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Original scientific paper

Influence of Occlusal Stabilization Splint on the Asymmetric Activity of Masticatory Muscles in Patients with Temporomandibular Dysfunction

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A B S T R A C T

The aim of present study was to evaluate the symmetry of masticatory muscles' activity at various clenching levels in the intercuspal position in patients with functional disorders and in healthy subjects. The purpose was also to determine the effect of full-arch maxillary stabilization splint on the asymmetry of masticatory muscle activity in patients with temporomandibular dysfunction. In this study 6 TMD patients and 12 healthy subjects were investigated. Surface EMG recordings were obtained from left and right anterior temporal, left and right masseter and from the sub-mandibular group in the region of the anterior belly of the digastric muscle on the left and right side during clenching with the maximum 100% voluntary contraction (MVC) as well as during clenching at 50% and 25% of the maximum activity in the position of maximal intercuspation of teeth. In order to quantify asymmetrical masticatory muscle activity, the asymmetry index (AI) was calculated for each subject and for each muscle from the average anterior temporal, masseter and digastric potentials recorded during each test (100% MVC, 50% MVC and 25% MVC). In the group of patients EMG recordings were repeated during and after the splint therapy. The asymmetries of masticatory muscle activity was present in both groups, but in the group of TMD patients the asymmetry indices for anterior temporal muscle at 100% MVC (p=0.049) and 50% MVC (p=0.031) were significantly higher. Results have shown that the use of splint suppressed the asymmetry of all muscles, as during the splint therapy the asymmetry indices were lowered. After the therapy, the level of temporal muscle symmetry during submaximal clenching in the intercuspal position increased significantly (p=0.046). This investigation points out that electromyography may be a valuable method of documenting that asymmetric activity of masticatory muscles improves after occlusal splint therapy in patients with TMD.

Key words: *occlusal stabilization, masticatory muscles, temporomandibular dysfunction*

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Introduction

Temporomandibular dysfunction (TMD) represents disorders affecting temporomandibular joints and masticatory muscles. Epidemiological studies suggest that a large number of the population (60–70%) have clinically detectable dysfunction but without any significant symptom[1]. Increased or dysfunctional muscular activities, induced by emotional stress, TMJ disease or occlusal disturbances, have been considered to cause TMD[2].

Occlusal appliances, commonly referred to as interocclusal splints, are routinely used in the management of temporomandibular disorders by temporarily improving the functional relationship of the masticatory system[3,4]. There are many different types of orthopedic appliances, but the type commonly used for the management of TMD is the stabilization appliance, which provides joint stabilization, relaxation of the elevator muscles as well as redistribution of occlusal forces[5–8]. The stabilization appliance is generally used in treating muscle hyperactivity, but it is also helpful for patients with retrodiscitis secondary to trauma, as well as for patients with local muscle soreness[5,9].

The precise mechanism of the action of occlusal appliances is inconclusive. Nevertheless, there are several explanations that confirm the occlusal splint's ability to reduce TMD symptoms: a change toward a more stable occlusal condition, alteration of the condylar position to a more musculoskeletally stable position, increasing in the vertical dimension as well as increased peripheral input to CNS[5].

Many studies have attempted an objective assessment of occlusal appliance effects using electromyographic (EMG) measurements of masticatory muscle activity[10–15].

Occlusal interferences and a nonuniform distribution of tooth contacts along the dental arch tend to disturb the muscle symmetry in the masticatory system[16]. While many studies have indicated that the introduction of occlusal interferences lead to changes in the asymmetry of masticatory muscle activity[17], only few have attempted to demonstrate that removal of these interferences by using stabilization splint[12], or through equilibration of occlusion[18], leads to predictable changes in this activity.

As the properly adjusted stabilization splint temporarily eliminates occlusal interferences and restores uniform tooth contacts, it is expected to improve muscle symmetry. Considering that, in this investigation we tried to show whether properly adjusted stabilization splint could actually improve muscle symmetry.

