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Masticatory force and electromyographic activity of the mandibular elevators muscles in different rehabilitation treatments

Força mastigatória e atividade eletromiográfica dos músculos elevadores mandibulares em diferentes tratamentos de reabilitação

Isabela Silva Gomes MOURA[1], Leonardo Silva Gomes KAMEZAWA[1], Eduardo Galera da SILVA[3], Jose Benedito Oliveira AMORIM[4], Guilherme Schmitt de ANDRADE[2], Clovis PAGANI[1]

1 - São Paulo State University (Unesp) - Institute of Science and Technology, São José dos Campos - Department of Restorative Dentistry – São José dos Campos – SP – Brazil.

2 - São Paulo State University (Unesp) - Institute of Science and Technology, São José dos Campos - Department of Dental Materials and Prosthodontics – São José dos Campos – SP Brazil.

3 - São Paulo State University (Unesp) - Institute of Science and Technology, São José dos Campos - Department of Social Dentistry and Children's – São José dos Campos – SP Brazil.

4 - São Paulo State University (Unesp) - Institute of Science and Technology, São José dos Campos - Department of Biosciences and Oral Diagnosis – São José dos Campos – SP Brazil.

ABSTRACT

Objective: The masticatory function is one of the most complex neuropsychological mechanisms in human motor performance and it depends on several factors, such as bite force, muscle coordination, morphology, and number of teeth in occlusion. To evaluate the influence of different rehabilitation treatments such as complete and partial dentures, masticatory forces, and the dynamics of mandibular elevator muscles. **Material and Methods:** the maximum bite force (force transducer) and electrical activity (superficial electromyography) associated with the masseter and temporal muscles were quantified. These factors were evaluated at rest position and isometric contraction. The data were subjected to descriptive statistics and compared based on the experimental groups, through ANOVA and Tukey's tests. **Results:** for bite force, the ANOVA test showed statistical difference between groups and Tukey's test showed that the force measured in the removable partial dentures group was 44.75% lower than that of the control group, while for complete denture wearers, there was a reduction of 74.4% in bite force in relation to the control group. For electromyographic activity, there was no statistical difference between groups. Pearson's correlation test ($\alpha = 5\%$) showed positive correlation between the variables of bite force and electromyographic activity only for the control group. **Conclusion:** it was concluded that the loss of dental

RESUMO

Objetivo: A função mastigatória é um dos mecanismos neuropsicológicos mais complexos no desempenho motor humano e depende de vários fatores, como força de mordida, coordenação muscular, morfologia e número de dentes na oclusão. Avaliar a influência de diferentes tratamentos de reabilitação, como próteses totais e parciais, forças mastigatórias na dinâmica dos músculos elevadores da mandíbula. **Material e Métodos:** quantificaram-se a força máxima de mordida (transdutor de força) e a atividade elétrica (eletromiografia superficial) associadas aos músculos masseteres e temporais. Esses fatores foram avaliados na posição de repouso e contração isométrica. Os dados foram submetidos à estatística descritiva e comparados com base nos grupos experimentais, através dos testes ANOVA e Tukey. **Resultados:** para força de mordida, o teste ANOVA mostrou diferença estatística entre os grupos e o teste de Tukey mostrou que a força medida no grupo próteses parciais removíveis foi 44,75% menor que a do grupo controle, enquanto para os usuários de prótese total houve redução 74,4% na força de mordida em relação ao grupo controle. Para a atividade eletromiográfica, não houve diferença estatística entre os grupos. O teste de correlação de Pearson ($\alpha = 5\%$) mostrou correlação positiva entre as variáveis força de mordida e atividade eletromiográfica apenas para o grupo controle.

elements and their replacement with either partial or complete dentures has a great influence on bite force and electromyographic activity of the masseter and temporal muscles.

KEYWORDS

Bite force; Dentures; Electromyography; Gerontology; Rehabilitation.

Conclusão: concluiu-se que a perda de elementos dentais e sua substituição por próteses parciais ou totais têm grande influência na força de mordida e na atividade eletromiográfica dos músculos masseteres e temporais.

PALAVRAS-CHAVE

Força de mordida; Prótese total; Eletromiografia; Reabilitação.

