Masticatory muscle activity in complete denture wearers: a surface electromyographic analysis

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ABSTRACT
The investigation of the adaptation process to a new denture is relevant to understand the control of muscles. Surface electromyography provide reproducible data of masticatory muscle function and helps to assess the performance of dentures. This longitudinal study simultaneously evaluated electric potential in masseter and anterior temporalis during clenching at maximum intercuspation position and mastication at 2 months after denture insertion and one year later was done in complete denture patients. The surface electrodes were placed in anterior temporalis and masseter region of 22 patients during maximum voluntary clenching and chewing. Statistical analysis was performed by paired t-test. A significant increase in electrical activity was found during clenching and chewing after one year compared to two months. The overall mean EMG value of masseter was significantly higher during chewing at 2 months ($p<0.001$) and 1 year ($p<0.001$). A negative correlation was found with respect to age and EMG value of masseter. It is concluded that the electrical activity presented statistically significant difference after one year indicating improved functional quality. A good rehabilitation improves the efficiency of muscles. Monitoring the effect of rehabilitation on stomatognathic system help to preventively warn about dysfunctions and treatment modifications needed.
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INTRODUCTION

Rehabilitation of lost teeth with conventional complete denture (CD) are still widely performed in general clinical settings owing to economic conditions and non-invasiveness of procedure. Mastication is a highly coordinated neuromuscular function involving fast effective movements of the jaw and continuous modulation of force. In edentulous subjects, sensory feedback is altered. Pattern of chewing function is different in CD wearers as compared to dentate individuals. One of the best proven methods to evaluate masticatory muscle activity is surface electromyography.[1] To provide further insight into the adaptation to new CD in edentulous subjects, a longitudinal study was done for the evaluation of jaw muscles activity by EMG. SEMG measurements can provide objective, documentable, valid, reproducible data on functional condition of masticatory muscles[2]; SEMG of both static (clenching) and dynamic (chewing) procedures are taken into account due to it being combination of masticatory efficiency.

This study attempts to determine the difference in masticatory muscle activity during clenching and mastication in CD wearers.

METHODS

Research question is there any change in muscle activity of masseter and temporalis muscle at 2 months and one year of removable CD use during clenching and mastication. The null hypothesis stated that there is no significant difference between masseter and anterior temporalis activity during clenching and mastication at 2 months and after one year of denture wearing.

The sample size of this longitudinal study was calculated as 22 with a confidence interval of 95%, power of study as 80% based on values from previous literature.[3,4] All patients were above 40 years of age who visited Department of Prosthodontics for conventional CDs and met the inclusion criteria were selected. Twenty-two volunteers were chosen upon the criteria that their dentures had satisfactory interocclusal and maxillomandibular 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 and have class 1 maxillomandibular arch relation. The dentures fabricated with same heat cure acrylic resin and denture teeth by compression moulding technique. The patients were ready to cooperate with study.
A written informed consent was obtained from research participants. The investigation was approved by the Institutional Ethics Committee (PCDS/IEC/K11/11/15).

The exclusion criteria were patients with neurologic disease, lack of motor coordination, with uncontrolled jerky movements; patients with para-

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functional habits such as clenching, bruxism, tongue thrust etc; presence of mucosal irritation or inflammation; history of diseases of muscles of mastication; patients with other systemic conditions affecting cooperation for lengthy appointments; and patients wearing pace makers, implantable defibrillators.

Patients at 2 months after insertion are named as group 1, consist of group 1A namely muscle activity of group 1 during clenching, and group 1B namely muscle activity of group 1 during chewing; patients at 1 year after insertion were named as group 2, consist of 2A namely muscle activity of group 2 during clenching, and group B namely muscle activity of group 2 during chewing; RT is right temporalis, LT is left temporalis, RM is right masseter, and LM is left masseter.

There two study variables: EMG amplitude (microvolt) of right and left masseter and anterior temporalis during clenching and chewing at 2 months, and EMG amplitude (microvolt) of right and left masseter and anterior temporalis during clenching and chewing at one year.