Therefore, the aim of the present study was to evaluate the symmetry of masticatory muscles' activity at various clenching levels in the intercuspal position in patients with functional disorders and compare it with healthy subjects. The purpose of this investigation was also to determine the effects of a maxillary full-arch stabilization splint on the asymmetric activity of masticatory muscles in patients with temporomandibular dysfunction.

Material and Method

Subjects

Eighteen subjects, age ranged 20–27 years, participated in this study. The symptomatic group (S) consisted of 6 subjects (mean age 23.9 ± 1.8 years). They were chosen among the patients referred to the Dental Clinic because of the TMD problems. All of them had two or more TMD signs/symptoms identified by two experienced dentists according to the proposed criteria[19]. Patients were clinically examined according following study protocol: pain in the jaw, facial, neck and back muscles, palpable TMJ pain, audi-

ble TMJ sounds, and presence of the mandibular deviations during opening and closing. Tenderness to palpation was considered positive when it elicited a blink reflex or if the subject stated that it produced pain. Occlusal analysis was focused on the number of teeth, dental wear, and the occlusal relation. Subjective and objective symptoms in TMD patients are shown in Table 1.

The asymptomatic, control group (C) consisted of 12 healthy subjects (mean age 22.4 ± 1.37 years). To be included in this group, a subject had to be free of signs and symptoms of myoarthropaties of the masticatory system. Spontaneous maximum opening had to be at least 40 mm and laterotrusive movements at least 7 mm. All subjects had a full complement of natural teeth, at least up to second molars, they had to be free of periodontal diseases and none of them was being treated orthodontically at the time of examination.

Each subject gave hers/his written informed consent for participating in this investigation.

Treatment

The full-arch maxillary stabilization splint was made for each TMD patient, to be worn during rest and while sleeping[20]. The fabrication of maxillary occlusal appliance involved several steps. After taking alginate impressions of the maxillary and mandibulary arches, the casts were fabricated. With a pressure or vacuum adapter, a 2 mm thick sheet of hard, clear resin material was adapted to the cast of maxilla. After the cutting the outline of the appliance with a separating disk, the appliance was evaluated intraorally. The next step involved taking the centric relation interocclusal record, which is used to replicate, on the articulator, the relationship between maxillary and mandibular arches that exist when the condyles are in their most anterosuperior position in the glenoid fossae. Centric relation record was made in patients' mouth of a hard pink baseplate wax, which was softened and placed on the maxillary teeth and the mandible was then manipulated in the position of centric relation. The aluwax was added onto the inferior surface of the pink wax arch form to insure contacts of the mandibulary teeth with the record. The casts were then mounted on an articulator, appliance was adapted again to the cast of maxilla and the self-curing acrylic is added in order to make slight impressions of the antagonizing bearing cusps in the splint, as well as the anterior teeth incisal edge contacts. The vertical dimension of the occlusion was increased

TABLE 1
SUBJECTIVE AND OBJECTIVE SYMPTOMS IN PATIENTS WITH TEMPOROMANDIBULAR DYSFUNCTION TMD

Symptoms	Subjects with TMD					
	1	2	3	4	5	6
Pain in the jaw				+		
Pain in facial muscles	+	+				+
Pain in neck muscles		+				
Pain in back muscles						+
TMJ pain		+			+	
TMJ sounds	+	+	+		+	
Mandibular deviation	+	+	+	+	+	
Limited mouth opening			+			
Clenching			+	+	+	+

by approximately 2 mm when measuring the central incisal distance. On laterotrusion, the mandibular canine was guiding, preventing mediotrusive contacts. Protrusion was directed through contacts of mandibular incisors.

