The influence of dental status on masticatory muscles activity in elderly patients

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Running title: The influence of prosthetic appliance on mastication

Abstract

Aims. The objective of this study was to determine whether the elevator and depressor muscle activity during five minutes mastication is affected by the presence of the prosthetic appliance in elderly patients.

Methods. Thirty edentulous subjects (EG) and 30 age-matched dentate subjects (DG) were studied. Surface electromyographic (EMG) recordings were obtained from the anterior temporal muscle (T), masseter muscle (M) and from the submandibular group in the region of the anterior belly of the digastrics muscle (D) on the left (L) and right (R) side. Muscle activity was registrated during maximal voluntary contraction (MVC) at the intercuspal position, maximal opening (Omax), and during five minutes of mastication. Elevator muscle activity during mastication was expressed in percentages of the maximal muscle activity in intercuspal position and depressor muscle activity was expressed in percentages of maximum opening. By using mixed ANOVA design, the effect of three factors was investigated: the factor of muscle with six muscles involved, the factor of time (five minutes of mastication), and the factor of dental status where some participants had their own natural dentition whereas others had complete dentures.

Results. The results revealed significant effects of factors muscle and time (~~p~~P<0.001 for factor "muscle"; ~~p~~P<0.001 for factor "time"). ~~The muscle was not significant by group interaction (p=0,254), while~~The time by group interaction was significant (~~p~~P=0~~,~~.046). In EG muscle activity gradually decreased during the whole five minute interval of mastication, while in DG it decreased more rapidly from the 1st to the 3rd minute and then it increased till the 5th minute. There was also a significant effect regarding the presence of natural teeth or complete dentures (~~p~~P<0.034). Complete denture wearers had higher muscle activity relatively to % of MVC or % of Omax than dentate subjects.

Conclusions. Muscle activity during five minutes of mastication depends greatly of the presence of the prosthetic appliance, since edentulous subjects had to use higher potentials of muscle activity (% of MVC or % of Omax) than age matched dentate subjects and were unable to increase activity at the end of mastication.

The difference in chewing patterns and activity between complete denture wearers and dentate subjects should be explained to the patients prior to the prosthetic treatment in order to put their expectations into right perspective.

Key words: masticatory muscles, complete dentures, mastication, electromyography

Introduction

In healthy population mastication is a highly coordinated neuromuscular function that involves fast effective movements of the jaw and continuous modulation of force. It is an alternating rhythm of isotonic and isometric contractions governed by central pattern generator, located in the brain steam [1]. Stimulation and feedback generated by sensory input from proprioceptors in the oral cavity, muscles and joints may have an influence on the governed pattern. In the elderly subjects these mechanisms act with some marked differences. Some age related changes, such as deterioration in the fast and slow fibres in the striated muscles, result in impaired muscle force [2]. Moreover, chewing efficiency is considerably reduced when natural teeth have been replaced by complete dentures [3]. The loss of teeth and elimination of periodontal afferent flow lead to changes in the neuro-muscular pattern [4]. Edentulous persons are considered as oral invalids with reduced capacity in various functions of the stomatognathic system such as bite force, tactile thresholds and chewing ability [5].

Although various techniques are available for examining chewing behaviour, EMG recording is a convenient and useful method as it directly measures muscle activity. Serious attempts have been made to explain how the stomatognathic system reacts to a functional stimulation such as chewing training or chewing exercises [6]. The authors, however, mostly investigated the activity of elevator muscles (anterior temporal and masseter muscle), while the depressor muscle activity during chewing has not been completely studied. Even though some studies were concerned with depressor muscles EMGs, their results consider only subjects that have their own natural teeth and could not be applied on complete denture wearers [7].

Masticatory activity in complete denture wearers has been aim of some investigations [3,~~7~~8]. No clear description, however, can be found regarding the comparison of masticatory function between elderly dentate and complete denture wearers, considering both elevator and depressor muscle activity.

The objective of this study was to test the hypothesis that the elevator and depressor muscle activity during mastication depend on the presence of the prosthetic appliance. This study attempted to determine whether denture wearers with clinically and subjectively satisfactory dentures presented differences in a pattern of muscle activity during mastication in comparison to dentate subjects.

