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Alterations in masticatory cycle efficiency and bite force in individuals with periodontitis

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ABSTRACT

Objectives: The objective of this research was to evaluate the effect of periodontitis on masticatory cycle efficiency and maximum molar bite force.

Methods: Twenty-four individuals were divided into two groups: With periodontitis (Group I; mean age ± standard deviation (SD), 51.3 ± 2.8 years; $n = 12$) and without periodontitis (Group II; mean age ± SD, 48.9 ± 2.4 years; $n = 12$). Masticatory cycle efficiency was obtained from the value of the ensemble-averaged integrated linear envelope electromyographic signal of the masseter and temporalis muscles. Maximum bite force was recorded for the right and left molar regions. The data were tabulated and submitted to statistical analysis ($P \leq 0.05$).

Results: There was a significant difference between the groups for the left masseter muscle when chewing raisins ($P = 0.04$), peanuts ($P = 0.02$), and biocapsules ($P = 0.01$). Multiple regression analysis demonstrated the influence of dental mobility on masticatory cycle efficiency for peanuts ($P = 0.03$) and biocapsules ($P = 0.01$). The maximum bite force for the left molar region was significantly different between the groups ($P = 0.02$). Dental mobility was a variable that had a greater effect on masticatory cycle efficiency. The periodontitis group had a reduced bite force.

Conclusion: The present study findings indicate that the loss of periodontal supporting structures had a negative impact on masticatory cycle efficiency and molar bite force. This finding suggested that dental mobility should be considered when determining clinical treatments aimed at improving masticatory efficiency and bite force in individuals with the periodontal disease.

Keywords: Bite force, electromyography, mastication, periodontitis

Introduction

Periodontal disease has a high prevalence and is the second most important oral disease to affect people worldwide.[1,2] According to the World Health Organization database, an advanced periodontal disease with a gum pocket depth of ≥6 mm affects 15–20% of the world's adult population (35–44 years).[3]

The main purpose of dental treatment is to prevent tooth loss and aid in maintaining the functions of the stomatognathic system.[4] However, the maintenance of teeth with reduced bone support can affect the sensory function of the periodontal attachment and reduce the stability of mechanical support for the teeth, which can consequently impair the process of mastication.[5,6] Thus, understanding the physiology of masticatory muscles could contribute positively to determining a correct diagnosis, proper oral rehabilitation, and restoration of masticatory function.[7]

The evaluation of masticatory cycle efficiency using electrical activity represents an important tool for the diagnosis, evaluation, and monitoring of alterations that affect the performance of facial muscles during chewing. Such an evaluation is essential for investigating the oral condition and treatments used for oral rehabilitation.[8,9] The ensemble average of masticatory cycles is a mathematical measure used to evaluate performance and efficiency in dynamic nonstationary activities such as chewing, but only for periods of isometric contractions.[10]

Masticatory function depends on the relationship between the jaw elevator muscles and bite force, and extrinsic factors such as the texture of a food and the amount of food used in each masticatory cycle.[11] Therefore, it is relevant to evaluate an individual's bite force because the adaptation of the intensity of the bite force and the hardness of the food depend on the information from the periodontal mechanoreceptors, which is reduced in individuals with periodontal impairment.[12] Thus, based on the hypothesis that alterations may occur in the process of chewing due to reduced alveolar bone support and due to the scarcity of studies in the literature on electromyographic potentials occurring during mastication, the present study aimed to evaluate the effect of periodontal disease on masticatory cycle efficiency and the maximum bite force in the molar region.

Methods

Sample selection

The present study was approved by the Research Ethics Committee of the School of Dentistry of Ribeirão Preto, University of São Paulo (Ribeirão Preto, SP, Brazil; protocol no., 2009.1.66.58.3), based on Resolution 466/2012 of the Brazilian National Health Council. The cross-sectional analytical study design was used to evaluate the effect of periodontitis on masticatory cycle efficiency and maximum molar bite force. The study was carried out from September 2016 to November 2017.

