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The influence of age and dental status on elevator and depressor muscle activity

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SUMMARY The objective of this study was to determine whether the muscle activity at various mandibular positions is affected by age and dental status. Thirty edentulous subjects (E), 20 young dentate individuals (G1) and 20 older dentate individuals (G2) participated in this study. Surface electromyographic (EMG) recordings were obtained from the anterior temporal (T), masseter (M) and depressor muscles (D). Muscle activity was recorded during maximal voluntary contraction (MVC), maximal opening (O_{max}) and in six different mandibular positions. One way ANOVA and the Bonferroni tests were used to determine the differences between groups. Significant differences between the three tested groups were found at MVC and O_{max} for all examined muscles ($P < 0{\cdot}001$). The differences in muscle activity in dentate subjects of different age were found in protrusion for depressor muscles ($P < 0{\cdot}05$) and in lateral excursive positions for the working side temporal ($P < 0{\cdot}05$) and non-working side masseter and depressor muscle ($P < 0{\cdot}05$). There was a significant effect regarding the presence of natural teeth or complete dentures in protrusion and maximal protrusion for all muscles ($P < 0{\cdot}05$) and in lateral excursive positions for non-working side temporal ($P < 0{\cdot}05$) and working side masseter muscle ($P < 0{\cdot}05$). Muscle activity at various mandibular positions depends greatly on the presence of the prosthetic appliance, as edentulous subjects had to use higher muscle activity levels (percentages of maximal EMG value) than age matched dentate subjects in order to perform same mandibular movement. Different elevator muscles were preferentially activated in the edentulous subjects when compared with dentate group in lateral excursive positions of the mandible. The pattern of relative muscle activity was not changed because of ageing.

KEYWORDS: electromyography, masticatory muscles, complete dentures, dentate subjects, mandibular positions

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Introduction

The edentulous patient prosthetic treatment success depends not only on the anatomic and morphologic characteristics of complete denture-bearing areas, but also on the physiologic and psychological status of the patient. Unfortunately, even if the technical quality of the dentures is high, muscle function and neuromuscular coordination of edentulous patients are greatly decreased when compared with dentate individuals. The presence of foreign objects (prostheses) in an edentulous mouth will cause different stimuli in the sensory-motor system, which in turn influences oral motor behaviour. Oral sensory receptors are affected by the shape, size, position and pressure from the prosthetic appliance. Several studies have shown that, after the tooth extraction, the loss of periodontal receptors, together with altered sensory input from the periosteum and temporomandibular joints and some mechanical factors such as instability of dentures, contributes to reduced tactile discrimination (1) and reduced masticatory efficiency (2) in complete denture wearers. Trulsson and Gunne (3) demonstrated a disturbance in the control of precisely directed, low biting forces in

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subjects lacking periodontal receptors and suggested that the receptors play a significant role in the specification of the level and direction of forces used to hold and manipulate food between teeth. With the loss of all teeth, complete dentures restoration is a compromise replacement, which only partially restores function (4). The ability of accommodation to prosthetic appliance as well as the role of mucosal stimuli in the control of jaw movement still remains unclear. Culver and Watt (5) showed that the dentures of a satisfied group moved more during mastication than those of patients in an experimental unsatisfied one. In the study of Perez *et al.* (6), the improvement of retention and stabilization of old poorly fitting dentures had no influence on the masticatory ability of patients. The acceptance of a denture is always accompanied by a process of adjustment, or decrease of reaction to stimuli. A patient's adaptation to prosthetic therapy is also determined by age, as some aspects of coordination diminish with age (7).

The functioning of the masticatory muscles in dentate individuals as well as in subjects wearing dentures have been evaluated previously by electromyography (EMG) (8–12). The results suggest that a long edentulous period is visible not only in the functioning of the masticatory muscles, in terms of decreased EMG activity, but also as decreased density of the muscles, as seen by computed tomography, in the masseter and medial pterygoid muscles (13).

No clear description, however, can be found regarding the contribution of elevator and depressor muscle activity at different mandibular positions.

