The Influence of Dental Status on Masticatory Muscle Activity in Elderly Patients

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Purpose: The objective of this study was to determine whether elevator and depressor muscle activity during 5 minutes of mastication is affected by the presence of a prosthetic appliance in elderly patients. ***Materials and 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, masseter muscle, and the submandibular group in the region of the anterior belly of the digastric muscle on the left and right sides. Muscle activity was recorded during maximal voluntary contraction (MVC) in the intercuspal position, maximal opening (Omax), and during 5 minutes of mastication. Elevator muscle activity during mastication was expressed as a percentage of maximal muscle activity in the intercuspal position (%MVC), and depressor muscle activity was expressed as a percentage of maximal opening (%Omax). The effect of 3 factors was investigated using a mixed analysis of variance design: the factor of muscle, with 6 muscles involved; the factor of time (5 minutes of mastication); and the factor of dental status, where some participants had their own natural dentition and others had complete dentures. ***Results:*** The results revealed significant effects for the factors "muscle" and "time" ($P < .001$ for the factor "muscle"; $P < .001$ for the factor "time"). The time by group interaction was significant ($P = .046$). In the EG, muscle activity gradually decreased during the 5-minute interval of mastication, while in the DG it decreased more rapidly from the first to the third minute and then increased until the fifth minute. There was also a significant effect regarding the presence of natural teeth or complete dentures ($P < .034$). Complete denture wearers had higher muscle activity relative to %MVC or %Omax than dentate subjects. ***Conclusions:*** Muscle activity during 5 minutes of mastication depended greatly on the presence of the prosthetic appliance, since edentulous subjects had to use higher potentials of muscle activity (%MVC or %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 patients prior to prosthetic treatment to help them adjust their expectations. *Int J Prosthodont 2005;18:333–338.*

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In healthy subjects, 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 a central pattern generator located in the brainstem.[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 older subjects, these mechanisms act with marked differences. Some

age-related changes, such as deterioration in the fast- and slow-twitch fibers of 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 neuromuscular patterns.[4] Edentulous persons are considered to have reduced capacity in various functions of the stomatognathic system, such as occlusal force, tactile thresholds, and chewing ability.[5]

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

Masticatory activity in complete denture wearers has been investigated by some authors.[3,8] 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 elevator and depressor muscle activity during mastication is altered by the presence of a prosthetic appliance. This study attempted to determine whether denture wearers with clinically and subjectively satisfactory dentures presented with differences in their muscle activity patterns during mastication, in comparison to dentate subjects.

Materials and Methods

Subjects

Sixty subjects participated in this study, and they were divided in 2 groups. The complete denture (edentulous) group (EG) consisted of 30 subjects (21 female, 9 male, mean age 65.73 $\pm$ 7.81 years). All subjects had worn maxillary and mandibular complete removable dentures for an average of 6 months. Complete denture participants were included in the study if their dentures had a satisfactory interocclusal and maxilomandibular relationship. All participants reported 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 had a history of mandibular dysfunction or any disease that might affect the muscles of the masticatory system.

The control group (CG) consisted of 30 healthy subjects (20 female, 10 male, mean age 61.85 $\pm$ 7.77 years). Subjects were 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.[9] Each subject gave 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 an 8-channel, computer-based EMGA-1 apparatus specially designed and developed for the purpose of kinesiological examinations of stomatognathic system function.[10] This system allows 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 to 1 kHz, programmable input sensitivity from 100 μ Vpp to 20 mVpp, a 12-bit resolution A/D conversion, and a 2kHz sampling rate. The analogue EMG signal was amplified, digitized, and digitally filtered. The instrument was directly interfaced with a computer, which presented the data graphically and stored them for further quantitative and qualitative analyses.