This study was performed at Pushpagiri College of Dental Sciences, Thiruvalla and EMG studies were done at Department of Neurology, Pushpagiri Medical College, Thiruvalla.

Electromyography evaluation

Surface EMGs were performed using Nihon Kohden Neuropack EMG machine,[5] made in Japan 2006, MEB-9400) with quantitative EMG software (QP-946BK). The low noise amplifier speeds up examination and gives values easily and quickly. Reports were generated in Microsoft excel. MUP wave forms were automatically detected and measurement results were displayed. EMG signals were recorded at a filter setting of 20 Hz for the low filter and 10 kHz for the high filter and amplified.

EMG was recorded after the complete absence of any discomfort, when the patients were presumed to be adapted to their dentures, after 2-months. During all recording, the patients were seated with their head unsupported with Frankfort horizontal plane parallel to floor and were asked to maintain a naturally erect position to avoid the postural effect on the recorded muscle activities. Thus seating position for each patient was standardised.

Application of surface EMG electrodes requires proper skin preparation beforehand. In order to obtain a good quality EMG signal, the skin's impedance must be considerably reduced. For this purpose, the dead cells on the skin e.g. hair must be completely removed from the location where the EMG electrodes are to be placed.

The site of electrode placement was rubbed with abrasive gel and cleansed with a cotton pellet moistened with alcohol (Avagard antiseptic solution) before electrode placement to remove excess oil that reduces skin electrical resistance. This enhanced contact with the electrodes helped to obtain signals of good quality. The patient was asked to hold the jaws tightly closed to palpate the muscles for proper placement.

Care was taken that for each individual the electrode placement was as far as possible identical at the two sessions. The disposable surface electrodes were positioned on muscle bellies parallel to muscle fibres with adhesive tape. The electrodes were circular with a diameter of 1 cm. The centre-to centre interelectrode distance was 2 cm. Prior to test resting values were collected for a period of 10 seconds.[6]

Location and orientation of the electrode

Two detecting surfaces (or EMG electrodes) were placed on the skin in bipolar configuration.[8,9] Muscle function test was used to position the electrodes over the evaluated muscles.[10]

EMG recording of the muscles

For masseter, the electrodes were placed parallel to the muscle fibres, with the electrode at the intersection between the tragus-labial commissure and the exocanthion-gonion lines, perpendicular to the skin surface, according to the technique described in literature.[11] The electrode was placed in the centre of the masseter muscle, at an equidistant point from the upper and lower insertions, main-taining the teeth in occlusal contact

In the case of the anterior temporalis muscle, during mandibular movement, the anterior border was located and the electrode was placed perpen-pendicular to the sagittal plane 1.5-2.0 cm over the zygomatic arch immediately behind the frontal process of the zygomatic bone.[11]

EMG evaluation during clenching-mastication

For clenching, each patient was instructed to clench their teeth for 3 seconds to measure the muscle activity. Next the patient was asked to relax the muscles, slightly separating the teeth for another three seconds. All the recordings were repeated 3-three times.[12] The machine automatically displayed the mean activity of muscle. The recordings were made at 2-months and 1-year of denture use.

The masseteric and anterior temporal myoelectric activities of left and right sides were recorded by means of bipolar electrodes. The recording electrodes were approximately 20 mm apart. The patient was grounded by grounding electrode by fixing the third electrode on the forehead.