The objective of this study was to test the hypothesis that the contribution of muscle activity at different mandibular positions varies in the groups of people regarding age and dental status. Comparing the findings of edentulous and dentate subjects we tried to evaluate the influence of prosthetic appliance on EMG activity parameters.

Materials and methods

Subjects

Seventy subjects participated in this study, and they were divided in to three groups.

The experimental group (E) consisted of 30 edentulous individuals, 21 females and 9 males (65·7 ± 7·8 years) who had worn an upper and a lower complete removable denture for an average period of 6 months. The edentulous 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 first control group (G1) consisted of 20 healthy younger dentate subjects, 12 females and 8 males (26·7 ± 2·8 years), and the second control group (G2) consisted of 20 older dentate individuals, 12 females and 8 males (60·9 ± 7·8 years).

All dentate subjects had natural teeth and they had to be free of periodontal diseases and none of them was being treated orthodontically at the time of examination. 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. They had no history suggesting neuromuscular disease or a disease affecting neuromuscular performance, not undergoing treatment for any medical problem (14).

All participants were informed about the experimental procedure and their consent was obtained. The investigation was approved by the Ethics committee of the School of Dental Medicine, University of Zagreb.

EMG recording and procedure

Electromyographic registrations were taken on the 8 channel PC based EMG apparatus (15). 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. This system allows simultaneous recording of myoelectrical activity from six muscles (six differential EMG channels, input impedance 100 MΩ, CMRR >95 dB at 50 Hz, bandwidth 2 Hz–1 kHz, programmable input sensitivity from 100 μVpp to 20 mVpp, an 12-bit resolution A/D conversion, 2 kHz sampling rate). The EMG signal was amplified and digitized. Prior to further analysis, DC offset was calculated and subtracted from digitized EMG signal.

The EMG activity was 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 digastrics muscle (D) on the left and right side. Disposable surface disc electrodes (Ag/AgCl, diameter 10 mm) were placed 2 cm apart in the main direction of the muscle fibres, and remained untouched throughout the experimental session. Every participant had electrodes placed in the same manner, with regard to her/his anthropometric features. To reduce the skin impedance, the skin was carefully cleaned prior to electrode placement. The common ground electrode was clipped to the left wrist. All measurements were performed in calm and peaceful atmosphere between 10 and 11 AM.

Experimental procedure

In the first part of the experiment the continuous biting with the maximum voluntary contraction (MVC) was evaluated, when the 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 s and repeated the clench five times with 15-s intervals of rest. During the five clenching tasks, the highest EMG activity was considered the maximum clenching EMG activity. 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 it visualizes the average myoelectrical activity. To establish the maximal activity of the depressor muscles, subjects had perform maximal wide opening (O_{max}) while contracting depressor muscles as strongly as possible.

The next part of the examination included EMG registrations in the following order: protrusion with the teeth at an edge-to-edge position (P), maximal protrusion (P_{max}), right lateral excursive position with the teeth at an edge-to-edge position (RO), maximal right lateral position (R_{max}), left lateral excursive position with the teeth at an edge-to-edge position (LO) and maximal left lateral position (L_{max}). The subjects were instructed to carry out these tasks for periods of *c.* 2 s.

As it is well known that EMG is vulnerable to extramuscular factors that may alter and distort the true electric signal (16, 17), the normalization (standardization) was carried out in order to allow a useful comparisons of muscle activity between different subjects. Therefore, myoelectric activity of a certain muscle was compared with its maximal activity, as previously suggested (18). For each subject, the levels of muscles activity in different mandibular positions were calculated in relation to their 100% reference value [maximal voluntary contraction at the ICP (% MVC) for elevator muscles and maximal wide opening (% O_{max}) for depressor muscles].

Reproducibility of EMG data

The analysis was performed by the same experienced examiner. The between-session variation of the EMG data was investigated by testing five subjects separately at two different sessions with 7 days between each session. The precise relocation of elevator and depressor muscle electrodes was achieved by using flexible transparent isosceles triangle as template, as described previously (19).

The relationship between replicate tests performed at the same patients at two different sessions was evaluated by calculating the correlation coefficient. The correlation was found to be strong for all tested parameters indicating a high degree of similarity between replicate tests ($P < 0{\cdot}05$).

