All on Four® Fixed Implant Support Rehabilitation: A Masticatory Function Study

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ABSTRACT

Background: Fixed implant-supported prostheses according to All-on-Four® (Nobel Biocare, Goteborg, Sweden) principles have become an accepted treatment modality in totally edentulous patients, whereas the functional effect of this therapy is limited.

Purpose: The purpose of this study was to evaluate the muscular function of patients totally rehabilitated with All-on-Four.

Materials and Methods: This study evaluated 63 patients. Twenty-one patients were successfully rehabilitated with maxillary and mandibular All-on-Four (no dropout implants, satisfactory aesthetic and function demands prosthesis), 21 patients were dentate, and 21 were rehabilitated with double complete dentures. Electromyography was carried out during clenching, nonhabitual and habitual chewing, and rest. All values were standardized as percentage of a maximum voluntary contraction. Data were analyzed by ANOVA to compare groups and paired *t*-test was used for comparison between sides within each group.

Results: All groups presented symmetric muscular activity. The All-on-Four and dentate groups had a similar muscles surface electromyography (sEMG) contraction pattern, that is, a higher sEMG activity of masseter than temporalis muscles, differing ($p \leq .05$) from those of denture group. Not one statistical difference was found between All-on-Four and dentate groups.

Conclusion: The muscular function similarity of All-on-Four and dentate patients shows that this treatment concept may be considered as a good option for oral rehabilitation in edentulous patients.

KEY WORDS: All-on-Four®, electromyography, fixed implant prosthesis, implant, masticatory muscles

INTRODUCTION

The success rate of oral rehabilitations fixed by osseointegrated implants[1,2] has been an option to minimize the mechanical instability of conventional complete dentures and its negative psychological social impacts. However, the loss of alveolar bone remained as a great challenge to the treatment of edentulous patients. Driven by the need of placing osseointegrated implants on resorbed bone areas, especially in posterior regions, studies were encouraged to create alternatives to use the existing bone to fix implants.

The All-on-Four® (Nobel Biocare, Goteborg, Sweden) concept was developed to overcome anatomical limitations in the mandible and maxilla that make it challenging to treat without the use of complex technique.[3,4] The protocol includes the placement of four anterior implants for supporting a full-arch prosthesis in an edentulous jaw. The tilting of the two distal implants, between 35° and 45°, allows the use of longer implants favoring a good primary stability without interference in mental foramen or inferior alveolar nerve, in the case of the mandible, and without the need of maxillary sinus graft, in the case of the maxilla.[5,6] An immediate prosthesis can be made after surgery and the final prostheses are made 4 to 6 months after. The reduced number

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of implants promotes a cantilever that may result in a higher mechanical stress on prosthesis and implants. These turn necessary a shortened arch rehabilitation.[5]

The literature regarding All-on-Four technique relates a survival rate between 92.2% and 100%; however, the scientific dates are still restrict. The All-on-Four treatment has been evaluated based on bone or implant loss and a few considerations are made about patients' satisfaction, cosmetic results, and health of soft tissues.[3,4,7–12] The functional effects and the possible interferences of this type of rehabilitation in the stomatognatic system have not been established.

Recognizing the muscles' importance in the maintenance and integrity of stomatognatic system, the modern dentistry valorizes the use of different methodologies in the study of function to help diagnosis, establish prognosis, and evaluate the effects of different types of treatments. Among these, the surface electromyography (sEMG) stands out by its clinical convenience, no deleterious effects, and wide acceptance by patients. Taking into account special methodological recommendations,[13] sEMG procedures have been widely used to measure the muscular performance of the stomatognatic system in both static and dynamic.[14,15]

The purpose of this clinical study was to evaluate the muscular function, by masticatory muscles' sEMG, of patients that received upper and lower All-on-Four rehabilitations and compare them with those of complete dentures rehabilitated and natural dentition patients.

The research hypothesis was that subjects using All-on-Four rehabilitation would present muscular function similar to dentate subjects and better than patients with complete dentures prostheses. The detection of a possible harmonic function may support the functional success of this therapy and provide scientific support to this clinical procedure.