In mastication, on a command signal the subject placed the gum into the mouth. The subject closed the teeth into occlusion keeping the test food between the tongue and started unilateral chewing when the signal was given. The test food was chewed side for 15-seconds while the EMG was recorded.[13] Chewing movements were tested three times. This phase is one sequence. Participants were asked not to move their heads during the recordings, two sessions were held for each individual. The first session was held to familiarize subjects with the experimental protocol. Only data from the second session were analyzed.[6]

Test specimen

Test specimen was one piece of spearmint flavoured sugarless gum. On a command signal the subject placed the gum into the mouth and chewed deliberately on the right side for 15 sec. The patient was asked to chew the chewing gum first on the preferred side, which was always the right side. Unless stated to the contrary, the observations made apply to chewing on the side of preference.[13]

After using the denture for a period of 1-year, masticatory function was evaluated by recording the EMG activity for masseter and anterior temporalis muscles during clenching and mastication.

Statistical analysis

Data was collected and entered in MS Excel sheet. The descriptive and analytical statistics were computed with the statistical package of social sciences (SPSS) v.22 software. Percentages, mean and standard deviation were computed. Analytical statistics of the EMG recordings was performed by paired-*t* test. Normality was checked for the data. The significance was set at $p<0.05$.

Table 1 Age distribution of the study group

	Frequency	Percent
55-60	6	27.2
60-65	8	36.36
65-70	6	27.2
Above 70	2	9
Total	22	100

Table 2 Gender of study group

Gender	Frequency	Percent
Male	11	50
Female	11	50
Total	22	100

RESULTS

The mean age of samples were 62.13 years with SD of 4.34 (Table 1). Gender distribution was maintained equally in the study (Table 2).

This study showed a significant difference in EMG values between the two time periods with higher mean scores of EMG activity at 1-year. The results suggest that there is a significant increase in EMG potential. The null hypothesis was rejected and the alternate hypothesis stated was that there is a difference in EMG amplitude at 1-year compared to 2 months of denture use.

The mean EMG value of RM is found to be significantly higher than LM during clenching at 2 months ($p<0.001$) and 1-year ($p<0.001$). In the same way it was observed for temporalis muscle also where in the mean EMG-value of RT is found to be significantly higher than LT during clenching at 2 months ($p<0.001$) and 1 year ($p<0.001$) (Table 3 & Fig.5). During clenching, significantly higher mean EMG values are recorded at 1-year for RM ($p<0.001$) and LM ($p<0.001$) as well as RT ($p< 0.001$) and LT muscles ($p<0.001$) (Table 3 & Fig.5).

The overall mean EMG value of masseter is found to be significantly higher than temporalis during clenching at 2-months ($p=0.005$) and 1-year ($p=0.045$) (Table 4).

During clenching, the overall mean EMG value of masseter ($p<0.001$) and temporalis ($p<0.001$) muscles are found to be significantly higher at one year than that recorded at 2 months (Table 4,10).

During chewing, the mean EMG value of RM is found to be significantly higher than LM at 2 months ($p<0.001$) and 1 year ($p<0.001$) (table 8). The mean of EMG value of RT is found to be significantly higher than LT 2 months ($p<0.001$) and 1 year ($p<0.001$) (Table 5).

At 1-year also, the mean of EMG-value of RM ($p<0.001$) and RT ($p<0.001$) are observed to be higher than LM and LT muscles, respectively (Table 5).

The overall mean EMG value of masseter is found to be significantly higher than temporalis during chewing at 2-months ($p=0.001$) and 1-year ($p=<0.001$) (Table 6,9).

During chewing, the overall mean EMG values are found to be statistically higher at 1-year as compared to 2-months for both masseter ($p<0.001$) and temporalis ($p<0.001$) muscles (Table 6 & Fig.6,7). Comparing tables 4 and 6, it is found that clenching values are higher than chewing values.

A negative correlation was found with respect to age and masseter EMG value. As age increases, during clenching and chewing, the mean EMG values of masseter decreased at 2 months and one year, but the results are not statististically significant (Table 7).

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Table 3 Mean, standard deviation of each muscle during clenching at each recording time.