The individuals with generalized chronic periodontitis were triad in dental clinics, following the criteria of inclusion and exclusion, individuals with a diagnosis of moderate-to-severe generalized chronic periodontitis by a specialist in periodontics. The ratio between alveolar bone height/tooth length (AB/T) was determined in the superior and inferior dental arch. At the same time, individuals without a diagnosis of chronic periodontitis were also selected.

In the present study, the participants were 24 dentate volunteers (12 women and 12 men) who were aged 23–76 years (mean age ± standard deviation [SD], 50.1 ± 2.6 years). The volunteers were divided into the following two groups: Without periodontitis (Group I; mean age ± SD, 48.9 ± 2.4 years; $n = 12$) and with periodontitis (Group II; mean age ± SD, 51.3 ± 2.8 years; $n = 12$). All individuals in the periodontitis group had moderate-to-severe generalized periodontitis. A comparative test revealed no significant difference between the groups with regard to age and body mass index.

Individuals were excluded from the study, if they presented with any of the following criteria: Splinting of teeth after orthodontic treatment, fixed prostheses with more than one element, dental implants, partial removable dentures, endodontic lesions, absence of more than four pairs of teeth in occlusion, and absence of all pairs of molars from any hemiarch, and use of medication that could interfere with muscle activity.

Experimental design

AB was measured using digital panoramic radiography with a computer-customized system (Software ImageJ, developed by Wayne Rasband of Branch Research Services, National Institutes of Mental Health, Bethesda, MD, USA). The following reference points were used for this study: Root apex (A), alveolar crest (AC), and the highest part of the crown (C).[11,12] Measurements were recorded for T (linear distance = A – C) and AB (linear distance = A – AC).[13,14] The AB/T ratio for each studied site was recorded as a percentage, the mean value was calculated, and a single value was obtained.[15]

The manufacturer's measurement protocol developed for Periotest (Siemens M, Germany) was used to measure the degree of dental mobility.[16] The volunteers placed their chin on a support platform. The pen was positioned at an angle of approximately 90° in the center of the vestibular face of each tooth. The teeth were maintained in disocclusion by means of one roller cotton placed between the teeth of the hemiarch opposite to the register. The degree of mobility for each volunteer was expressed as the mean value for all teeth.[14,15]

Surface electromyography was recorded with the Myosystem-Br1 electromyography (Data Homins, Uberlândia, Brazil). The differential active electrodes were used with two silver-chloride bars of 10.0 mm × 1.0 mm that were separated by a distance of 10.0 mm and fixed in an encapsulating resin of 40 mm × 20 mm × 5 mm. A stainless steel circular electrode (ground electrode; 3-cm diameter) was the reference. The reference electrode was fixed to the skin in the frontal bone region.

A variety of natural and artificial foods are commonly used to evaluate masticatory function.[9,17] Artificial foods are more favorable; however, both types of food are adequate for evaluating masticatory function.[17] There is no consensus on a universally accepted test food because both food types have been used in chewing tests. In the present study, in addition to using the biocapsule food simulator in chewing tests,[15] we chose to use natural foods with distinct consistencies (i.e., peanuts and raisins) beyond the food simulator Parafilm (Parafilm M; Pechiney Plastic Packaging, Batavia, IL, USA) standardized in the electromyographic analysis.

In this study, masticatory cycle efficiency was quantified by the ensemble-averaged integrated linear envelope electromyographic signal of the masticatory cycles for the masseter and temporalis muscles measured by 10 s of chewing Parafilm, raisins, peanuts, and biocapsules. During the time, values of the ensemble-averaged integrated linear envelope of the masticatory cycles were obtained in microvolts per second. These values were normalized with the value of the electromyographic signal for maximum dental clenching (4 s).[10]