EMG recording and procedure

EMG registrations were taken on the 8 channel PC-based EMGA-1 apparatus for simultaneous recording of myoelectrical activity, (6 differential EMG channels, input impedance 100 MΩ, CMRR (common mode rejection ratio) >95 dB at 50 Hz, bandwidth 2 Hz–1 kHz, programmable input sensitivity from 100 μVpp to 20 mVpp, an 8 bit resolution A/D conversion, 2 kHz sampling rate), specially designed and developed for the purpose of kineziological examinations of stomatognathic system's function[21–23]. (Figure 1) Surface EMG recordings were obtained from left and right anterior temporal, masseter and digastric muscles. The disc electrodes (Ag/AgCl, diameter 10 mm) were placed 2 cm apart in the main direction of the muscle fibbers and as far as possible in the same position with respect to the muscles in all subjects. The conductivity of the electrode-skin interface was increased using conductive gel after thorough cleaning of the skin with alcohol. The common ground electrode was clipped to the left wrist. All EMGs were recorded with the patient seated on a chair with the head unsupported and in as silent and tranquil atmosphere as possible.

Experimental procedure

The investigation was made according to the study protocol. First the continuous biting with the maximum voluntary contraction (MVC) in the position of maximal intercuspation of teeth was evaluated. The subjects clenched maximally for 3 seconds and repeated the clench 5 times with 15-second intervals of rest. On the five clenching tasks, the highest total

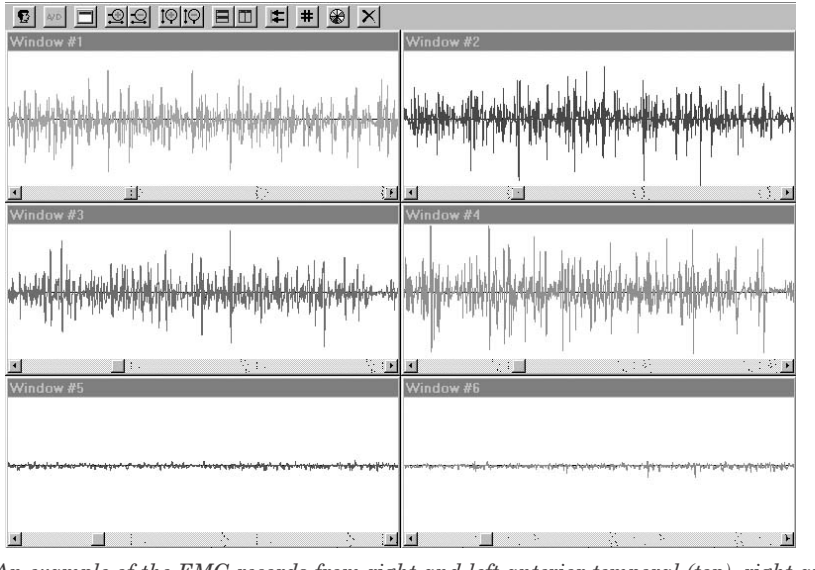

Fig. 1. An example of the EMG records from right and left anterior temporal (top), right and left masseter (middle) and right and left digastric muscle (bottom) during clenching in the position of maximal intercuspation of teeth with 50% of MVC effort.

EMG activity was considered the maximum clenching EMG activity for each patient at each visit. EMG recordings were also made at 25% and 50% levels of MVC effort, when the subject was asked first to bite as hard as possible to determine his/her MVC ability, than to maintain the 50% and 25% MVC level for 3 seconds under visual feedback. For that purpose, the recording system was connected to the clenching level indicator, which was used for visual feedback information about the clenching level. The mentioned indicator is an additional unit, which rectifies and smoothes the amplified myoelectric signal obtained from one of the amplifiers of EMGA-1 apparatus and visualizes the average myoelectrical activity (voltage) through switching of a correspondent number of light emitting diodes (LED) on.

In the symptomatic group, the patients were first examined before the beginning of the splint therapy (S). One month after the insertion of the splints EMG, recordings were made in a similar manner to that already described above (S1). The last recordings were made at the end of the therapy, e.g. after three to four months (S2).