Muscle	**2 Month**	**1 Year**	*p* value
Masseter			
RM	419.40±37.10	434.54±32.71	<0.001
LM	407.86±37.95	428.72±37.04	<0.001
p value	<0.001	<0.001	
Temporalis			
RT	399.40±31.87	408.95±30.38	<0.001
LT	393.09±37.38	404.13±33.12	<0.001
p value	<0.001	<0.001	

Table 4 Overall mean, standard deviation of each muscle during clenching at each recording time

Muscle	**2 Month**	**1 Year**	*p* value
Masseter	827.27±74.69	863.27±69.62	<0.001
Temporalis	813.09±63.24	792.50±65.95	<0.001
p value	0.005	0.045	

Table 5 Mean, standard deviation of each muscle during chewing at each recording time.

Muscle	**2 M**	**1 Year**	*p* value
Masseter			
RM	348.95±35.51	366.86±32.59	<0.001
LM	332.18±30.30	357.81±26.22	<0.001
p value	<0.001	<0.001	
Temporalis			
RT	286.36±31.51	310.40±32.59	<0.001
LT	276.59±31.87	301.90±32.96	<0.001
p value	<0.001	<0.001	

Table 6 Overall mean, standard deviation of each muscle during chewing at each recording time

Muscle	**2 Month**	**1 Year**	*p* value
Masseter	681.13±64.23	724.68±57.44	<0.001
Temporalis	562.95±62.96	612.31±65.16	<0.001
p value	0.001	0.000	

Table 7 Correlation between age and masseter EMG amplitude

Correlation	**r value**	*p* value
Age and masseter		
clenching –1 year	-.240	0.28
2 months	-.200	0.37
Age and masseter		
chewing – 1 year	-.089	0.69
2 months	-.187	0.40

Table 8 Simplified table showing Mean EMG activity of RM and LM during chewing at 2 months

Muscle	EMG value	P value
Right Masseter	348.95±35.51	<0.01
Left Masseter	332.18±30.30	

Table 9 Mean EMG activity of masseter and temporalis during chewing at 2-months

Muscle		P value
Masseter	681.13±64.23	0.001
Temporalis	562.96±62.97	

The comparison of EMG values obtained during clenching is presented in table 3 and Fig.3,4,5.

The comparison of EMG values obtained during chewing is presented in table 5 and Fig.6,7.

Table 10 Mean EMG activity of masseter and temporalis during clenching at 2 months and 1 year

Muscles	2 months	One year	Overall
Masseter	8237.27±74.67	863.273±69.62	1690.54±143.46
Temporalis	792.50±68.95	813.09±63.24	1605.59±131.97
P value	0.005	0.045	0.016

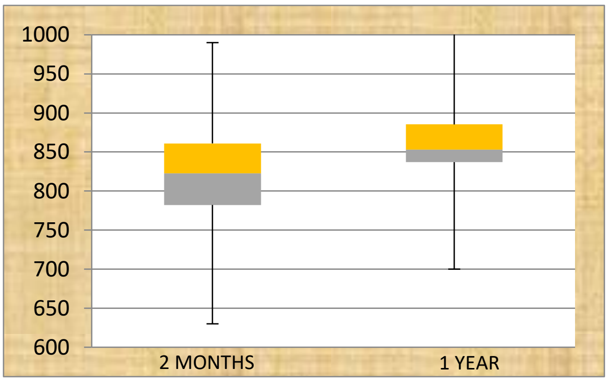

Figure 3 The graph of masseter mean of EMG during clenching

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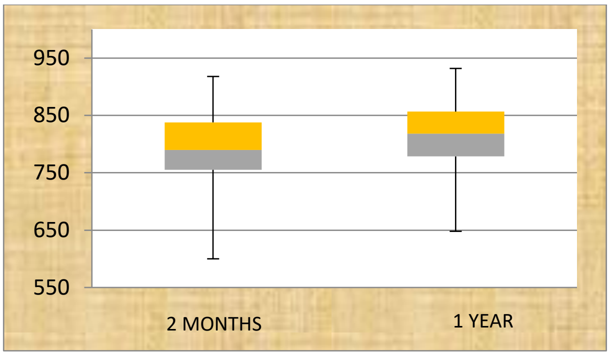