Surface EMG recordings were obtained from the left and right anterior temporal muscles, the left and right masseter muscles, and the submandibular group of muscles in the region of the anterior belly of the digastric muscle on the left and right sides. The disc electrodes (Ag/AgCl, diameter 10 mm) were placed 2 cm apart in the main direction of the muscle fibers. Every participant had electrodes placed in the same manner with regard to his or her 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 to 6 minutes later, which allowed the conductive paste to adequately moisten the skin surface. The common ground electrode was clipped to the left wrist. All measurements were performed between 10:00 am and 11:00 am in a 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 their molars in the inter-

cuspal position (ICP) to establish the maximal activity of the elevator muscles. The subjects clenched maximally for 3 seconds and repeated the clench 5 times with 15-second intervals of rest. During the 5 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 a clenching level indicator, which was used for visual feedback information about the clenching level. It is an additional unit that rectifies and smoothes the amplified myoelectric signal obtained from 1 of the amplifiers of the EMG device, and by switching on a corresponding number of light-emitting diodes it shows the average myoelectrical activity. To establish the maximal activity of the depressor muscles, subjects performed 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). Each subject was asked to chew "as normal" for 5 minutes while seated upright in a dental chair. During that period, EMG recordings were made once a minute for 10-second periods. It is well known that EMG is vulnerable to extramuscular factors that may alter and distort the true electrical signal.[11,12] To obtain useful comparisons between different subjects and different studies, the EMG potentials should be standardized (normalized). Therefore, myoelectric activity of a certain muscle was compared to its maximal activity, as previously suggested.[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. 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 7 days between each session. The accurate and precise relocation of elevator muscle electrodes was achieved by using a flexible transparent isosceles triangle as a template (with sides measuring 15.5, 15.5, and 22.0 cm). The width of the masseter muscle was measured by palpation, and electrodes were placed over the center of the fleshiest part of the superficial portion of the muscle, 2 cm apart, and in line with the muscle fibers. The hypotenuse of the triangle was placed on the Camper line, with the right angle facing downward. The line representing the height of a triangle (the line vertical to the hypotenuse, connecting the right angle and the middle of the hypotenuse) was placed on the tragus of the ear. The positions of the electrodes were then marked and holes were drilled on a transparent triangle. With this template, repeatable electrode positions could be accurately marked for the second measuring session. For the temporal muscle, the muscle was palpated at its anterosuperior border. One electrode was placed 5 mm behind this point, and the next one was placed in the temporal fossa parallel to the direction of the muscle fibers. An interelectrode distance of 2 cm was maintained. To produce the template, the triangle's hypotenuse was placed parallel to and above the Camper line, with the right angle facing downward. The center of the hypotenuse was placed at the point where the temporal line crossed the zygomatic process of the frontal bone at the level of the supraorbital margin. The positions of the electrodes were recorded and secured in the manner described above.

For the 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 interelectrode distance of 2 cm was maintained. To produce the template, the triangle's hypotenuse was put on the line connecting left and right gonion, with the right angle pointing to the anterior, and the triangular height line intersecting the mental protuberance. Each subject's head was maximally retroflexed while the electrode locations were marked on the template, so that the level of muscular extension would be repeatable. The electrode positions were recorded and secured by drilling holes, as described above. Altogether, three custom-made templates were fabricated for every subject (one for each side for the elevator muscles and 1 for the depressor muscles). The results of both measurements were analyzed statistically, and the Student *t* test for dependent samples showed no significant differences between the 2 sessions ($P > .05$).

Statistical Analysis

The design employed was a $6 \times 5 \times 2$ mixed analysis of variance that included three different factors: the factor of muscle with 6 levels (6 muscles involved); the factor of time with 5 levels (5 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 the mean values of myoelectrical signals recorded in the CG during MVC at intercuspal position and during wide opening (Omax), as well as the mean values of myoelectrical activity for each muscle during

Table 1 EMG Registrations Recorded during MVC in ICP, in Omax, and During 5 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	86.25	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 during MVC in ICP, in Omax, and During 5 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 Evaluation of Statistical Significance Regarding the Effect of Factors Muscle, Time, and Dental Status

	Value	F	df	*P*
Muscle	0.642	25.398	5	< .001
Time	0.247	7.056	4	< .001
Group by time*	0.196	3.044	4	.046
Dental status	0.257	4.726	1	.034

F = F value (analysis of variance); df = degrees of freedom.