The right-left activity of the muscles investigated at a given level was calculated from the RMS values at that level:

$$U_{RMS} = \sqrt{\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} u^2(t)dt}$$

where t_1 and t_2 represent positions of cursor, and u(t) temporary value of muscular activity tension.

In order to quantify asymmetrical masticatory muscle activity, the asymmetry index (AI), introduced by Naeije et al.[24] was calculated for each subject and for each muscle from the average anterior temporal, masseter and digastric potentials recorded during each test (100% MVC, 50% MVC and 25% MVC).

$$AI = \frac{U_{RMS_R} - U_{RMS_L}}{U_{RMS_R} + U_{RMS_L}} \times 100\%$$

The asymmetry index has a range from –100% to +100%, where a negative number indicates a left side muscle dominance, and a positive number a right side one. In this study only the absolute value of the asymmetry index was used because it was investigated whether the use of a stabilization splint improved muscle symmetry regardless of whether the left or right side was originally dominated.

Statistics

A Mann-Whitney test was applied for comparison of the EMG parameters between the group of patients and healthy control. The Friedman ANOVA was used to determine differences in muscle activity at different levels of contraction, while the Wilcoxon matched pair test for dependent samples was used to determine possible differences between asymmetry of masticatory muscles' activity in the group of patients with TMD before and after the splint therapy. Probability level at $p<0.05$ was considered as statistically significant.

Results

Comparison of patients and controls

The mean values (as well as median and range) of the absolute asymmetry indices for anterior temporal, masseter and digastric muscle at different clenching levels were calculated. In the healthy control group, the results of Friedman ANOVA (Table 2) showed significant differences in muscle activity during clenching at 100% MVC ($p=0.013$, $\chi^2=8.667$, df=2) and 50% MVC ($p=0.016$, $\chi^2=8.213$, df=2).

The results of Mann-Whitney test for independent samples, used for the comparison of the EMG parameters between the group of patients and healthy control, showed that in the symptomatic group

TABLE 2
DIFFERENCES IN MUSCLE ACTIVITY AT VARIOUS LEVELS OF CONTRACTION IN PATIENTS WITH TMD (S) AND HEALTHY CONTROL GROUP (C): FRIEDMAN ANOVA

Level of contraction	Control group (C) (N=12)					Group with TMD (S) (N=6)			
	Muscle	Mean rank	df	χ^2	p	Mean rank	df	χ^2	p
100%	T(100)	1.33	2	8.667	0.013*	2.00	2	1.333	0.513
	M(100)	2.50				2.33			
	D(100)	2.17				1.67			
50%	T(50)	1.33	2	8.213	0.016*	2.08	2	3.739	0.154
	M(50)	2.29				2.50			
	D(50)	2.38				1.42			
25%	T(25)	1.83	2	0.977	0.614	2.00	2	3.000	0.223
	M(25)	1.96				2.50			
	D(25)	2.21				1.50			

T = anterior temporal muscle asymmetry index; M = masseter muscle asymmetry index; D = digastric muscle asymmetry index; 100, 50, 25% = various levels of contraction in the intercuspal position at which variable were measured

TABLE 3
COMPARISON OF MASTICATORY MUSCLES' ASYMMETRY BETWEEN THE TMD PATIENTS AND HEALTHY CONTROL GROUP

	Asymmetry indices (AI)						
	Symptomatic group (S) (N=6)			Control group (C) (N=12)			
	Mean	Range	Median	Mean	Range	Median	p[a]
T100	0.0961	0.1896	0.094	0.036	0.08488	0.029	0.049
T50	0.1720	0.3460	0.1956	0.057	0.1525	0.048	0.031
T25	0.0945	0.1028	0.1054	0.1372	0.400	0.1292	0.399
M100	0.1756	0.5219	0.083	0.1057	0.2087	0.1048	0.925
M50	0.2544	0.4684	0.2479	0.1552	0.4657	0.1320	0.399
M25	0.2563	0.6148	0.2442	0.1637	0.3333	0.1342	0.349
D100	0.1038	0.2575	0.057	0.1003	0.3142	0.1055	0.925
D50	0.0706	0.1429	0.069	0.1397	0.2727	0.1180	0.120
D25	0.0775	0.2000	0.058	0.1646	0.2727	0.2000	0.064