Figure 4 Graph of temporalis mean EMG during clenching

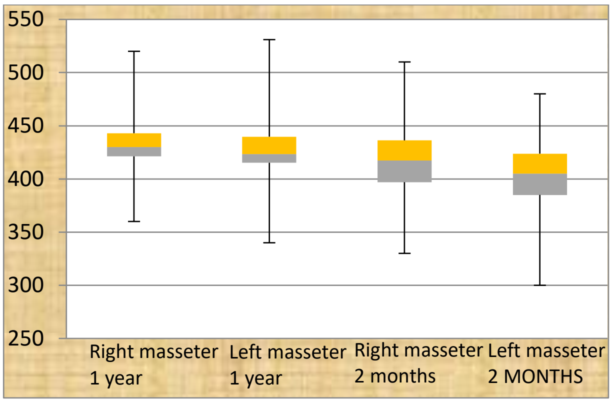

Figure 5 The graph mean of EMG of right and left masseter during clenching

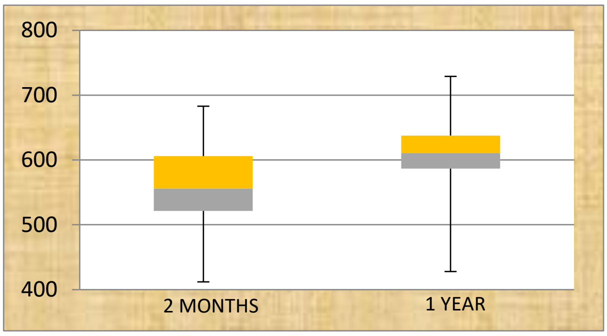

Figure 6 The graph of EMG values of temporalis during chewing

DISCUSSION

Twenty-two subjects were studied aged 58-72 years (mean 62.13 years, SD 4.34) who had all undergone total rehabilitation by means of conventional CD prostheses. The aim of this study was to evaluate through EMG the muscular behaviour after CD insertion between the paired masticatory muscles at 2 months and one year of denture use.

The sEMG has long been the "gold standard" for monitoring muscle activity of masticatory muscle at rest and in function. This pain free examination, allows the study of the muscular activity, enabling the capture of action potentials generated during the muscular contraction, which can be analyzed considering the parameters of length and amplitude.[12] The theory behind these electrodes is that they form a chemical equilibrium between the detecting surface and the skin of the body through electrolytic conduction, so that current can flow into the electrode. These electrodes are simple and very easy to implement. The conductive properties of the whole nerve and muscle allow measurement of electrical activity with extra-cellular (surface) electrodes. These electrodes do not penetrate the cell membrane, but detect potential differences external to the muscle fibre and distant from the potential source. So, they do not interfere with natural function. EMG techniques permit more precise assessment of muscle functions than that was previously possible by clinical observation.[4]

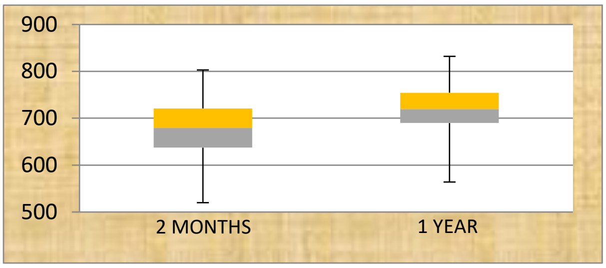

Figure 7 The graph of EMG values of masseter during chewing

As the muscle contraction increases, the muscle gives a higher EMG-values and works better. There is an increase in the EMG values if the retention is better, if the prosthesis functions better or also if the muscle works better. Hence, better readings are obtained. Analysis of masseter and temporalis muscles permit determining muscle activity during function. The present sEMG analysis of both static (clenching) and dynamic (chewing) procedures were taken into account due to it being the combination of the masticatory efficiency.

