Maximum Voluntary Isometric Activity of Elevator Masticatory Muscles at Symmetrical Occlusal Positions of the Mandible

Maksimalna voljna izometrična aktivnost elevatora mandibule prigodom simetričnih okluzijskih položaja

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Summary

Mean voltages of right and left temporal and masseter muscle (RAT, LAT, RM, LM) during maximum voluntary clenching in maximal intercuspal position (MI), retruded contact position (RCP) and incisal position (IP) were examined. There was no significant difference between sexes in any of the examined positions ($p>0.05$). For the symmetric positions of the lower jaw (MI,P,RCP) there was slightly higher muscle activity on the right side, although not significant ($p>0.05$). The biggest reduction of the activity of masseter muscle was observed in RCP and the biggest reduction of the activity of temporal muscle was observed in IP, indicating that masseter muscle is more responsible for the protrusive isometric contraction and temporal muscle is more responsible for the retrusive isometric activity. Greater inhibitory input was observed on the masseter motoneurons than on the motoneurons of the temporal muscle in RCP, while greater inhibitory input was observed on the motoneurons of the temporal muscle than on the motoneurons of the masseter muscle in IP, indicating that various receptors might be responsible for the reduction of maximal voluntary clenching efforts: spatial receptors in temporomandibular joints and muscle tendon organs, as well as the receptors in periodontal membrane of the anterior and posterior teeth.

Key words: *EMG, masseter muscle, anterior temporal muscle, symmetrical occlusal positions*

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Introduction

Masticatory muscles move the lower jaw through the isotonic activity and develop the clenching force through the isometric contraction. The biomechanical models of human mandible underline the importance of quantifying the contribution of isometric muscle activity to the position of the lower jaw (1-10).

Surprisingly, accurate evaluation of the physiological values in a normal population is still lacking, especially as far as muscle activity in occlusal positions is concerned.

The aim of this study was to evaluate isometric muscle activity at different symmetrical occlusal positions of the lower jaw in order to establish normal values of the EMG activity of the masseter and anterior temporal muscle.

Subjects and Methods

EMG activity was recorded on the 8 channel EMGA-1 device, a new configuration of a PC controlled multichannel system for electromyographic and audio-signal registrations (11). EMG signals were recorded in 35 individuals who had all teeth in the jaws, normal occlusion and normal jaw relationship and who were without any history of previous orthodontic treatment. Fifteen males and twenty females, 20-26 years old, participated in the study. The EMG signals were recorded by the methods of surface electromyography during maximal voluntary clenching effort from 4 elevator masticatory muscles: right and left anterior temporal (RAT, LAT) and right and left masseter muscles (RM, LM) in 3 symmetrical occlusal positions of the lower jaw: maximum interscupal position (MI), incisal position (IP) and the retruded contact position (RCP). In order to reduce impedance the skin was cleansed prior to electrode placement and conductive jelly was used. Electrodes were placed according to standard techniques (12). The time base for the registration in each position was 2.4 s. Recorded signals were stored on a floppy disk for subsequent analysis.

All the measurements of the mean voltages of muscle activity were made directly on the screen of the EMGA-1 device by using the Medwin software package which enables the use of the tracers and directly calculates the mean muscle activity between the tracers (Figure 1).

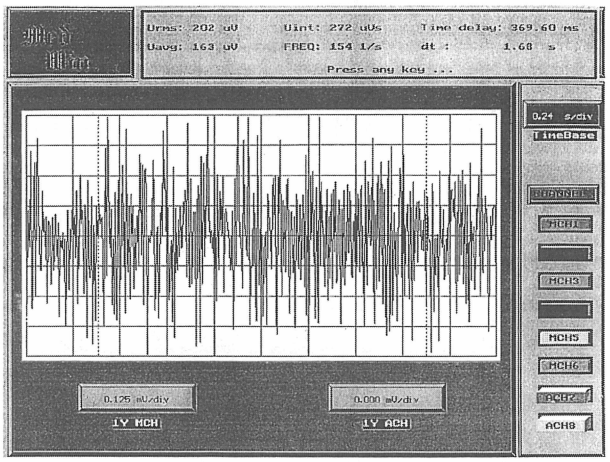


Figure 1. *Direct calculation of mean muscle activity (between the tracers) on the screen by using "Medwin" software on the EMGA-1 device*

Slika 1. *Izravno mjerenje srednje mišićne aktivnosti (između markera) na ekranu s pomoću softwera "Medwin" i EMGA-1 aparature*

Mean values of the 3 maximal clenching efforts during 2.4 s for each position were statistically analysed. Statistical analysis was made by using the SPSS software (Microsoft Corp.) on the IBM compatible 486 configuration (descriptive statistics, analysis of variance).