[a] Mann-Whitney test for independent samples
The mean values of the asymmetry indices of anterior temporal (T), masseter (M) and digastric (D) muscle during clenching with the maximum 100% voluntary contraction (MVC) as well as during clenching at 50% and 25% of the maximum activity in the position of maximal intercuspation of teeth in group with TMD (S) and in healthy control (C).

the asymmetry of temporal muscle was greater than in the healthy control group (100% MVC U=15,000, N_1=12, N_2=6, p= 0.049; 50% MVC U=13,000, N_1=12, N_2=6, p=0.031) (Table 3). The mean masseter muscle asymmetry was at all levels of contraction higher in the symptomatic group, but without any statistical significance (p>0.05). The digastric muscle asymmetry, however, tended to be higher in the healthy control group, especially at lower contraction levels.

Influence of occlusal splint on myoelectrical activity

The results of the EMG investigation for the six patients recorded before (S) and during (S1) the splint therapy showed improvement in muscle symmetry as a result of the stabilization splint, as the values of asymmetry indices during the therapy (S1) were lower. This finding was presented for the masseter muscle at all levels of contraction, for anterior temporal muscle during clenching at 100% MVC and 50% MVC, and for digastric muscle only during clenching with maximal voluntary contraction. The Wilcoxon matched pair test for dependent samples (Table 4) demonstrated that the insertion of splint resulted in a small, but not significant decrease in the mean asymmetry index values of anterior temporal and masseter muscle ($p>0.05$). The digastric muscle showed to be unresponsive to a splint treatment at lower contraction levels.

The diagram (Figure 2) of the mean values of the absolute asymmetry indices for the six subjects recorded before (S) and after (S2) the splint therapy showed that the subjects recorded after the splint therapy (S2) showed lower values of AI than the subjects recorded before the therapy (S), except for digastric muscle at 25% MVC. The AI of the anterior temporal muscle at 100% MVC was not affected, but the AI of the anterior temporal muscle at 50% MVC was decreased significantly ($z= -1.992$, $p=0.046$). Despite the lack of significant changes in the mean muscle asymmetry, at 100% MVC the masseter muscle activity showed an improvement in symmetry as a result of splint treatment ($p=0.075$).

Discussion

Some previous researches[25–27] were made to evaluate the asymmetric activity of masticatory muscles and compare the quantitative contribution of the EMG activities of muscles to the clenching effort. The most outstanding findings were that the asymmetry in muscle activity depends upon the clenching level and that at each level of contraction masseter muscle asymmetry was more significant than anterior temporal's[24].

The present study confirmed that the masseter muscle asymmetry was at each level of contraction higher than in anterior temporal one, both in patients with TMD and in healthy controls. Although the asymmetry of masticatory muscle activity was present in both examined

TABLE 4
INFLUENCE OF OCCLUSAL STABILIZATION SPLINT ON MASTICATORY MUSCLE ASYMMETRY

		Anterior temporal			Masseter			Digastric		
		100% MVC	50% MVC	25% MVC	100% MVC	50% MVC	25% MVC	100% MVC	50% MVC	25% MVC
Wearing of splint[a]	S–S1[c]	0.753	0.345	0.463	0.345	0.173	0.753	0.60	0.40	1.0
Removal of splint[b]	S–S2[d]	0.917	0.046*	0.753	0.075	0.463	0.753	0.463	0.345	0.345