Statistical analysis

The design employed was one-way between subjects ANOVA design. The *post hoc* Bonferroni tests were used to determine the differences regarding the influence of dental status (natural teeth versus complete dentures) and age (young dentate versus older dentate).

Results

Table 1 shows mean values of myoelectrical signals recorded in edentulous group and in both dentate groups during MVC at ICP and during maximal wide opening (O_{max}). Mean values of elevator muscle activity during MVC, as well as mean values of depressor muscle activity during maximal wide opening, were highest in young dentate group, and lowest in edentulous subjects with complete dentures.

Significant differences between the three tested groups of subjects were found for all examined muscles ($P < 0{\cdot}001$). The Bonferroni *post hoc* tests (Table 2) showed that differences were found for all muscles

Table 1. Comparison of muscle activity in maximal voluntary contraction at the intercuspal position and in maximal opening in three tested groups (ANOVA)

	Mean value (in μV)	*P*-value
MVC (RT)		
E	77·7	<0·001
G2	143·7	
G1	239·2	
MVC (LT)		
E	84·1	<0·001
G2	134·9	
G1	239·8	
MVC (RM)		
E	80·1	<0·001
G2	149	
G1	198·1	
MVC (LM)		
E	85·9	<0·001
G2	138·5	
G1	228·5	
O_{max} (RD)		
E	89·6	<0·001
G2	93·9	
G1	142·3	
O_{max} (LD)		
E	82·1	<0·001
G2	86·1	
G1	132·1	

MVC, maximal voluntary contraction at the intercuspal position; O_{max}, 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.

between dentate subjects of different age groups. Significant differences in muscle activity were also found for the denture wearers when compared with the elderly dentate subjects except for depressor muscles in O_{max} ($P = 0·7$).

To compare the myoelectrical activities between three examined groups in various mandibular positions, muscle activities were expressed as percentages of MVC in ICP for the elevator muscles, and as percentages of maximal wide opening for the depressor muscles (Figs 1–3).

The influence of factor 'age' on elevator and depressor muscle activity

For all examined variables, the percentages (of maximal EMG value) of young dentate subjects were lower than that of elderly dentate. The differences in muscle activity in dentate subjects of different age were found in the protrusion (Fig. 1) for depressor muscles of the right ($P = 0·01$) and the left side ($P = 0·02$). In the right lateral excursive position of the mandible (Fig. 2) differences were found for the working side temporal muscle ($P < 0·01$), the non-working side masseter ($P = 0·03$) and the non-working side depressor muscle ($P = 0·03$). In the left lateral excursive position of the mandible (Fig. 3) differences were found for the working side temporal muscle ($P = 0·04$), the non-working side masseter ($P = 0·03$) and the non-working side depressor muscle ($P < 0·05$).

Despite the significant differences in the percentages of maximal EMG value in different mandibular positions, the similar unique muscular activity pattern was observed in both groups. In protrusion all dentate subjects achieved the lowest levels of temporal muscle activity. In lateral excursive positions, the EMG activity

Table 2. Comparison of muscle activity in maximal voluntary contraction at the intercuspal position and in maximal opening regarding age and dental status (*post hoc* Bonferroni test)

Factor	Bonferroni test			Mean difference	s.e.	*P*-value
Dental status	MVC (RT)	COMP. dentures	E. dentate	−66·1	22·4	0·01
	MVC (LT)	COMP. dentures	E. dentate	−50·8	18·8	0·03
	MVC (RM)	COMP.dentures	E. dentate	−68·9	21·6	0·01
	MVC (LM)	COMP. dentures	E. dentate	−52·6	22·5	0·02
	O_{max} (RD)	COMP. dentures	E. dentate	−4·3	11·9	0·72
	O_{max} (LD)	COMP. dentures	E. dentate	−4	10·3	0·7
Age	MVC (RT)	E. dentate	Y. dentate	−95·5	24·6	0·01
	MVC (LT)	E. dentate	Y. dentate	−104·9	20·6	<0·001
	MVC (RM)	E. dentate	Y. dentate	−49·1	23·6	0·04
	MVC(LM)	E. dentate	Y. dentate	−90·1	24·6	0·01
	O_{max} (RD)	E. dentate	Y. dentate	−48·4	12·9	0·01
	O_{max} (LD)	E. dentate	Y. dentate	−46·1	11·3	<0·001

s.e., Standard error; MVC, maximal voluntary contraction at the intercuspal position; O_{max}, 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.