Bite force measures were collected with a digital dynamometer (model IDDK; Kratos, Equipamentos Industriais Ltda, Cotia, São Paulo, Brazil). The equipment was placed in the molar region where the bite force is greater. The volunteer was asked to bite with maximum force (measured in Newtons [N]). Three repetitions were conducted on the right and left sides with 2 min of rest between recordings. The highest value of the three recordings was considered the maximum bite force.[18,19]

Statistical analysis

All data were subjected to statistical analysis using IBM SPSS STATISTICS 21.0 (Chicago, IL, USA). Descriptive analysis and Shapiro–Wilk normality test were used for each variable. The Student t-test was used for independent samples to compare masticatory cycle efficiency and maximum bite force between the groups. Multiple regression analysis was used for the dependent variables masticatory cycle efficiency and maximum bite force, and for the independent variables AB/T, dental mobility, and age. A confidence level of 95% was established.

Results

The alveolar bone height/tooth length (i.e., AB/T) and dental mobility measurements submitted for statistical analysis showed that the AB/T ratios for Group II (i.e., without periodontitis) were >50% and for Group I (i.e., with periodontitis) was <50% [Table 1].

The statistical analysis of data on non-habitual chewing of Parafilm (10 s) showed no statistically significant difference between the groups in the masticatory cycle efficiency. However, there was a statistically significant difference between the groups for the left masseter muscle only during the chewing of Parafilm, raisins, peanuts, and biocapsules [Table 2].

As presented in Table 3, there was no statistically significant difference in the right hemiarch bite force, although Group II had the highest mean value. By contrast, the left hemiarch bite force presented significant intergroup differences with Group II having the highest value.

Multiple regression analysis revealed that dental mobility had a significant effect on masticatory cycle efficiency for chewing peanuts and the biocapsules [Table 4]. No relationship was demonstrated between the AB/T ratio and masticatory cycle efficiency and bite force.

Table 1: Confidence interval (set at 95%) for the mean and for the difference in the with periodontitis group (Group I) and the without periodontitis group (Group II), which takes into account the AB/T ratio and dental mobility

Variables	Confidence interval for the mean		Confidence interval of the difference	*P* value
	Group I	Group II		
AB/T	44.9–48.2	54.6–59.4	7.7–13.1	0.001*
Mobility	6.4–10.8	2.4–4.4	−7.5−3.0	0.001*

*Statistically significant difference by Student's *t*-test ($P \leq 0.05$). AB/T: Alveolar bone height/tooth length

Table 2: The mean (standard deviation) values and statistical significance of the normalized electromyographic for the with periodontitis group (Group I) and the without periodontitis group (Group II)

Chewing	Muscles	Group I	Group II	*P* value
Parafilm	Right masseter	0.86±0.34	0.84±0.48	0.67
	Left masseter	0.93±0.50	0.80±0.45	0.52
	Right temporal	0.85±0.34	0.80±0.40	0.70
	Left temporal	0.87±0.36	0.86±0.38	0.92
Raisins	Right masseter	0.82±0.23	0.77±0.50	0.36
	Left masseter	0.85±0.27	0.58±0.34	0.04*
	Right temporal	0.79±0.33	0.64±0.35	0.29
	Left temporal	0.77±0.20	0.69±0.34	0.51
Peanuts	Right masseter	1.02±0.37	0.95±0.52	0.69
	Left masseter	1.23±0.37	0.83±0.42	0.02*
	Right temporal	1.04±0.34	0.86±0.43	0.26
	Left temporal	1.16±0.43	0.95±0.48	0.25
Biocapsule	Right masseter	2.12±0.85	1.64±0.80	0.17
	Left masseter	2.66±1.11	1.67±0.52	0.01*
	Right temporal	2.45±1.14	1.83±0.95	0.16
	Left temporal	2.33±0.126	1.88±0.54	0.22

*Statistically significant difference by Student's *t*-test ($P \leq 0.05$)

Table 3: Mean (standard deviation) and statistical significance of the maximum molar bite force (N) for the with periodontitis group (Group I) and the without periodontitis group (Group II)