INTRODUCTION

One of the reasons for dental treatment is the maintenance and restoration of the oral function, especially in patients with missing teeth [1]. Tooth loss is usually associated with the reduction of bite force [2], impairing the masticatory function [3–5] and affecting the digestive process, which reduces the sufficient absorption of nutrients during food intake. [6]

Although there is sufficient evidence on the success and longevity of oral rehabilitations with osseointegrated implants, some patients still refuse implant-supported treatments, because of either the high cost or the long duration of treatment, or even the resistance to surgical procedures. Thus, the treatment with complete dentures may improve masticatory performance and the quality of life of edentulous patients [7], and the treatment with removable partial dentures might be an alternative as an economical tooth replacement. [5,8]

Bite force is determined by the mandibular elevator muscles and it is a physiological characteristic with a direct impact on the quality of life of patients. [9] Its magnitude depends on the volume, activity, and coordination of said muscles. [10] The literature reports that the values of bite force vary according to gender, [11] tooth region [11,12], number of remaining natural teeth [2], and presence of partial or complete dentures. [1,3,9,13,14].

The maximum bite force may be measured through electromyography, considering this technique is an important tool in the assessment of mandibular movements and neuromuscular performance during chewing. [15] Moreover, bite force is an indicator of the functional state of the masticatory system and its measurement is important for diagnosing and evaluating the function and activity of the mandibular elevator muscles, besides contributing to the evaluation of prosthetic rehabilitation treatments.

This study evaluated the maximum bite force values and the electromyographic (EMG) activity of the masseter muscles in fully dentate patients and removable partial and complete denture wearers. The null hypothesis tested is that bite force and electromyographic activity in the masseter and temporal muscles are not influenced by different rehabilitation treatments.

MATERIAL AND METHODS

Patients selection

The sample size of the present study was based on the calculation of the power based on previous works [16,17], for an alpha bidirectional of 0.05 and a power of 80%, requiring a minimum of 10 participants for the control group and 10 participants for the other experimental groups. The group with fully dentate individuals (control group - CTRL) included students of the School of Dentistry of the São Paulo State University, SP, Brazil (n = 52).The inclusion criteria of the CTRL group was: individuals with all teeth present, no use of any kind of dental prostheses or intraoral devices, without oral lesions or inflammatory processes, with absence of systemic morbidities and/or use of drugs that could interfere in the electromyographic evaluation (analgesics, anti-inflammatories, tranquilizers). The other groups included patients previously treated with complete denture (n = 28) and removable partial denture (n = 27) at the same

institution. The Research Ethics Committee (protocol #005PH/CEP) approved the project.

The patients excluded presented systemic disorders that might influence the masticatory system, such as neurological disorders and cerebral palsy; parafunctional habits such as finger-sucking, biting objects, bruxism, and mouth breathing; and the use of medications that could interfere with masticatory force, such as antihistamines, sedatives, and central nervous system depressants. The presence of bruxism was diagnosed by a specialist in this field who evaluated facets of wear, joint sounds, limitations in range of motion or deviations during mandibular function or pre-auricular and masticatory muscles pain [18].

Bite force measurement

A force transducer (São Paulo State University, São José dos Campos, São Paulo, Brazil) was used to measure bite force. The device was built with a load cell (Model PLA 100 kg, Lider Scales) (Figure 1) attached to a digital screen (Indicator ID-M LCD with RS 323 / Paralel, Filizola serial number 2805), which allowed measuring the force applied by the patient's maximum bite force. For this, the force transducer was positioned in the oral cavity (between the dental arches) by a calibrated integrant and the subjects were instructed to occlude the teeth and developing maximum strength for approximately 7 seconds. After 2 minutes of interval the procedure was repeated two more times, obtaining the records in triplicate, being considered the maximum value of peak. [18]