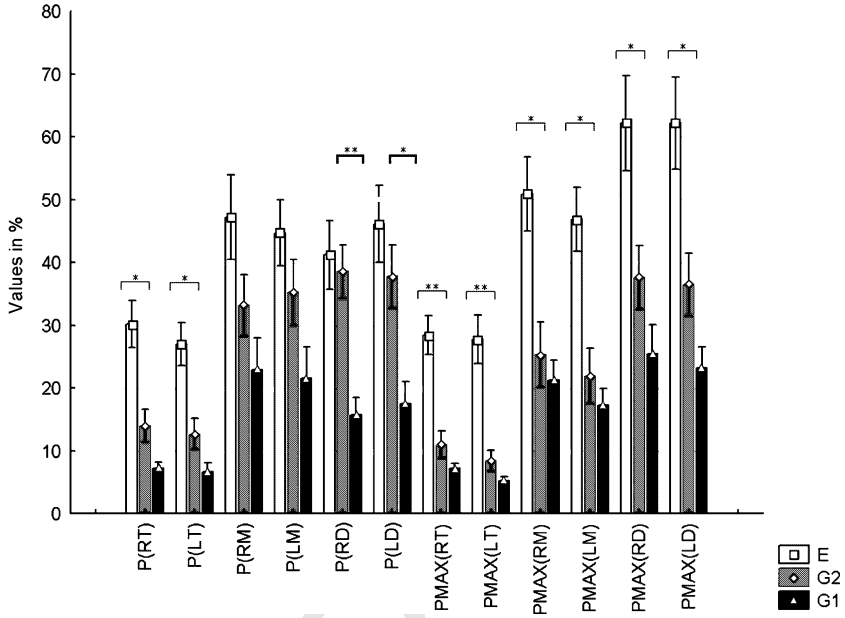

Fig. 1. Presentation of elevator and depressor muscles myoelectrical signals in three tested groups in protrusion and maximal protrusion (values are expressed in percentages of the maximal muscle activity). P, protrusion; P_{max}, maximal protrusion; RT, right temporal muscle; LT, left temporal muscle; RM, right masseter muscle; LM, left masseter muscle; RD, right depressor muscle; LD, left depressor muscle; *$P < 0,05$; **$P < 0,001$.