The reasons for evaluating the two muscles, masseter and temporalis, only are firstly as these are one of the two muscles of mastication, and as these are the muscles which are not deep and can be palpated and so their function can be recorded by the surface EMG.[14] Measurements were done at 2 months which is considered as the minimum adaptation period. Marcelo et al[12] suggested that a period longer than five months of wearing the new dentures is required for adaptation and the acquisition of functional capacity.

Clenching

The clench test is able to record the patient's ability to clench and recruit the masticatory muscles (temporalis anterior and masseter muscle groups are recorded). Higher sustained amplitude readings are a good indicator that the muscles are able to function. During clenching, recruitment of motor

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units increases so as to allow maximum biting force to be developed. It seems clear that the better the masticatory system works, the greater the force it will be able to develop comfortably, and that requires perfect motor co-ordination and the absence of any discomfort in teeth or TMJ that would inhibit the application of force. Thus, the potential recorded during clenching is a measure of the quality of the masticatory system.

It is known that there is a linear relationship between the strength of a muscle and the amplitude of EMG. The mean values obtained during clenching were comparable to that reported in literature.[14] (masseter 430.60 and temporalis 426.80)

There is an evidence-based studies reporting that maximal bite force and the electrical muscle activity during maximal bite in the intercuspal position are significantly weaker in patients with functional disorders of the masticatory system.[15] A reduction in sEMG amplitude during a functional clench test is a clear indication of a physiologic impairment. In our study during clenching, in masseter muscle after one year EMG amplitude increased with respect to 2 months (p<0.001) (table 3,4). According to some authors, less myoelectric activity indicates atrophy.[11] This was not found in any samples of this research. For this reason, the effects of dental prosthesis can be considered as beneficial. Therefore, the rehabilitation with CDs may be considered as beneficial to patients allowing aesthetical, functional and physiologic improvements with relatively low cost.

Chewing

Mastication is controlled neurologically. According to literature,[16] alterations in occlusal relation due to residual ridge resorption and CD seating would affect the EMG activity of masticatory muscles. However, there are few EMG studies on the effects of tooth loss and CD use.

In this study sugarless chewing gum was used as the test material for chewing. The right side was chosen at random. To standardize the test-material it was used chewing gum as it has uniform properties that provide an ideal test bolus for our study. As salivary stimulation can influence masticatory-function it was used a commercially available sugarless chewing gum. Many authors have used chewing gum in their studies.[17-19]

Masseter muscle

The masseter is the most active muscle during the chewing process.[20,21,54,61] This activity was noticed in this study also at 2-months and one-year after prosthetic rehabilitation. Therefore, the difference between right and left masseter muscles were recorded. Literature review shows that this difference may be found in most cases since patients usually prefer one side rather than the other during chewing, independently of age, gender or food type, even after myofunctional therapy.[20,21] Significantly higher values were observed for masseter than temporalis during clenching at both sessions which mean that masseter is more active in clench.

In clenching, the comparative means electrical activity values of the masseter muscle during the tooth clenching test at two months (RT side 419.40 ±37.10, LT side 407.86±37.95) are comparable to that reported in literature.[4]

The comparative means electrical activity values of the masseter muscles and the anterior temporal muscles during the tooth clenching test, after two months of having the new dentures put in place (Table 3). These findings are in keeping with the fact that the masseter muscle is more active in raising the mandible, especially during masticatory function.[12] According to literature, the mean electrical activities recorded at the surface of the muscles increases with the force of muscular contraction.[12,8]

During chewing, EMG amplitude from the muscle of right side was significantly higher than the left side at 2 months (p<0.001) (Table 2) which is in accordance with previous literature.[22] At 1-year also EMG amplitude from the muscle of right side was significantly higher than the left side during chewing (p<0.001) (Table 2). Comparisons are not available in the literature for 1-year for similar ridge conditions.