Muscle activity measurement

The EMG-800 C electromyograph (EMG System do Brasil Ltda, São José dos Campos, SP, Brazil), previously calibrated with magnification of 2000 times and resolution of 16 bits, was used to measure muscle activity. [18] The following four input channels were used: channel 1 – anterior portion of the right temporal muscle (RT); channel 2: superficial portion of the right masseter muscle (RM); channel 3: anterior portion of the left temporal muscle (LT); and channel 4: superficial part of the left masseter muscle (LM). The electrodes (Meditrace™ Kendall-LTP, Chicopee, MA, USA) were positioned along the direction of muscle fibers [19] with an inter-electrode distance of 20 mm, and one reference electrode (earth) was located in the frontal bone. The sites for electrode placement were cleaned with a cotton ball soaked in 70% alcohol to minimize impedance. A rectangular metallic electrode measuring 3 x 2 cm coated with Lectron II conductive gel (Pharmaceutical Innovations®) to increase the conduction capacity and avoid interference from external noise were bilaterally placed according to anatomical references and the procedures were guided by the direction of muscle fibers in two points: anterior temporal muscle – 2 to 3 cm superoposteriorly distant to the lateral corner of the eyes in the region with the greatest evidence of muscle mass and no hair, parallel to the muscle fibers, but with the sensing surface perpendicularly oriented; and superficial masseter muscle – 1 to 2 cm above the mandibular gonial angle in the region with the greatest evidence of muscle mass, and muscle fibers parallel to the surface. Readings were performed with the mandible in the resting position as well in isometric contraction. It was performing three readings in the resting position with a two-minute interval between readings. After three minutes, three readings were performed maximum bite force (isometric contraction), with a five-minute interval between readings. The signals were recorded for 10 seconds each under each condition. All data collected was performing an observed calibrated. The Root Median Square (RMS) was obtained through the mean of these measurements (Figure 2). All data collected was performed by a calibrated integrant trained prior to the collection of the electromyographic records, in order to know the protocol of execution of data collection, being supervised by a researcher experienced in the area, receiving the guidelines [21].

Figure 1 - Force transducer used in this study.

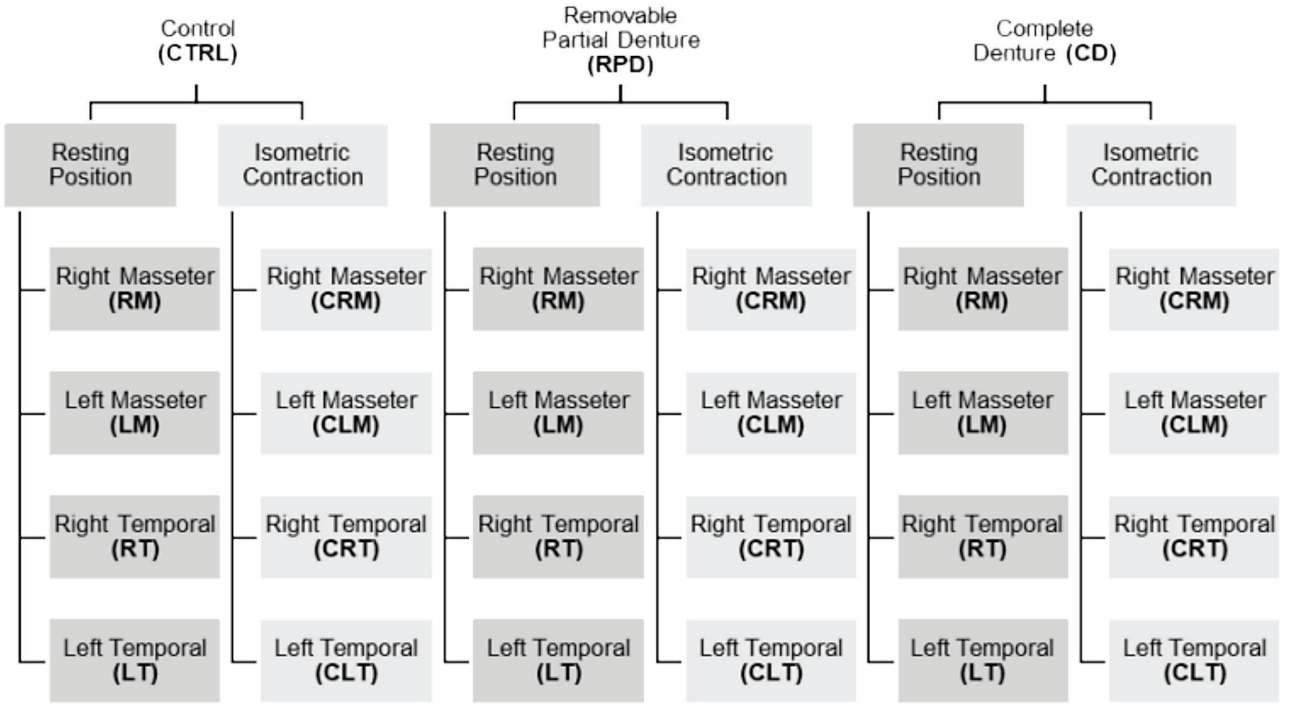

Figure 2 - Study design for the EMG activity measurement.

