
39. Miyaura K, Morita M, Matsua Y, Yamashita A, Watanabe T. Rehabilitation of biting abilities in patients with different types of dental prosthesis. J Oral Rehabil. 2000;27:1073-1076.
40. Nam C, Park Y, Lee J. Impact of cervical stabilization exercises and breathing retraining impact on the respiratory function of elderly stroke patients with hemiplegia: a randomized controlled trial. Int J Biosci Biotech. 2015;7(4):159-168.