Temporalis muscle

The overall mean EMG value of masseter is found to be significantly higher than temporalis during clenching at 2 months (p=0.005) and 1-year (p=0.045). The temporalis muscle activity was significantly lower than the masseter activity when the subjects clenched with a CD (Table 4). Similar data were found in literatur.[16,23] Our results support the findings in the literature that during voluntary dental clenching, the myoelectric activity of the temporal muscle does not exceed the activation of the masseter muscle.[12]

During clenching electrical activity of the temporal muscle was lower than that of the masseter muscle at 2 months of having the new CDs put in place. Similar data were found in literature.[16,23]

During clenching, at one year also electrical activity of the temporal muscle was lower than that of

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the masseter muscle. Comparisons are not available in the literature.

The maximum tooth clenching recordings revealed an increase in the mean electrical activity value of the anterior temporal muscles at 1-year compared to 2-months (p<0.001) (Table 5). Also, high SD were observed in the initial data for temporalis during clenching. After one year of denture use SD values decreased in similarity with some authors.[21]

Chewing

EMG activity of temporalis muscle in the side of chewing was higher than the other side at 2 months and 1-year (p<0.001) similar to that obtained in few studies.[21] The mean EMG values of temporalis during chewing at 2 months are comparable to that reported in literature.[24]

The overall results agree with some authors who reported that the chewing efficiency showed marked increased by time in favour to the conventional acrylic because improving the denture adaptation which may be due to the neuromuscular control, which is gradually and slowly generated by time, i.e. the longer the period of denture wearing, the better the neuromuscular control gained.[9,24] Clinically, the use of the new CD should allow, functional benefit of the masticatory system.[21] Thus, the results of the present study indicate that masseter contributes to most of isometric force during maximum clenching and temporalis is the postural muscle controlling mandibular movements in excursive function. So, their electrical activity helps in assessing physiologic process of mastication adaptation.

Age

The results demonstrate that EMG activity of masseter muscles during clenching negatively correlates with age. Elderly patients exhibited significantly lower EMG voltage.[25] In our study it was observed that EMG activity was less in older patients (above 70 years old) similar to studies reported.[6] This is mainly due to a late and progressive weakening of masticatory muscle that takes place with ageing. Ageing seems to modify the neuromascular controls involved in mastication. This point is in accordance with the fact that masticatory performances decrease with age as other motion activities.[4] Some age-related changes such as deterioration in the fast and slow fibres in striated muscle result in impaired muscle force.[26]

Limitations of the study

Future research is needed to better characterrize the complex process of mastication and how this function is influenced by food properties. Observing a larger sample size with more homogenous groups and use of free mastication while subjects are processing different foods in a random manner will likely help to detect additional meaningful differences on the outcomes of various prosthodontic treatments. Adaptations of neuromascular system may take an extended time and may be a determinant factor in influencing the EMG activity and this aspect can change the results.

Further investigations are needed to explore the relationship between occlusal features and muscular activity Moreover prolonged use of devices in the oral cavity can cause changes in muscle activivity. Longitudinal studies are to be done to appraise the long-lasting effects and modifications in neuromuscular control induced by prosthetic rehabilitation. It would be convenient to perform EMG studies in a larger number of patients who initiate the use of a new CDs, even carry it out routinely, to implement measures that contribute to a better adaptation to dentures.

Within the limitations of this study, it was possible to conclude that the new prosthesis has positive effect on subject's muscular activity. Understanding the functional behaviour of masticatory muscles of CD wearers are important in the prognosis of treatment.

Jaw muscles are versatile entities with dynamic nature. By EMG, we can see muscular changes in patients with prosthetic rehabilitation; therefore, it can be stated that good-rehabilitation interferes on muscle harmony thus improving the efficiency of muscles.

Electrodiagnostic resources are still far from a concrete professional reality due to the lack of knowledge about the technique along with high-cost equipment. It is essential to explain to CD users, the importance of attending periodical visits in order to evaluate their dentures and oral conditions.

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