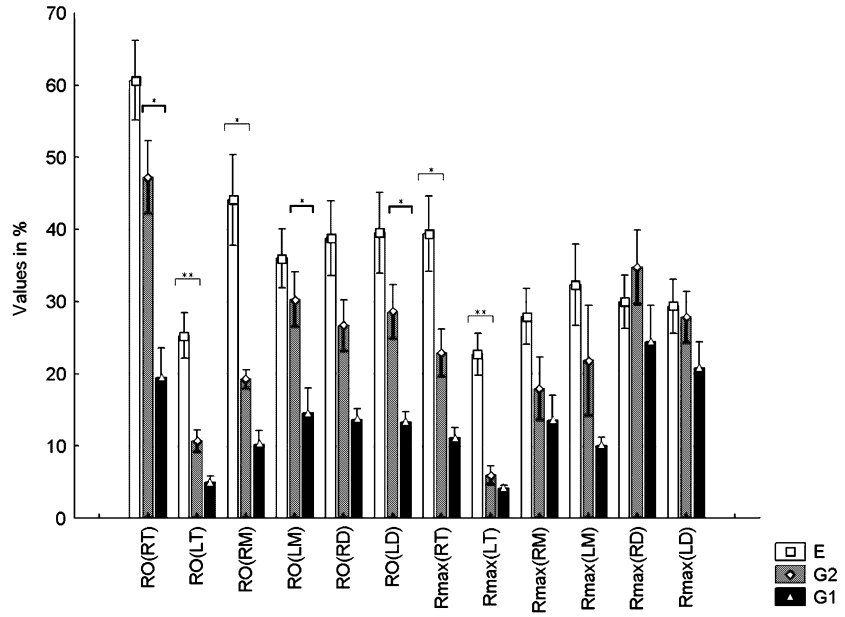

Fig. 2. Presentation of elevator and depressor muscles myoelectrical signals in three tested groups in right lateral and right maximal lateral position (values are expressed in percentages of the maximal muscle activity). RO, right lateral position; R_{max}, maximal right lateral position; RT, right temporal muscle; LT, left temporal muscle; RM, right masseter muscle; LM, left masseter muscle; RD, right depressor muscle; LD, left depressor muscle; *$P < 0,05$; **$P < 0,001$.

of the anterior temporalis was higher on the working side while the EMG activity of masseter muscle was higher on the non-working side, both in young and in older dentate subjects.

The influence of factor 'dental status' on elevator and depressor muscle activity

For all examined variables, the percentages (of maximal EMG value) of elderly dentate subjects were lower than that of subjects wearing complete dentures. Significant differences were found in protrusion (Fig. 1) for both temporal muscles ($P < 0{\cdot}01$) and in maximal protrusion for all elevator and depressor muscles ($P < 0{\cdot}05$). In the right lateral excursive position of the mandible (Fig. 2) differences were found for non-working side temporal muscle ($P < 0{\cdot}001$) and working side masseter muscle ($P < 0{\cdot}01$). In the left lateral excursive position of the mandible (Fig. 3) differences were found for non-working side temporal muscle ($P < 0{\cdot}01$) and working

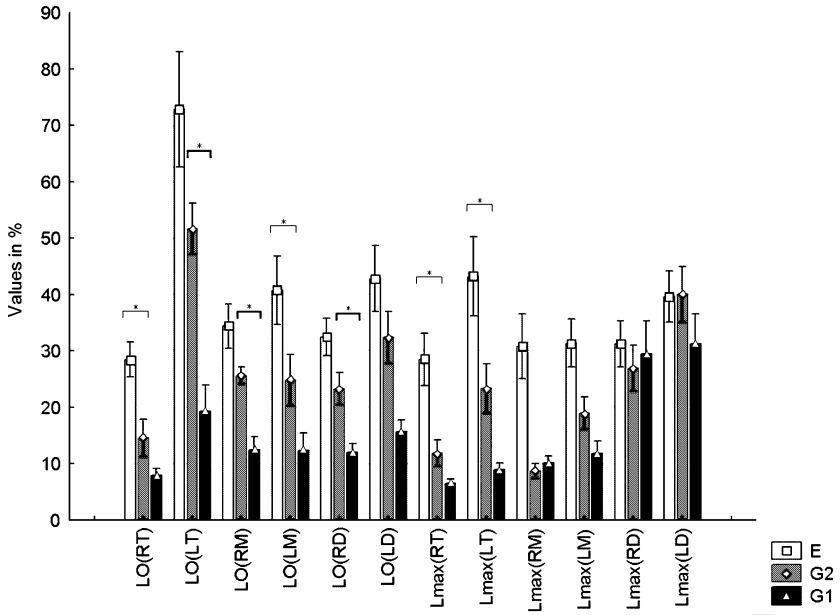

Fig. 3. Presentation of elevator and depressor muscles myoelectrical signals in three tested groups in left lateral and left maximal lateral position (values are expressed in percentages of the maximal muscle activity). LO, left lateral position; L_{max}, maximal left lateral position; RT, right temporal muscle; LT, left temporal muscle; RM, right masseter muscle; LM, left masseter muscle; RD, right depressor muscle; LD, left depressor muscle; $*P < 0,05$; $**P < 0,001$.

side masseter muscle ($P = 0{\cdot}03$). In the maximal lateral positions of the mandible differences were found for temporal muscles of both sides ($P < 0{\cdot}05$).

In protrusion both dentate and edentulous subjects achieved the lowest levels of temporal muscle activity and similar, higher, levels of masseter and depressor muscle activity. During lateral excursive positions, however, the edentulous subjects achieved the highest levels of working side temporal muscle activity, while the levels of masseter muscle activity were higher on the working than on the balancing side.