Materials and methods

Subjects

Sixty subjects participated in this study, and they were divided in two groups. The complete denture (edentulous) group (EG) consisted of 30 subjects, 21 females and 9 males (65.73 ±7.81 years). All subjects had worn an upper and a lower complete removable denture for an average period of six months. Complete denture participants were chosen upon the criteria that their dentures had satisfactory interocclusal and maxilomandibular relationship. All participants reported an adequate masticatory efficiency and were satisfied with their dentures. The oral mucosa was free of irritation and clinical signs of inflammation. None of the subjects ever had a history of mandibular dysfunction or any disease that might affect muscles of the masticatory system.

The control group (CG) consisted of 30 healthy subjects, 20 females and 10 males (61.85±7.77 years). An inclusion criterion was that subjects had to be free of signs and symptoms of any dysfunctions of the masticatory system. All of them had complete dentition with Angle Class I occlusion, and there were no occlusal interferences in any mandibular excursions [~~8~~9]. Each subject gave hers/his written informed consent for participating in this study. The investigation was approved by the Ethics committee of the School of Dental Medicine, University of Zagreb.

EMG recording and procedure

EMG activity was recorded by the 8 channel PC based EMGA-1 apparatus specially designed and developed for the purpose of kinesiological examinations of stomatognathic system's function [10]. This system allows ~~electromyographic apparatus for~~ simultaneous recording of myoelectrical activity from 6 muscles (6 differential EMG channels, input impedance 100 MΩ, CMRR> 95 dB at 50 Hz, bandwidth 2 Hz-1 kHz, programmable input sensitivity from 100µVpp to 20 mVpp, an ~~8~~ 12 bit resolution A/D conversion, 2 kHz sampling rate). The analogical EMG signal was amplified, digitized, and digitally filtered. The instrument was directly interfaced with a computer which presented the data graphically and stored them on hard disc for further quantitative and qualitative analyses.

Surface EMG recordings were obtained from the left and right anterior temporal muscle (T), the left and right masseter muscle (M) and from the submandibular group of muscles in the region of the anterior belly of the digastric muscle (D) on the left and right side. The disc electrodes (Ag/AgCl, diameter 10 mm) were placed 2 cm apart in the main direction of the muscle fibres. Every participant had electrodes placed in the same manner, with regard to her/his anthropometric features. Prior to electrode attachment, the skin was carefully degreased with alcohol and rubbed with grinding paper to reduce impedance. Recordings were performed 5-6 minutes later, allowing the conductive paste to adequately moisten the skin surface. The common ground electrode was clipped to the left wrist. All measurements were performed between 10 and 11 AM, in calm and peaceful atmosphere.

Experimental procedure

The investigation was made according to the study protocol. First the continuous biting with the maximum voluntary contraction (MVC) was evaluated, when subjects were asked to clench the molar teeth at the intercuspal position (ICP), in order to establish the maximal activity of the elevator muscles. The subjects clenched maximally for 3 seconds and repeated the clench 5 times with the 15-second intervals of rest. During the five clenching tasks, the highest EMG activity was considered the maximum clenching EMG activity during a given period (3 seconds). During EMG recording, the EMG device was connected to the clenching level indicator, which was used for visual feedback information about the clenching level. It is an additional unit, which rectifies and smoothes the amplified myoelectric signal obtained from one of the amplifiers of the EMG device and by switching on a corresponding number of light emitting diodes (LED) it visualizes the average myoelectrical activity.

To establish the maximal activity of the depressor muscles, subjects had perform maximal wide opening (Omax) while contracting depressor muscles as strongly as possible.

For chewing tests subjects had to chew a stick of rubber dental silicone (Optosil, Bayer, Germany). Each subject was asked to chew "as normal" for five minutes, while seated upright in a dental chair. During that period EMG recordings were made once a minute during a period of 10 seconds. It is well known that EMG is vulnerable to extra-muscular factors that may alter and distort the true electric signal [11,12]. To allow useful comparisons between different subjects and different studies, the EMG potentials should be standardized (normalized). Therefore, ~~M~~myoelectric activity of a certain muscle was compared to its maximal activity, as previously suggested [~~9~~13]. Elevator activity was expressed in percentages of maximal voluntary contraction at the intercuspal position (%MVC) and depressor activity was expressed in percentages of maximal wide opening (%Omax).

Reproducibility of EMG data

Data analysis was performed by the same experienced examiner. The between-session variation of the EMG data during chewing was tested as previously suggested by other authors [11,14].