Results and Discussion

Statistical analysis of the obtained data (analysis of variance) showed that there was no significant difference for the mean voltages of RAT ($F=0.649$, $p>0.05$, Table 1), RM ($F=1.018$, $p>0.05$, Table 1), LAT ($F=.125$, $p>0.05$, Table 1) and LM ($F=0.00$, $p>0.05$, Table 1) between sexes in any occlusal positions examined so, further analysis was made for the whole sample. On the contrary, mean muscle activity was changed by the occlusal position ($p>0.01$, Table 1).

Descriptive statistics (mean voltages and standard deviations) of the RAT, RM, LAT and LM during maximum voluntary activity in MI, IP and RCP is presented in Table 2.

Table 1. *Effects of gender and occlusal position of the lower jaw on the maximal voluntary activity of the right and left temporal muscle (RAT;LAT) and the right and left masseter muscle (RM;LM)*

Tablica 1. *Utjecaj spola i okluzijskoga položaja mandibule na maksimalnu voljnu aktivnost desnoga i lijevoga tempomandibularnog mišića (RAT; LAT) i desnoga i lijevoga massetera (RM;LM)*

RIGHT ANTERIOR TEMPORAL MUSCLE BY GENDER AND OCCLUSAL POSITION					
Soure of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	341648.496	3	113882.832	35.777	.000
GENDER	2064.896	1	2064.896	.649	.423
O. POSITION	339583.600	2	169791.800	53.341	.000
2-way Interactions	41.878	2	20.939	.007	.993
GENDER O. POSITION	41.878	2	20.939	.007	.993
Explained	341690.374	5	68338.075	21.469	.000
Residual	315131.683	99	3183.148		
Total	656822.057	104	6315.597		
RIGHT MASSETER MUSCLE BY GENDER AND OCCLUSAL POSITION					
Soure of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	635898.686	3	211966.229	24.442	.000
GENDER	8832.457	1	8832.457	1.018	.315
O. POSITION	627066.229	2	313533.114	36.153	.000
2-way Interactions	18055.005	2	9027.502	1.041	.357
GENDER O. POSITION	18055.005	2	9027.502	1.041	.357
Explained	653953.690	5	130790.738	15.081	.000
Residual	858562.367	99	8672.347		
Total	1512516.057	104	14543.424		
LEFT ANTERIOR TEMPORAL MUSCLE BY GENDER AND OCCLUSAL POSITION					
Soure of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	345589.506	3	115196.502	38.766	.000
GENDER	370.229	1	370.229	.125	.725
O. POSITION	345219.276	2	172609.638	58.087	.000
2-way Interactions	810.335	2	405.167	.136	.873
GENDER O. POSITION	810.335	2	405.167	.136	.873
Explained	346399.840	5	69279.968	23.314	.000
Residual	294185.550	99	2971.571		
Total	640585.390	104	6159.475		
RIGHT MASSETER MUSCLE BY GENDER AND OCCLUSAL POSITION					
Soure of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	432587.887	3	144195.962	28.382	.000
GENDER	1.087	1	1.087	.000	.988
O. POSITION	432586.800	2	216293.400	42.573	.000
2-way Interactions	2418.144	2	1209.072	.238	.789
GENDER O. POSITION	2418.144	2	1209.072	.238	.789
Explained	435006.031	5	87001.206	17.124	.000
Residual	502972.483	99	5080.530		
Total	937978.514	104	9019.024		

Table 2. *Means (x) and standard deviations (SD) of maximal voluntary muscle activity: right anterior temporal muscle (RAT), right masseter muscle (RM), left anterior temporal muscle (LAT) and left masseter muscle (LM) at maximal intercuspal position of the mandible (MI), incisal position (IP), and retruded contact position (RCP); n=35*

Tablica 2. *Aritmetičke sredine (x) i standardne devijacije (SD) maksimalne voljne mišićne aktivnosti: desni prednji temporalis mišić (RAT), desni maseter (RM), lijevi prednji temporalni mišić (LAT) i lijevi maseter (LM) u položaju maksimalne interkuspidacije (MI), incizalnome zagrizu (IP), i u retrudiranome kontaktnom položaju (RCP); n=35*

OCCLUSAL POSITION	MUSCLE							
	RAT		RM		LAT		LM	
	x (uV)	SD	x (uV)	SD	x (uV)	SD	x (uV)	SD
MI	160.3	65.0	248.5	127.8	158.8	74.5	211.1	85.7
IP	24.7	24.0	92.6	64.1	20.4	16.6	75.5	50.8
RCP	120.2	69.7	77.5	74.2	110.0	53.4	74.5	70.3