Discussion

This study revealed that the maximal elevator muscle activity levels in ICP were highest in the group of young dentate subjects. The lowest elevator muscle activity levels in ICP, found in the group of denture wearers, agrees with other authors (20, 21) who have reported that denture wearers are unable to produce levels of bite force comparable with those of individuals with natural teeth. Miralles *et al*. (22) reported that low muscular activity in patients with complete dentures might be the consequence of a change in the influence of peripheral or central neural mechanisms because in edentulous patients periodontal receptors are missing, and mucosal mechanoreceptors play the main role replacing them. It is also important to consider the influence of some psychological factors such as fear of pain, fracture or instability of dentures, which may play an important role in muscular activity reduction.

The results of presented study revealed that the maximal depressor muscle activity levels during maximal opening were highest in the group of young dentate subjects, while in the groups of elderly dentate and complete denture wearers depressor muscle activity levels were similar.

Regarding muscle activity in various mandibular positions, presented in our study, it is obvious that in all mandibular positions elevator and depressor muscle activity levels (expressed as percentages of maximal EMG value), were higher in elderly dentate subjects when compared with young dentates. This means that the elevator and depressor muscles of elderly subjects should need stronger activation than those of young subjects for the same effort. Significantly higher values in the elderly group were observed in protrusion for depressor muscles and even more in laterotrusive positions for working side temporal muscle and for non-working side masseter muscle. Ott *et al*. (23) found that even performing small excursions of the mandible led to a drastic decrease of elevator muscle activity in patients with natural dentition providing anterior front-canine guidance. It is generally accepted (24, 25) that canine guidance exists in many young mouths with a healthy periodontium and minimum wear. In elderly subjects, however, canines are usually not in the proper position to accept the horizontal forces and other teeth

must contact during eccentric movements. It appears that fewer muscles are active when canines contact during eccentric movements than when posterior teeth contact (26). Although significant differences were found for working side temporal and non-working side masseter and depressor muscle, the pattern of relative muscle activity was not changed because of ageing and the neuromuscular function is similar in older dentate subjects to that found in young people with natural teeth. In protrusion the masseter muscle EMG activity was higher than temporal muscle activity. In lateral excursive positions, the EMG activity of the anterior temporal muscle was higher on the working side while the EMG activity of masseter muscle was higher on the non-working side, both in young and in older dentate subjects.

The influence of dental status on muscle activity was also a matter of concern in our study. The edentulous subjects showed significantly higher percentages of maximal muscle activity in comparison with dentate subjects in same mandibular movements. Regarding dental status, significantly higher values of muscle activity (in proportion to maximal EMG value) in patients wearing dentures were observed during protrusion for temporal muscles and during maximal protrusion for all elevator and depressor muscles when compared with elderly dentate subjects. In laterotrusive positions significantly higher values of muscle activity (in proportion to maximal EMG value) in the edentulous group were observed for the non-working side temporal muscle and the working side masseter muscle, while in maximal laterotrusive positions significantly higher values in the edentulous group were observed for both temporal muscles.

The pattern of relative muscle activity was thus changed because of denture wearing. The differences in muscle activity pattern were mostly observed in lateral excursive positions. In edentulous subjects the levels of masseter muscle activity were higher on the working than on the balancing side. This indicates that the elevator muscles in the edentulous group change a pattern compared with the dentate group in order to perform the same mandibular movement with the increased relative muscle activity because of denture insertion and different reflex mechanisms of neuromuscular control as in these patients the sensory mechanism from the stomatognathic receptors is dramatically altered.

In summary, dental status (elderly dentates – edentulous subjects) had a significant effect on the muscle activity in different mandibular positions, as edentulous subjects had to use higher muscle activity levels (percentages of maximal EMG value) than age matched dentate subjects in order to perform same mandibular movement. It was also found that different elevator muscles were preferentially activated in the edentulous subjects when compared with dentate group in lateral excursive positions of the mandible.

The elevator and depressor muscles need stronger activation by the ageing. The pattern of relative muscle activity was not changed because of ageing and the neuromuscular function in older dentate subjects remains similar to that found in young people with natural teeth.

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