Five subjects were examined separately at two different sessions with seven days between each session. The accurate and precise relocation of elevator muscle electrodes was achieved by using flexible transparent isosceles triangle as template (sides measuring 15.5, 15.5, and 22.0 cm). The masseter muscle width was measured by palpation and electrodes were placed over the centre of the fleshiest part of the superficial portion of the muscle 2 cm apart and in the line with the muscle fibers. Triangle's hypotenuse was placed on the Camper line, with the right angle facing downwards. Line representing the height of a triangle (the line vertical to hypotenuse, connecting the right angle and the middle of a hypotenuse) was placed on the tragus of the ear. Electrodes' position was then marked and holes were drilled on a transparent triangle. Repeatable electrodes' positions could be accurately marked for second measuring session by using this template. In case of temporal muscle, the muscle was palpated at its antero-superior border. One electrode was placed 5mm behind this point and the next one in the temporal fossa parallel to the direction of muscle fibers. An inter-electrode distance of 2 cm was maintained. For producing the template, triangle's hypotenuse was placed parallel to and above the Camper line, with the right angle facing downwards. Hypotenuse center was placed at the point where temporal line crosses the zygomatic process of frontal bone, at the level of supraorbital margin. Electrodes' positions were recorded and secured in the manner described above.

For depressor muscles the subject had to press the tongue against the palate, and the electrodes were fixed along the anterior belly of the digastric muscle in the suprahyoid triangle. An inter-electrode distance of 2 cm was maintained. For producing the template, triangle's hypotenuse was put on the line connecting left and right gonion, with the right angle pointing anteriorly, and triangular height line intersecting the mental protuberance. Subject's head would be maximally retroflexed while electrode locations were marked on the template, so that level of muscular extension would be repeatable. Electrodes' positions were recorded and secured by drilling holes, as described above.

Altogether, three custom made templates were fabricated for every subject (one for each left and right side for elevators and one for depressors).

Results of both measurements were statistically analysed, and Student t-test for dependent samples showed no significant differences between the two sessions ($P>0.05$).

Statistical analysis

The design employed was a 6*5*2 mixed ANOVA design including 3 different factors: the factor of muscle with six levels (six muscles involved), the factor of time with five levels (five sequences of 10 seconds during each of 5 minutes of mastication) and the factor of dental status (natural teeth versus complete dentures).

Results

Table 1 shows mean values of myoelectrical signals recorded in dentate group during maximal voluntary contraction (MVC) at intercuspal position and during wide opening

(Omax), as well as mean values of myoelectrical activity for each muscle during 10 second sequences of five minutes of mastication. The mean values in edentulous group are shown in Table 2. Values are expressed in µV.

Mean values of elevator muscle activity during maximal voluntary contraction, as well as mean values of depressor muscle activity during maximal wide opening, were higher in elderly dentate group than in age-matched edentulous subjects with complete dentures. During chewing mean values of elevator muscle myoelectrical activities were also higher in the dentate group.

To compare the pattern of myoelectrical activity between the two groups, muscle activities were expressed as percentages of maximal voluntary contraction in intercuspal position for the elevator muscles, and as percentages of maximal wide opening for the depressor muscles.

The results of statistical significant differences between groups, regarding the main effect of factors: muscle, time and dental status are shown in Table 3.

There was a significant effect of factor "muscle" (~~p~~P<0~~,~~.001). In both groups elevator muscles myoelectrical activities were significantly higher than depressor's during chewing, but were similar between the same muscle of left and right side.

There was a significant main effect of factor "time" (P<0.001). In EG the highest myoelectrical activity was observed in the 1st and the lowest in the 5th minute of mastication. In DG the highest myoelectrical activity was observed in the 1st and the lowest in the 3rd minute of mastication. ~~Elevator muscles myoelectrical activities were significantly higher than depressor's.~~ The time by group interaction was also significant (P=0.046).

There was significant main effect of factor “group“(dentate vs. edentulous) (P=0.034).

~~The muscle by group interaction was, however, not significant (p=0,254).~~ Figure 1 shows myoelectrical activities of elevator and depressor muscles in the both groups, expressed as percentages of the maximal muscle activity. Edentulous subjects had to use relatively higher muscle potentials (% of MVC or % of Omax) than dentate subjects during a five minute period of chewing, which was most pronounced for temporal muscles.