Molar region	Group I	Group II	*P* value
Right	436.10±177.50	598.40±247.91	0.07
Left	386.38±140.43	591.12±262.42	0.02*

*Statistically significant difference by Student's *t*-test ($P \leq 0.01$)

Table 4: Multiple regression in which the AB/T ratio, dental mobility, and age are the independent variables

Masticatory cycle's efficiency	AB/T	Mobility	Age
Parafilm chewing	0.14	0.11	0.26
Raisins chewing	0.63	0.38	0.53
Peanuts chewing	0.20	0.03*	0.90
Biocapsule chewing	0.27	0.01*	0.62
Right bite force	0.82	0.28	0.87
Left bite force	0.96	0.37	0.40

*Statistically significant difference by Student's *t*-test ($P \leq 0.05$). AB/T: Alveolar bone height/tooth length

Discussion

Electromyographic activity presumedly reveals the symmetry between masticatory muscles (i.e., masseter and temporalis) while an individual chews Parafilm.[10] The findings of the present study showed more symmetry in the group without periodontitis, although there was no significant difference between the groups during nonhabitual chewing of Parafilm. These findings corroborated those reported by Fernandes *et al*.,[20] who observed that, during the mastication of several foods (e.g., Optosil, Optosil/peanuts, carrots, and white bread), the electromyographic activity of the jaw elevator muscles was unaffected by bone support height because the activity was similar in individuals with reduced periodontal bone support and individuals with normal periodontal bone support. However, in the present study, the statistically significant difference for the left masseter muscle when chewing raisins, peanuts, and biocapsules suggested differences in masticatory side preference between the groups.

It is possible to determine masticatory side preference through electromyography.[10] Electromyographic activity levels were higher in the ipsilateral masseter muscle than in the contralateral masseter. Felício *et al*.[21] observed that when the biocapsule beads were chewed on the right side, the electromyographic activity of the right masseter muscle was higher than that of the left masseter muscle, and *vice versa*. In the present study, even for alternate bilateral chewing of biocapsules, raisins, and peanuts, we observed that the group without periodontitis had a masticatory preference for the right side ($n = 7$), whereas the group with periodontitis had a preference for the left side ($n = 7$). These preferences could explain the statistically significant differences between the left masseter muscles in both groups. However, in the present study, the effect of tooth mobility when chewing peanuts and the biocapsules suggested that dental mobility affected masticatory cycle efficiency with possible interference on the chewing side preference. The analysis of mobility of the posterior teeth - right and left sides separately - showed a correlation between the mobility the teeth and electromyographic activity of the masseter muscles when chewing peanuts and the biocapsules.

Maximum bite force is generated when an individual voluntarily generates a bite force that is as strong as possible; their normal bite force would be consistently lower than this maximum force.[22]

In their literature review, Orchardson and Cadden[23] reported the maximum bite force in the molar region in dentate patients varies between 490.33 N and 686.46 N and varies between 68.64 N and 147.10 N for natural chewing. Thus, a wide range in values exists for unilateral maximum bite force. Regalo *et al*.[24] reported the average values of 402.07 N and 413.84 N for the right and left molar regions, respectively, in white dentate individuals. By contrast, Palinkas *et al*.[18] reported mean values of 257.91 N and 259.87 N for the same regions in dentate adults. In the present study, Group I (i.e., with periodontitis group) had the lowest average values for bite force (436.39 N, right molar region; 386.38 N, left molar region), compared with these values in Group II (598.40 N and 597.12 N, for the right and left molar regions, respectively).

It is important to emphasize that in the present study, the maximum bite force was reduced by more than 150 N in Group II, relative to Group I. A statistically significant difference between the groups was observed in the maximum bite force for the left molar region. Gilbert and Newton[25] indicated that, as a result of the loss of bone support and consequent tooth mobility, individuals with difficulty and discomfort in chewing may consciously or subconsciously reduce the occlusal forces generated when chewing. Use of the masticatory muscles is reduced, which reduces muscle mass and may explain the difficulty in chewing hard and fibrous foods.