[a] EMG recordings after wearing the splint for one month while subjects were clenching on the occlusal splint
[b] EMG recordings at the end of the therapy e.g. after three to four months
[c] Wilcoxon matched pair test for dependent samples was used to determine possible differences in asymmetry indices before (S) and during (S1) the occlusal splint therapy
[d] Wilcoxon matched pair test was used to determine possible differences in muscle asymmetry before (S) and after (S2) the splint therapy

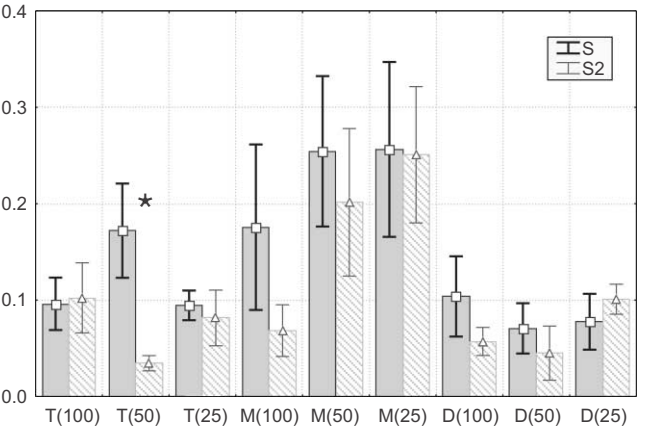

Fig. 2. The comparison of asymmetry indices of masticatory muscles in patients with temporomandibular dysfunction before and after splint therapy.

Muscle asymmetry index (mean value and standard error of mean) during clenching with the maximum 100% voluntary contraction and at clenching levels of 50% and 25% of maximum clenching effort in group before (S) and after (S2) the splint therapy.
T = anterior temporal muscle asymmetry index; M = masseter muscle asymmetry index; D = digastric muscle asymmetry index; 100, 50, 25% = various levels of contraction in the intercuspal position at which variable were measured
* $p<0.05$ (Wilcoxon matched pair test)

groups, in the group of TMD patients the asymmetry indices for anterior temporal muscle were significantly higher. Despite the lack of significance in the mean masseter muscle asymmetry, it was at all levels of contraction higher in the symptomatic group.

Lobbezzo[28] have investigated the effects of an occlusal splint and the mode of visual feedback on the activity balance between jaw elevator muscles and have reported that the use of splint caused a redistribution of muscle activities, in particular by reduction of the activity of the anterior temporal muscle. Holmgren et al.[29] found that the occlusal splint did not change the level of symmetry in patients with craniomandibular disorders.

In the present study, although the asymmetry indices recorded during the splint therapy (S1) were not as significantly pronounced as compared with those recorded before the beginning of the therapy (S), the degrees of the asymmetry generally tended to be lower during the therapy for all recorded muscles at 100% MVC. At lower levels of contraction (50% MVC and 25% MVC) asymmetrically indices for digastric muscle were higher during the splint therapy. The result of this study indicated that a properly adapted stabilization splint could improve the symmetry in elevator muscle activity, but it also suggests the need for further adjustments of the splint in order to temporarily eliminate occlusal interferences and provide muscular balance.

In the group of patients with TMD the asymmetry in the masseter muscle was higher than in the anterior temporal muscle at all levels of contraction, as has already been shown by other studies[24,25].

Our results, however, showed that the insertion of stabilization splint increased the level of muscular symmetry and caused the equalizing of the elevators' asymmetry indices. The proposed role of the splint was in its effect of changing toward more stable and optimal conditions, which generally decrease muscle activity and eliminate symptoms.

After the therapy, the asymmetrical muscle activity was influenced significantly by the application of an occlusal stabilization splint. The level of temporal muscle symmetry during clenching at 50% MVC in the intercuspal position increased significantly. Despite the lack of significance, the asymmetry indices of the masseter muscles were also decreased at all levels of contraction.

Humsi et al.[9] showed that in the patients with mainly myogenous origin of pain, splints that required no adjustment during the treatment caused an immediate improvement in masseter muscle symmetry. They have considered that, during submaximal clenching, masseter muscle activity was sensitive to occlusal stability.