Muscle activity, expressed in percentages of the maximal muscle activity, during five sequences of mastication in the both groups is shown in Figure 2. Edentulous subjects showed higher percentages of maximal muscle activity in comparison to dentate subjects during the five minute mastication interval. ~~There was a significant main effect of factor “time” (p<0,001). The time by group interaction was also significant (p=0,046).~~ In the edentulous group myoelectrical activity continuously decreased from the first to the fifth minute. In the group of dentate subjects the highest myolelectrical activity was obtained during the first minute, and the lowest during the third minute, while myoelectrical activity again increased from the third to the fifth minute~~e myoelectrical activity continuously increased~~. ~~Muscle activity, expressed in percentages of the maximal muscle activity, during five sequences of mastication in the both groups is shown in Figure 2.~~

~~There was significant main effect of factor “group“(p=0,034).~~

Discussion

This study revealed that maximal elevator muscle activity levels in intercuspal position were higher in dentate subjects than in edentulous group, while during maximal wide opening depressor muscle activity levels were similar in both groups.

Considering elevator muscle activity during maximal clenching trial, ~~. During maximal wide opening depressor muscle activity levels were also higher in the dentate group. These~~our results are in agreement with other authors [~~10~~15,~~11~~16] who had reported that denture wearers are unable to produce levels of muscle activity at MVC comparable to those with natural teeth. Miralles et al. [~~12~~17] showed that low muscle activity in patients with complete dentures might be the consequence of a change in the influence of peripheral or central neural mechanisms, since in edentulous patients periodontal receptors are missing, and mucosal mechanoreceptors play the main role, replacing them. Change in the input from peripheral receptors and their influence on trigeminal motoneurone pools could be expected with the loss of natural teeth.

In the study of Proeschel and Raum [7], which included healthy dentate subjects, digastrics muscles produced the highest activity during mandible balancing trial, while depressor activation in chewing exceeded depressor activation in clenching. No reports, however, have been devoted to considering these factors in denture wearers.

Although numerous studies have described normal masticatory performance in young adults and children [~~13~~18,~~14~~19], little comparative information has been shown regarding the differences in mastication between dentate and edentulous subjects of similar age. Impairments induced by replacement of natural teeth by complete dentures have been described with regard to bite force, tongue motor skill, and chewing efficiency measured by the quality of comminution [3,5,~~15~~20]. Subject satisfaction has been examined in various surveys in terms of subjective criteria such as chewing ability, chewing comfort, stability and speech [~~16-18~~21-23]. but the results could not completely clarify whether the functional capacity of the edentulous patients' masticatory system is reduced when compared to dentate subjects.

~~None of these attributes, however, reflect completly the quality of mastication [19].~~

Considering muscle activity during chewing, presented in our study, it is obvious that higher values of myoelectrical signals (in µV) were found in dentate subjects than in complete denture wearers during five sequences of mastication. However, the amounts of muscle activity in proportion to its maximal activity were higher in edentulous subjects when compared to elderly dentates. This indicates that the elevator and depressor muscles in the edentulous group change a pattern compared to dentate group in order to perform optimal mastication~~.~~ with the reduced absolute muscle activity due to denture insertion and protective reflex mechanisms of neuromuscular control.

In the both groups values of muscle activity were similar between the left and right side, but were significantly higher for elevator than for depressor muscles ~~(p<0,001)~~ during chewing. Edentulous group had to use more muscle activity (in proportion to maximum voluntary contraction) than dentate subjects during chewing.

A significant main effect of factor "time" could be seen between the first and the third minute in the group of dentate subjects, and between the first and the fifth minute in the group of complete denture wearers. A significant interaction between the factor "group" and factor "time" suggests that different tendencies were recorded during five minute interval of mastication. Dentate subjects succeeded to increase muscle activity after third minute of mastication, while complete denture wearers gradually decreased muscle activity to the end of chewing task.

~~In the group of dentate subjects muscle activities continuously decreased from the first to the third minute (p<0,001), and then slightly increased to the fifth minute. In edentulous group, however, there was a constant decrease of muscle activity from the first to the fifth minute (p<0,001) of mastication.~~

Slagter and al. [3] recorded EMG activity from masseter and temporal muscles in dentate subjects and in complete denture wearers during mastication and concluded that dentate subjects and denture wearers generated equivalent amounts of muscle activity in proportion to maximum voluntary contraction. In the study of Veyrune and Mioche [4] muscle activity was less for the edentulous group, particularly that of the masseter muscle.