Statistical Analysis

The experimental groups included individuals with complete dentition (CTRL), removable partial denture (RPD), and complete denture (CD). The main variables were bite force (kgf) and electromyographic activity (RMS, μV) of the right masseter (RM) muscle, left masseter (LM) muscle, anterior portion of the right temporal (RT) muscle, and anterior portion of the left temporal (LT) muscle, collected at rest position and isometric contraction. The mean and standard deviation were subjected to descriptive statistics and the experimental groups were compared by ANOVA (one-way) and Tukey's test ($p<0.05$).

RESULTS

The 107 volunteers consisted of 66 women and 41 men. The average age was of 44 years, varying from 18 to 63 years old.

For bite force, a significant statistical difference was found between the experimental groups, with the highest mean found in the CTRL group, intermediate mean in the RPD group, and the lowest mean found in the CD group (Table 1). Thus, the force measured in the RPD group was 44.75% lower than that of the CTRL group, while for CD wearers, there was a reduction of 74.4% in bite force in relation to the CTRL group.

Regarding the electromyographic (EMG) activity at resting position, there was no statistical difference between the groups, which was also true for the isometric contraction of the right masseter muscle (CRM) (Table 1). On the other hand, the isometric contraction of the left masseter muscle (CLM) showed a significantly lower electromyographic activity for CD wearers, but no significant difference from the RDP group; and the highest values were found in the CTRL group (Table 1). Additionally, the isometric contraction of the right temporal muscle (CRT) showed no statistical difference between the CTRL and RDP groups, as well as between the RDP and CD groups, but there was difference between the CTRL and CD groups. The isometric contraction of the left temporal muscle (CLT) showed the highest values for the CTRL group, but there was no difference between RDP and CD wearers. Pearson's correlation test (α = 5%) showed no correlation between bite force and electromyographic activity in any of the muscles of groups RPD and CD.

Table 1 - Descriptive Statistics of Mean and Standard Deviation for the Variables of Bite Force and Electromyographic Activity. (BF) Bite force; (RRM) Rest position of the right masseter muscle (RLM) Rest position of the left masseter muscle; (RRT) Rest position of the right temporal muscle; (RLT) Rest position of the left temporal muscle; (CRM) Isometric contraction of the right masseter muscle; (CLM) Isometric contraction of the left masseter muscle; (CRT0 Isometric contraction of the right temporal muscle; (CLT) Isometric contraction of the left temporal muscle; (CTRL) Individuals with complete dentition; (RPD) Removable partial denture (CD) complete denture

Variables	Groups	n	Mean	Standard Deviation	p-value (ANOVA)	Homogeneous Groups (Tukey)		
BF (Kgf)	CTRL	52	51.49	16.24		A		
	RPD	27	28.45	15.43	0.0000*		B	
	CD	28	13.11	7.69				C
RRM (µV)	CTRL	52	64.82	32.85				
	RPD	27	68.38	31.96	0.1394			
	CD	28	86.80	75.8				
RLM (µV)	CTRL	52	71.80	37.54				
	RPD	27	62.91	44.73	0.6565			
	CD	28	74.20	62.20				
RRT (µV)	CTRL	52	99.95	60.48				
	RPD	27	95.10	52.00	0.5461			
	CD	28	85.46	50.84				
RLT (µV)	CTRL	52	129.81	67.41				
	RPD	27	108.2	66.10	0.4446			
	CD	28	124.3	83.40				
CRM (µV)	CTRL	52	142.3	88.20		A		
	RPD	27	99.61	38.96	0.0480*	A		
	CD	28	114.10	78.20		A		
CLM (µV)	CTRL	52	150.4	81.60		A		
	RPD	27	99.30	48.83	0.0001*		B	
	CD	28	85.96	45.49			B	
CRT (µV)	CTRL	52	162.90	82.80		A		
	RPD	27	127.34	48.56	0.0036*	A		
	CD	28	105.90	47.30			B	
							B	
CLT (µV)	CTRL	52	190.30	112.30		A		
	RPD	27	138.00	59.70	0.0036*		B	
	CD	28	124.90	60.30			B	

n Ó number of volunteers; *p<0.05.

DISCUSSION

The literature reports discrepancies masticatory force data, which justifies the need to quantify this force in fully dentate individuals and those rehabilitated with removable partial and complete dentures, as well as to evaluate whether tooth loss affects masticatory force.