*Gives the values for the interaction between the factor "group" and the factor "time".

10-second sequences of 5 minutes of mastication. The mean values for the EG are shown in Table 2. Values are expressed in microvolts. Mean values of elevator muscle activity during MVC, as well as mean values of depressor muscle activity during maximal wide opening, were higher in the CG 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 MVC in ICP for the elevator muscles and as %Omax for the depressor muscles. The differences between groups regarding the main effect of the factors muscle, time, and dental status are shown in Table 3. There was a significant effect of the factor "muscle" ($P < .001$). In both groups, elevator muscle myoelectrical activity was significantly higher than that of the depressors during chewing but were similar between the same muscle on the left and right sides.

There was a significant main effect of the factor "time" ($P < .001$). In EG, the highest myoelectrical activity was observed in the first minute of mastication and the lowest in the fifth minute. In DG, the highest myoelectrical activity was observed in the first minute of mastication and the lowest in the third minute. The time by group interaction was also significant ($P = .046$).

There was a significant main effect of factor "group" (dentate versus edentulous) ($P = .034$).

Figure 1 shows the myoelectrical activities of the elevator and depressor muscles in both groups, expressed as percentages of the maximal muscle activity. Edentulous subjects had to use relatively higher muscle potentials (%MVC or %Omax) than dentate subjects during a 5-minute period of chewing, which was most pronounced for temporal muscles.

Muscle activity, expressed as percentages of maximal muscle activity during 5 sequences of mastication in both groups, is shown in Figure 2. Edentulous subjects showed higher percentages of maximal muscle activity in comparison to dentate subjects during the 5-minute mastication interval. In the EG, myoelectrical activity decreased continuously from the first to the fifth minute. In the CG, 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.

Discussion

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

Considering elevator muscle activity during the maximal clenching trial, our results are in agreement with those of other authors,[15,16] who had reported that denture wearers were unable to produce levels of muscle activity at MVC comparable to those in subjects with natural teeth. Miralles et al[17] showed that low muscle activity in patients with complete dentures might be a consequence of a change in the influence of peripheral or central neural mechanisms, since in edentulous patients the periodontal receptors are missing, and mucosal mechanoreceptors play the main role in

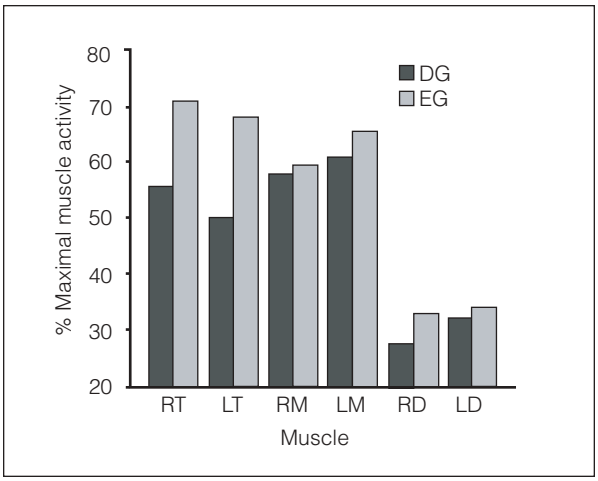

Fig 1 Evaluation of myoelectrical signals for temporal, masseter, and depressor muscles in dentate and edentulous subjects (values are expressed as percentages of maximal muscle activity). RT = right temporal muscle; LT = left temporal muscle; RM = right masseter muscle; LM = left masseter muscle; RD = right depressor muscle; LD = left depressor muscle.