The results of this study indicate that edentulous subjects had to use significantly higher potential of muscle activity than dentate subjects (in proportion to maximum voluntary contraction~~percentages of maximum activity~~) during ~~in order to perform satisfactory~~ mastication. This finding might add to the knowledge of mastication the fact that edentulous subjects, while chewing with dentures, involve more masticatory muscle fibres than dentate subjects, and gradually decrease muscle contractions, probably due to fatigue. Dentate subjects succeeded to increase muscle activity after three minutes of decreasing it during chewing, while EG showed continuous decrease. The pattern of relative muscle activity was thus changed due to denture wearing.

The present surface EMG analysis of both static (clenching) and dynamic (chewing) tasks showed that complete denture wearers were functionally inferior to natural dentition and therefore had to change a pattern muscle activity (in proportion to maximum voluntary contraction) which led to inability to increase muscle activity at the end of the chewing task. Reduced muscle activity and a difference in the chewing pattern should be explained to a patient prior to prosthodontic rehabilitation with complete dentures in order to put their expectations into right perspective.

~~This finding might indicate that greater involvement of masticatory muscle fibres during chewing was present in the edentulous group. In the same group, most probably due to the involvement of greater number of muscle fibres, fatigue occurs faster than in dentulous subjects.~~

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Table 1. EMG registrations recorded in maximal voluntary contraction (MVC) at the intercuspal position, in maximal wide opening and during five minutes of mastication in dentate subjects

	RT	LT	RM	LM	RD	LD
MVC (µV)	147,16	134,16	162,96	144,58	20,93	22,29
Omax (µV)	17,48	14,70	13,11	11,33	89,69	86,99
1 min (µV)	69,94	75,78	84,68	84,20	25,44	26,83
2 min (µV)	81,76	67,34	86,252	85,96	22,24	23,68
3 min (µV)	72,74	51,40	72,64	76,11	18,58	21,69
4 min (µV)	79,68	67,07	78,83	80,67	22,42	26,39
5 min (µV)	66,41	63,55	74,96	85,16	22,63	24,63

(MVC-maximal voluntary contraction; Omax-maximal opening; RT-right temporal muscle; LT-left temporal muscle; RM-right masseter muscle; LM-left masseter muscle; RD-right depressor muscle; LD-left depressor muscle)

Table 2. EMG registrations recorded in maximal voluntary contraction (MVC) at the intercuspal position, in maximal wide opening and during five minutes of mastication in complete denture wearers

	RT	LT	RM	LM	RD	LD
MVC (μV)	77,67	84,03	80,08	85,89	26,27	27,94
Omax (μV)	23,88	20,73	24,98	17,44	89,59	82,08
1 min (μV)	47,88	55,79	47,75	53,69	22,44	25,18
2 min (μV)	46,45	49,61	43,01	54,84	26,69	25,62
3 min (μV)	42,58	51,40	43,12	46,43	27,41	25,12
4 min (μV)	46,23	47,89	43,38	49,19	23,79	22,09
5 min (μV)	40,97	44,51	41,25	49,18	25,72	25,59

(MVC-maximal voluntary contraction; Omax-maximal opening; RT-right temporal muscle; LT-left temporal muscle; RM-right masseter muscle; LM-left masseter muscle; RD-right depressor muscle; LD-left depressor muscle)

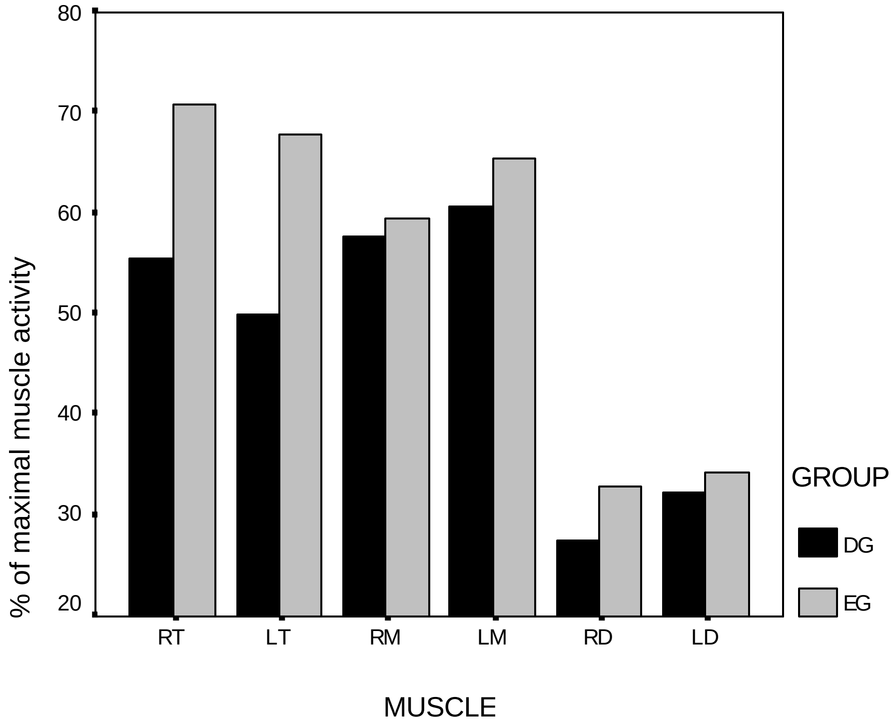
Table 3. The evaluation of statistical significances regarding the main effect of factors: muscle, minute and dental status