The findings of this study are in agreement with those of Takeuchi and Yamamoto[26] and Alkan *et al*.,[27] which demonstrated that the loss of periodontal bone support negatively affects the bite force, as evaluated through a pressure-sensitive device. However, Morita *et al*.,[28] who also used the same material to assess bite force, observed that periodontal disease had little effect on the bite force. Pereira *et al*.[29] evaluated the bite force in patients with chronic periodontitis before and after basic periodontal treatment and found a bite force of 204.95 N and 205.94 N, respectively. However, they did not include a group without periodontitis in their study, which prevents determining the effect of chronic periodontitis and its basic treatment. Despite the diverse values reported among different studies, we found that similar to the dentate groups studied by other investigators, there was a balance between the maximum bite force of the right and left molar regions, and no statistically significant difference between both sides in Group I.

This study has limitations. It was a cross-sectional study that involved a small number of samples; however, the design of the paired samples used in the present study reduced possible intraindividual variability, and thereby reinforced their clinical relevance. In some instances of generalized severe periodontal disease, a dentist will have to decide whether to maintain the teeth or whether there is the indication for multiple exodontia. Deficits in the patient's masticatory function should be considered in clinical management. The present study showed that a treatment plan should take into consideration the relevant consequences of tooth mobility and loss of bone support.

Conclusion

The loss of periodontal supporting structures associated with dental mobility showed a significant impact on masticatory cycle efficiency in chewing foods. Individuals with periodontitis showed the lower bite force values. In clinical planning, the findings suggested that dental mobility should be considered when determining clinical treatments aimed at improving masticatory efficiency and bite force in individuals with the periodontal disease.