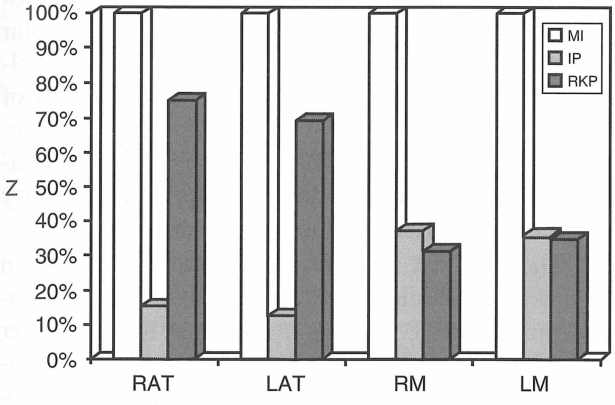
Table 3. *Analysis of variance for the significance of the differences of maximal voluntary activity of the examined muscles: right anterior temporal muscle (RAT), right masseter muscle (RM), left anterior temporal muscle (LAT) and left masseter muscle (LM) between different occlusal position of the mandible: maximal intercusparl position (MI), incisal position (IP), and retruded contact position (RCP); n=35*

Tablica 3. *Raščlamba varijacije za značajnost razlika maksimalne voljne aktivnosti mišića: desni prednji temporalni mišić (RAT), desni maseter (RM), lijevi prednji temporalni mišić (LAT) i lijevi maseter (LM) između različitih okluzijskih položaja mandibule: maksimalna interkuspidacija (MI), incizalni zagriz (IP) i retrudirani kontaktni položaj (RCP): n=35*

ANALYSIS OF VARIANCE FOR RAT AT DIFFERENT OCCLUSAL POSITIONS		
D.F. 2, 102	F Ratio 54.5923	F Proability .0001
SHEFFE ANALYSIS (.05)	OCCLUSAL POSITION IP RCP MI IP RCP * MI * *	
ANALYSIS OF VARIANCE FOR RM AT DIFFERENT OCCLUSAL POSITIONS		
D.F. 2, 102	F Ratio 36.1177	F Proability .0001
SHEFFE ANALYSIS (.05)	OCCLUSAL POSITION RCP IP MI RCP IP MI * *	
ANALYSIS OF VARIANCE FOR LAT AT DIFFERENT OCCLUSAL POSITIONS		
D.F. 2, 102	F Ratio 59.6080	F Proability .0001
SHEFFE ANALYSIS (.05)	OCCLUSAL POSITION IP RCP MI IP RCP * MI * *	
ANALYSIS OF VARIANCE FOR RM AT DIFFERENT OCCLUSAL POSITIONS		
D.F. 2, 102	F Ratio 43.6531	F Proability .0001
SHEFFE ANALYSIS (.05)	OCCLUSAL POSITION RCP IP MI RCP IP MI * *	

The significance between the differences of the mean values in various occlusal position for each muscle examined was tested by the analysis of variance (ranges Scheffe) and is shown in Table3.

Activity of the examined muscles in IP and RCP expressed in the percentages of MI (MI=100%) is shown on Graph 1.



Graph 1. *Activity of right and left anterior temporal muscle (RAT; LAT) and right and left masseter muscle (RM,LM) during incisal biting (IP) and retruded contact position RCP) expressed in the percentages of maximum intercuspation (MI)*

Grafikon 1. *Aktivnost desnog i lijevog anterior temporalnog mišića (RAT, LAT) i desnog i lijevog masetera (RM, LM) u incizalnome zagrizu (IP) i retrudiranome kontaktnom položaju (RCP) izrađena u postotoku maksimalne interkuspidacije (MI)*

Mean values obtained for the examined muscles during maximum voluntary clenching in MI resemble Ferrario's results (13), although he stated that the masseter muscle had greater activity than anterior temporal muscle in men, but not in women.

In this study, there was no significant difference between men and women for any of the muscles examined ($p>0.05$, Table 1) in any symmetrical occlusal position, as tested by the analysis of variance. However, the difference between the mean muscle activity was significantly different dependent on the position of the lower jaw ($p<0.01$, Table 1) and therefore one-way analysis of variance was performed for each muscle examined (ranges Sheffe, Table 3),

The activity of RAT showed the highest values in MI and significantly higher than in IP and RCP ($p<0.05$, Table 2,3). The activity of RAT in RCP was significantly greater than in IP ($p<0.05$, Table 2,3).

The activity of the RM was greatest in MI and significantly greater than in IP and RCP, ($p<0.05$, Table 2,3), while there was no significant difference between the activity of this muscle between RCP and IP, although in RCP the activity was smaller than in IP ($p>0.05$, Table 2,3).