	value	F	df	P
muscle	0.642	25.398	5	<0.001
minute	0.247	7.056	4	<0.001
group*minute[a]	0.196	3.044	4	0.046
dental status	0.257	4.726	1	0.034

(F=F value (analysis of variance), df= degrees of freedom, P=significance)

([a] this row gives the values for the interaction between the factor "group" and the factor "time")

Figure 1.



% of maximal muscle activity
80
70
60
50
40
30
20
RT
LT
RM
LM
RD
LD
MUSCLE
GROUP
DG
EG

Figure 2.

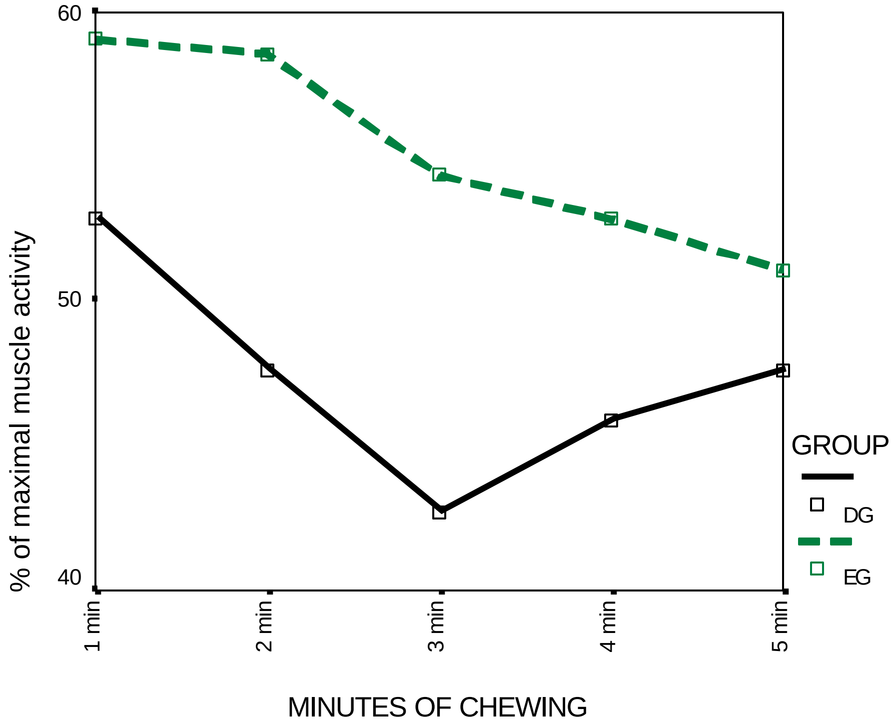


Figure 1. Evaluation of myoelectrical signals for temporal, masseter and depressor muscles in dentate and edentulous subjects (values are expressed in percentages of the maximal muscle activity)

RT-right temporal muscle

LT-left temporal muscle

RM-right masseter muscle

LM-left masseter muscle

RD-right depressor muscle

LD-left depressor muscle

Figure 2. Evaluation of myoelectrical signals during five minute period of mastication (values are expressed in percentages of the maximal muscle activity)

1 min-first minute of mastication

2 min- second minute of mastication

3 min- third minute of mastication

4 min- fourth minute of mastication

5 min - fifth minute of mastication