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References

1. Bascones-Martínez A, González-Febles J, Sanz-Esporrín J. Diabetes and periodontal disease. Review of the literature. Am J Dent 2014;27:63-7.
2. Vasconcelos DF, da Silva MA, Marques MR, Gibilini C, Vasconcelos AC, Barros S, *et al.* Effects of simultaneous nicotine and alcohol use in periodontitis progression in rats: A histomorphometric study. J Clin Exp Dent 2013;5:e95-9.
3. Petersen PE, Ogawa H. Strengthening the prevention of periodontal disease: The WHO approach. J Periodontol 2005;76:2187-93.
4. Kosaka T, Ono T, Yoshimuta Y, Kida M, Kikui M, Nokubi T, *et al.* The effect of periodontal status and occlusal support on masticatory performance: The suita study. J Clin Periodontol 2014;41:497-503.
5. Johansson AS, Svensson KG, Trulsson M. Impaired masticatory behavior in subjects with reduced periodontal tissue support. J Periodontol 2006;77:1491-7.
6. Zhang H, Cui JW, Lu XL, Wang MQ. Finite element analysis on tooth and periodontal stress under simulated occlusal loads. J Oral Rehabil 2017;44:526-36.
7. de Rossi M, Palinkas M, de Lima-Lucas B, Santos CM, Semprini M, Oliveira LF, *et al.* Masticatory muscle activity evaluation by electromyography in subjects with zygomatic implants. Med Oral Patol Oral Cir Bucal 2017;22:e392-e397.
8. Palinkas M, Cecilio FA, Siéssere S, Borges Tde F, de Carvalho CA, Semprini M, *et al.* Aging of masticatory efficiency in healthy subjects: Electromyographic analysis – part 2. Acta Odontol Latinoam 2013;26:161-6.
9. Iguchi H, Magara J, Nakamura Y, Tsujimura T, Ito K, Inoue M, *et al.* Changes in jaw muscle activity and the physical properties of foods with different textures during chewing behaviors. Physiol Behav 2015;152:217-24.
10. Siéssere S, de Albuquerque Lima N, Semprini M, de Sousa LG, Paulo Mardegan Issa J, Aparecida Caldeira Monteiro S, *et al.* Masticatory process in individuals with maxillary and mandibular osteoporosis: Electromyographic analysis. Osteoporos Int 2009;20:1847-51.
11. Zhao L, Monahan R. Functional assessment of the stomatognathic system. Clin Plast Surg 2007;34:e1-9.
12. Svensson KG, Trulsson M. Regulation of bite force increase during splitting of food. Eur J Oral Sci 2009;117:704-10.
13. Müller HP, Ulbrich M. Alveolar bone levels in adults as assessed on panoramic radiographs. (I) prevalence, extent, and severity of even and angular bone loss. Clin Oral Investig 2005;9:98-104.
14. Jorge JH, Giampaolo ET, Vergani CE, Machado AL, Pavarina AC, de Oliveira MR. Clinical evaluation of abutment teeth of removable partial denture by means of the Periotest method. J Oral Rehabil 2007 34:222-7.
15. Borges TF, Regalo SC, Taba M Jr., Siéssere S, Mestriner W Jr., Semprini M, *et al.* Changes in masticatory performance and quality of life in individuals with chronic periodontitis. J Periodontol 2013;84:325-31.
16. Goellner M, Schmitt J, Holst S, Petschelt A, Wichmann M, Berthold C, *et al.* Correlations between tooth mobility and the periotest method in periodontally involved teeth. Quintessence Int 2013;44:307-16.
17. Fontijn-Tekamp FA, van der Bilt A, Abbink JH, Bosman F. Swallowing threshold and masticatory performance in dentate adults. Physiol Behav 2004;83:431-6.
18. Palinkas M, Nassar MS, Cecílio FA, Siéssere S, Semprini M, Machado-de-Sousa JP, *et al.* Age and gender influence on maximal bite force and masticatory muscles thickness. Arch Oral Biol 2010;55:797-802.
19. Bavia PF, Vilanova LS, Garcia RC. Craniofacial morphology affects bite force in patients with painful temporomandibular disorders. Braz Dent J 2016;27:619-24.
20. Fernandes CP, Psarras V, Freitas LB, Ahlgren J. Jaw-closing muscles: Electromyographic activity of human subjects with reduced periodontal support. J Oral Rehabil 1994;21:165-75.
21. Felício CM, Couto GA, Ferreira CL, Mestriner Junior W. Reliability of masticatory efficiency with beads and correlation with the muscle activity. Pro Fono 2008;20:225-30.
22. Awawdeh L, Hemaidat K, Al-Omari W. Higher maximal occlusal bite force in endodontically treated teeth versus vital contralateral counterparts. J Endod 2017;43:871-5.
23. Orchardson R, Cadden SW. Mastication and swallowing: 1. Functions, performance and mechanisms. Dent Update 2009;36:327-30, 332-4, 337.
24. Regalo SC, Vitti M, Semprini M, Rosa LB, Martinez FH, Santos CM, *et al.* Electromyographic analysis of the masseter and temporal muscles in oralized deaf individuals. Electromyogr Clin Neurophysiol 2006;46:217-22.
25. Gilbert AD, Newton JP. The effect of chronic periodontal disease on human jaw muscles: A pilot study using computed tomography. J Oral Rehabil 1997;24:259-64.
26. Takeuchi N, Yamamoto T. Correlation between periodontal status and biting force in patients with chronic periodontitis during the maintenance phase of therapy. J Clin Periodontol 2008;35:215-20.
27. Alkan A, Keskiner I, Arici S, Sato S. The effect of periodontitis on biting abilities. J Periodontol 2006;77:1442-5.
28. Morita M, Nishi K, Kimura T, Fukushima M, Watanabe T, Yamashita F, *et al.* Correlation between periodontal status and biting ability in Chinese adult population. J Oral Rehabil 2003;30:260-4.
29. Pereira LJ, Gazolla CM, Magalhães IB, Ramos-Jorge ML, Marques LS, Gameiro GH, *et al.* Treatment of chronic periodontitis and its impacts on mastication. J Periodontol2 011; 82:243-50.