The first null hypothesis of this study suggested no difference in bite force for the different treatments, and it was rejected because fully dentate individuals obtained higher bite force values. The bite force of individuals rehabilitated with RPD decreased 44.75% in relation to the CTRL group. This reduction was even more significant for CD

wearers (74.54%). Similar results were found in the study by Miyaura et al. (2000) [20], who found a reduction of 65% in bite force in individuals rehabilitated with RPD, and of about 89% in CD wearers compared to fully dentate individuals. Although the values are different, this study showed the same decrease in bite force, confirming the evidence that tooth loss affects masticatory force and agreeing with previous studies. [21]

The loss of dental elements is an important factor in the change of bite force, which may be explained by the decreased number of mechanoreceptors in the periodontal ligament. These mechanoreceptors are responsible for controlling the force produced during chewing. The reduction of periodontal support obtained by the dental elements may result in a decrease of bite force. [22,23]

The mean value found for the CTRL group in this study was about 51.49 kgf, which is almost twice than that found by Lyons and Baxendale [24], who found a force of 22 kgf. However, it was similar to the values found for fully dentate patients by Tortopidis et al. [25] (59.04 kgf), Miyaura et al. [20] (49.96 kgf), and Van der Bilt et al. [10] (58.02 kgf).

The means found for bite force in RPD and CD wearers was 28.45 kgf and 13.11 kgf, respectively, differing from the means found by Miyaura et al. [20] (17.64 kgf for RDP and 5.57 kgf for CD). The values for CD wearers also differed from those found by Sharma et al. [3] (6.44 kgf), which may be justified by the evaluation method that recorded bite force values unilaterally. Van der Bilt [26] obtained closer results (18.66 kgf), as they performed the evaluation with the force transducer bilaterally, likewise the present study.

The maximum bite force may be achieved with a distance of either 14 to 16 mm (10º of mouth opening) or 26 to 28 mm (17º of mouth opening) between the incisors; distances in which the fibers of masseter and temporal muscles reach their optimal stretching, providing maximum bite force [27]. Therefore, the force transducer used in this study was 26-mm thick, which varied according to the force exerted by the patients.

The aging factor may be related to the reduced values of bite force in CD wearers, generally elderly ones. It is known that mass and strength decrease in the aging process due to the nutritional decline and consequently the reduction of protein synthesis [28, 29]. This deficiency may be worse in the elderly with masticatory impairments caused by the loss of teeth and use of poor-quality dentures. [28]

One possibility for increasing bite force and consequently the masticatory function of CD wearers is by means of implant rehabilitation, because the use of an overdenture may increase masticatory force from 43% to 53% in relation to the CD [13, 14]. When analyzing the electromyographic activity in relaxing muscles, the right temporal (RRT) and left temporal (RLT) muscles have shown to be more active than the masseter muscles, agreeing with a previous study [30]. This was expected because the temporal muscle is one of the main active muscles involved in the maintenance of mandibular posture position. [31]

The hypothesis that muscle electromyographic activity changes according to the different rehabilitation treatments was partially accepted, whereas the results showed no difference between treatments in muscle activity at rest position, but showed significant differences at isometric contraction.

The CTRL group showed higher values of electromyographic activity in relation to the groups of patients with prosthetic rehabilitations, agreeing with a previous study. [32]

The loss of dental elements leads to the loss of periodontal receptors, changing the nervous information from the oral cavity, consequently changing the electromyographic activity during the maximum volunteer contraction [33], and interfering with the

direction of the force used during chewing. [34] Even with adequate prosthetic rehabilitation, the neuromuscular coordination and the movement of masticatory muscles was impaired in edentulous patients when compared to dentate patients. [32]

When Pearson's correlation test was performed between bite force and EMG activity in the muscles aforementioned in this study for the experimental groups, there was correlation only for the CRM and CLM muscles in the control group. This shows that there is practically no reverse correlation between bite force and electromyographic activity, which was also observed in another study. [21]

This study showed a few limitations regarding the sample selected, mainly in relation to the groups of patients with prosthetic rehabilitations, because there was a smaller number of rehabilitated patients than the control group and there was no homogeneity regarding gender and type of rehabilitation. Further studies should be performed taking into account these considerations and approaching other types of prosthetic rehabilitations, such as dental implants. This study shows the importance of preserving the dental elements for bite force and electromyographic activity of the masticatory muscles.

CONCLUSION

For this experimental conditions and the sample studied, it can be concluded that the loss of dental elements has an influence on bite force and electromyographic activity.

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Clovis Pagani
(Corresponding address)
Av. Eng. Francisco José Longo, 777. São José dos Campos, São Paulo, Brasil.
E-mais: clovis.pagani@unesp.br

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