The activity of LAT showed the greatest values in MI and was significantly greater than in IP and RCP ($p<0.05$, Table 2,3). The activity of LAT in RCP was significantly greater than in IP ($p<0.05$, Table 2,3). The activity of LM was the greatest in MI and significantly greater than in IP and RCP ($p<0.05$, Table 2,3), while there was no significant difference between the activity of this muscle between RCP and IP, although in RCP the activity was smaller than in IP ($p>0.05$, Table 2,3,) .

During maximal voluntary clenching in symmetrical occlusl position (MI,P,RCP) mean muscle activity appears to be slightly greater on the right side, which is the preferred chewing side in a healthy population, although the difference was not significant, compared to the left side ($F=1.036;p>0.05$). This attributed to the fact that the right side is the preferred chewing side and muscles are therefore more trained on the right side.

The biggest activity of all the muscles are exhibited in MI (Table 2).

In the RCP position, the activity of both masseter muscles decreased significantly ($p<0.05$, Table 2) (this was the position of the smallest masseter activity) and the activity of both temporal muscles also decreased ($p<0.05$, Table 2), but not as much as the masseter muscles (Graph 1). A similar result was obtained by Kohno (14), although his study group consisted of only three subjects. This result indicates that temporal muscles are more engaged in the retrusive clenching than masseter muscles. The decrease of temporal muscle activity in RCP is probably due to the decreased opposing contacts between distal teeth in this position, compared to MI. This is in agreement with the results of some other authors who found decrease in muscle activity by reducing the number of occlusal contacts between lateral teeth (9,15,16).

During maximal incisal biting with the incisors in contact (IP) the activity of all the examined muscles significantly dropped ($p>0.05$, Table 2,3), compared to MI, although the activity of the temporal muscle dropped more than the activity of masseter muscle (Graph 1). This, once again indicates that masseter muscle generates more isometric activity in protrusive position, while temporal muscle generates more isometric activity in retrusive contact positions (greater activity in RCP than masseter muscle). Reduced muscle activity in the incisal position indicates that the scheme: anterior guidance (movements of the lower jaw that are guided through the contacts of incisive teeth) leads to the immediate reduction of elevator muscle activity and confirms the results of Williamson and Lündquist (15) and Grunert et al. (17). This also indicates that the periodontal receptors of frontal teeth are more sensitive to the mechanical load than posterior teeth and reduce the potential harmful activity through the reflex arch. Information from the sensory receptors in the periodontal ligament are conducted to the sensory tract of the fifth nerve and then through a various number of synapses to the motor nucleus in pons where inhibitory inputs reduce voluntary excitatory input and the final result is a decrease of muscle activity. By reducing the number of contacts between the opposing teeth, temporalis and masseter reduce activity in RCP. Sensory information about the contact between the frontal teeth in IP and complete reduction of the opposing contacts between the distal teeth leads to greater reduction of the activity of temporal muscle in IP than in RCP. However, spatial receptors in the temporomandibular joint and muscle tendon organs might also be involved, acting more inhibitory on the motoneurons of the masseter muscle in RCP and on the motoneurons of the temporal muscle in IP, reducing excitatory voluntary inputs during maximal voluntary clenching efforts.

The greatest reduction of masseter muscle in RCP ($p<0.01$) and the greatest reduction of temporal muscle in IP ($p<0.01$), indicates that masseter muscle is more responsible for the protrusive isometric contraction and temporal muscle is more responsible for the retrusive isometric activity.

MAKSIMALNA VOLJNA IZOMETRIČNA AKTIVNOST ELEVATORA MANDIBULE PRIGODOM SIMETRIČNIH OKLUZIJSKIH POLOŽAJA

Sažetak

Istraživana je aktivnost desnog m. temporalisa i massetera (RAT, RM) i lijevog m. temporalisa i massetera (LAT, LM) u različitim simetričnim okluzijskim položajima mandibule: u maksimalnoj interkuspidaciji (MI), incizalnom položaju (IP) i retrudiranome kontaktnom položaju (RCP). Nije bilo značajne razlike u mioelektričnoj aktivnosti mišića između muškoga i ženskoga spola ($p>0,05$). U simetričnim okluzijskim položajima postojala je naznatno veća aktivnost mišića na desnoj strani, premda ne i signifikantna ($p>0,05$). Najveće smanjenje aktivnosti massetera bilo je u RCP, a temporalisa u IP, što pokazuje da je masseter odgovorniji za protruzivnu izometričnu aktivnost, a temporalis za retruzivnu. U IP svi mišići znatno su smanjili aktivnost u odnosu prema MI, što upućuje na refleksni inhibicijski input periodontalnih receptora frontalnih zuba na n. motorius n. trigemini.

Ključne riječi: *EMG, m. masseter, m. temporalis anterior, simetrični okluzijski položaj*

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