MATERIALS AND METHODS

Ethical Aspects

The present research was approved by the Ethics Committee of the School of Dentistry of Ribeirão Preto, University of São Paulo, Ribeirão Preto, São Paulo, Brazil, number 2010.1.1352.58.1, and all the volunteers signed an informed consent form to participate in this study.

Selection of Volunteers

For the present study, 63 patients (30 women and 33 men; mean age 57.8; range: 32.8–75.8) were selected from private and public dental offices of Ribeirão Preto and Campinas, SP, Brazil, during their follow-up visits. The patients were consecutively included from January 2010 to July 2012, provided that they met the inclusion criteria and gave their written consent to participate in the study.

Figure 1 Intraoral photograph of the four implants installed and its abutments used to screw the immediate loading All-on-Four provisory prosthesis, 1 week after the surgery. The photograph was taken 7 days after the surgery.

The patients were divided into three groups: I = wearers of upper and lower All-on-Four prosthesis installed immediately after implant surgery ($n = 21$); II = dentates ($n = 21$); III = wearers of upper and lower complete dentures ($n = 21$).

Inclusion and Exclusion Criteria

The inclusion criteria were presence of lower and upper definitive prosthesis (All-on-Four or complete denture) for at least 6 months (Figures 1–3) or presence

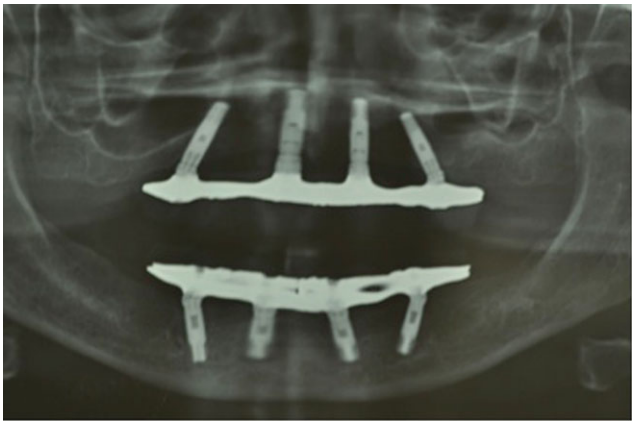

Figure 2 Panoramic RX of an illustrative patient treated by All-on-Four in upper and lower jaw. The central implants were uprighted and the tilting of the two distal implants was between 35° and 45°. The screwed definitive prostheses were placed 6 months after the surgery.

Figure 3 Extraoral photograph of a patient using the definitive All-on Four prosthesis.

of permanent dentition; satisfactory rehabilitations according to the methods of evaluation proposed by Misch[16] and reported satisfactory aesthetic and function demands (including no problems with mastication and no muscular or temporomandibular join pain).

As exclusion criteria, the patients with dental pathologies, buccofacial pain or muscular dysfunctions, as well as evidence of other neurological and articular pathologies were excluded from the study, as these data are based on medical history and clinical exam. The dentate patients with three or more dental loss, excluding third molars, were excluded. Teeth absence must have been rehabilitated by fixed prosthesis or corrected by closing the space by means of orthodontic treatment.

Electromyography

The electromyographic exams were carried out during the patient's follow-up visits at the private and/or public dental offices with the aid of the Myosystem-Br1 portable electromyograph (DataHominis Tecnologia Ltda, Uberlândia, MG, Brazil) connected to a notebook. For the electromyographic register, five channels of the Myosystem-Br1 apparatus were used, with simultaneous acquisition, common grounding to all channels, low-pass filters of 10 Hz to 5 KHz, channel input impedance of 10 GΩ in differential mode, 12 bites of dynamic resolution range, amplitude band of −10V to +10V, and channel sampling frequency of 2 KHz. For signal visualization and processing, the software Myosystem I version 3.5 (DataHominis Tecnologia Ltda) was used, also allowing after digitalization that the signals were analogically amplified with a 1000x× gain, filtered by a 0.01–1.5 kHz bandpass filter and sampled by a 12-b A/D converter with an acquisition frequency of 2 kHz.