In the present study, the elevator muscles' AI reduction during as well as after the stabilization splint therapy was found. The significant decrease, however, was find only for temporal muscle asymmetry at 50% MVC ($p<0.05$). This result is in agreement with the findings by Visser et al.[26], who found a decrease in temporal muscle activity as a response to the splint treatment. In their study, concomitantly with reduction of temporal muscle activity, significant reduction of static pain was found, so they suggested that temporal muscle plays an important role in the perception of static pain in the masticatory system.

The use of interocclusal appliance is commonly accepted treatment mode for patients with signs and symptoms of TMD. However, it remains unclear how these appliances work and why they may be effective in some patients while not in others. Further studies would be needed in order to evaluate whether specific criteria of TMD related diagnoses might predict differences in specific treatment related outcome measures[30]. Using randomized clinical trials and well-accepted quantified outcome measures, further studies including »non«, »placebo« and »standard« treatment groups in TMD-specified subgroups and non-TMD control groups may be warranted to assess the therapeutic efficacy of interocclusal appliances[31,32].

Conclusions

Our results point out that electromyography may be a valuable method of documenting that asymmetric activity of masticatory muscles improves after occlusal splint therapy in patients with TMD, as after the splint therapy the asymmetry indices were lowered.

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UTJECAJ OKLUZALNE STABILIZACIJSKE UDLAGE NA ASIMETRIJU AKTIVNOSTI ŽVAČNIH MIŠIĆA U ISPITANIKA S TEMPOROMANDIBULARNOM DISFUNKCIJOM

S A Ž E T A K

Svrha istraživanja bila je procijeniti simetriju mišićne aktivnosti pri različitim stupnjevima kontrakcije u položaju maksimalne interkuspidacije u pacijenta s temporomandibularnom disfunkcijom (TMD) i zdravih ispitanika. Također se nastojalo utvrditi utjecaj maksilarne stabilizacijske udlage na asimetriju mišićne aktivnosti u ispitanika s temporomandibularnom disfunkcijom. U ispitivanju je sudjelovalo 6 ispitanika s TMD-om i 12 zdravih ispitanika. Površinska elektromiografska mjerenja izvršena su na šest mišića (lijevi i desni prednji temporalni mišić, lijevi i desni maseter te submandibularna skupina mišića u području prednjeg trbuha digastrikusa s lijeve i desne strane). Mioelektrički signali registrirani su prilikom maksimalne voljne izometričke kontrakcije (MVC) u položaju maksimalne interkuspidacije sa 100% aktivnosti kao i tijekom maksimalne interkuspidacije s 50% i 25% aktivnosti. U svrhu procjene simetrije mišićne aktivnosti pri svim ispitivanim položajima (100%MVC, 50%MVC i 25%MVC) za svakog je ispitanika izračunat indeks asimetrije (AI) pojedinačno za mišiće temporalis, maseter i digastrikus. U skupini ispitanika s poremećajem elektromiografska su

mjerenja ponovljena tijekom i nakon terapije udlagom. Rezultati su pokazali da je asimetrija mišićne aktivnosti bila prisutna u obje ispitivane skupine, ali su indeksi asimetrije bili značajno viši u skupini ispitanika s TMD-om i to za prednji temporalni mišić tijekom 100%MVC (p=0,049) i 50%MVC (p=0,031). Tijekom trajanja terapije udlagom uočilo se smanjenje asimetrije aktivnosti žvačnih mišića. Nakon terapije udlagom nastupilo je značajno povećanje simetrije aktivnosti prednjeg temporalnog mišića tijekom maksimalne interkuspidacije s 50% aktivnosti (p=0,046). Elektromiografija se pokazala kao vrijedna metoda koja objektivno prikazuje smanjenje asimetrije žvačnih mišića u ispitanika s TMD-om nakon terapije stabilizaciskom udlagom.