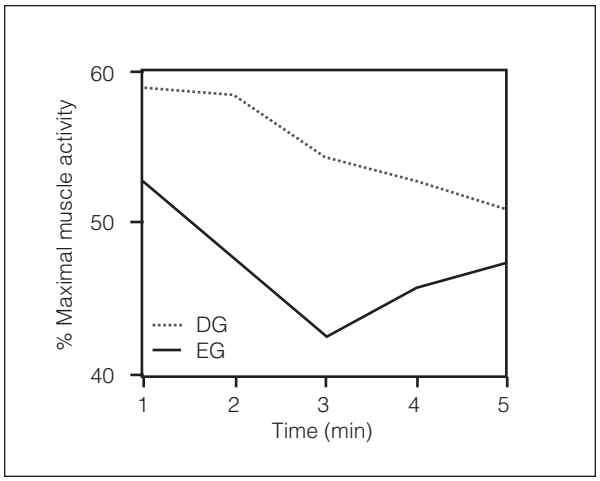

Fig 2 Evaluation of myelectrical signals during 5 minute period of mastication (values are expressed in percentages of the maximal muscle activity). 1 min = first minute of mastication; 2 min = second minute of mastication; 3 min = third minute of mastication; 4 min = fourth minute of mastication; 5 min = fifth minute of mastication.

replacing them. Change in the input from peripheral receptors and their influence on trigeminal motor neuron pools could be expected with the loss of natural teeth.

In the study of Proeschel and Raum,[7] which included healthy dentate subjects, the digastric muscles produced the highest activity during a mandible-balancing trial, while depressor activation during chewing exceeded depressor activation during clenching. No reports, however, have been devoted to the study of these factors in denture wearers. Although numerous studies have described normal masticatory performance in young adults and children,[18,19] 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.[3,5,20] Subject satisfaction has been examined in various surveys in terms of subjective criteria, such as chewing ability, chewing comfort, stability, and speech,[21–23] but the results could not completely clarify whether the functional capacity of edentulous patients' masticatory system is reduced in comparison to dentate subjects.

Considering muscle activity during chewing, as presented in our study, it is obvious that higher values of myoelectrical signals (in microvolts) were found in dentate subjects than in complete denture wearers during five sequences of mastication. However, the amounts of muscle activity in proportion to maximal activity were higher in edentulous subjects when compared to age-matched dentate subjects. This indicates that the elevator and depressor muscles in the EG changed their pattern, compared to the CG, to perform optimal mastication with the reduced absolute muscle activity as a result of denture insertion and protective reflex mechanisms of neuromuscular control.

In both groups, the values for muscle activity were similar between the left and right sides, but were significantly higher for elevator muscles than for depressor muscles ($P < .001$) during chewing. The edentulous subjects had to use more muscle activity (in proportion to MVC) than the dentate subjects during chewing.

A significant main effect of the factor "time" was 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 the factor "time" suggests that different tendencies were recorded during the 5-minute interval of mastication. Dentate subjects succeeded in increasing muscle activity after the third minute of mastication, while complete denture wearers gradually decreased muscle activity until the end of the chewing task.

Slagter et al[3] recorded EMG activity from the 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 MVC. In the study of Veyrune and Mioche,[4] muscle activity was lower in the edentulous group, particularly in the masseter muscles.

The results of this study indicate that edentulous subjects had to use a significantly higher potential of

muscle activity than dentate subjects (in proportion to MVC) during mastication. This finding might add to the knowledge of mastication the fact that edentulous subjects, while chewing with dentures, involve more masticatory muscle fibers than dentate subjects, and gradually decrease muscle contractions, probably because of fatigue. Dentate subjects succeeded in increasing muscle activity after 3 minutes of decreasing it during chewing, while the edentulous subjects showed a continuous decrease. The pattern of relative muscle activity was thus changed as a result of denture wearing.

The present surface EMG analysis of both static (clenching) and dynamic (chewing) tasks showed that complete denture wearers were functionally inferior to subjects with natural dentition, and therefore had to change their muscle activity patterns (in proportion to MVC), which led to an inability to increase muscle activity at the end of a 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, so that they can adjust their expectations.

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