Surface differential active electrodes (two 10 mm-long and 2 mm-wide silver-chloride bars, separated by a distance of 10 mm, with input impedance of 10 GΩ and common-mode rejection ratio of 130 dB at 60 Hz) were used. The skin region where electrodes were placed was cleaned with alcohol and shaved when necessary. The differential active electrodes were positioned on the skin in the region of the ventral portion of right and left masseter muscles and on the skin in the region of the anterior portion of right and left temporal muscles. The position of electrodes was determined according to the recommendations of Cram[17] who preconize the test of muscular function. Electrodes were fixed with adhesive bandage tape, with the longest extension of the bars perpendicular to the direction of the muscle fibers. A stainless steel circular electrode (3 cm in diameter) was used as reference electrode (ground electrode), fixed to the skin in the frontal bone region.

The electromyographic signals were acquired during rest and in the clinical conditions of maximum voluntary contraction (MVC), cotton roller contraction, parafilm chewing, and peanut chewing. This exam was performed with the volunteer comfortably seated in an office-type chair, with arms next to body and hands resting on the thighs.

Initially, rest was registered for 10 s, with the individual very relaxed. Then the volunteer was asked to clench the teeth with maximum strength for 4 seconds to allow the registration of MVC. Then they were asked to clench a peace of paraffin (Parafilm M® – Pechiney Plastic Packaging, Chicago, IL, USA) positioned between the first molar teeth.

Tests of mastication were performed during 10 seconds, with two products that presented different types of mastication and offer different viscoelastic properties. A Parafilm was used to offer a nonhabitual mastication and five units of japanese peanut (Mendorato®, Santa Helena, Ribeirão Preto, SP, Brazil) to offer a habitual mastication. Food was obtained from the manufacturers, having the same batch number and presenting no variation in consistency.

To reduce fatigue, the individuals could talk, drink or rest in the interval between each analysis, and were informed when they were ready for the next evaluation, with a minimum interval of 2 minutes between data collection. All the volunteers received previous training before performing the clinical conditions.

Data Analysis

For each muscle, the MVC electromyography (EMG) potential was set at 100%, and all further EMG potentials were expressed as a percentage of this value (μV/μV × 100). The root mean square of the amplitude (μV) was used to analyze static conditions (rest and clenching). The integrated area of EMG potential was used to analyze dynamic conditions (habitual and nonhabitual chewing).

Descriptive statistics (mean and standard error) of right masseter, left masseter, and temporalis were calculated for each electromyographic variable in static conditions and during both chewing tasks. Statistical analyses were set by the SPSS software version 17.0 (Chicago, IL, USA). Intergroup comparison was made by one-way ANOVA, followed by Duncan post hoc tests. Intragroup comparison was made using paired *t*-test. Significance level was set at $p \leq .05$.

RESULTS

Table 1 reports the mean sEMG outcomes of analyzed groups and the statistical results of between-side comparisons. All groups presented symmetric muscular activity during clenching, nonhabitual and habitual chewing, and rest.

Figure 4 reports the mean sEMG outcomes of the three analyzed groups and the intergroup statistically analyzed results. During clenching, the All-on-Four and dentate groups had a similar muscles sEMG contraction pattern, that is, a higher sEMG activity of masseter than temporalis muscles. The denture group presented a hyperactivity of couple temporalis muscles in comparison with those of masseters. Intergroup comparison showed that the right masseter of denture group was significantly ($p \leq .05$) less active than the other two groups. Not one significant difference was found between All-on-Four and dentate groups.

During nonhabitual chewing, the All-on-Four and dentate groups again presented a higher sEMG activity of masseter than temporalis muscles. The denture group had a higher temporalis activity when compared with masseters. The left temporalis sEMG activity of All-on-Four and dentate groups was significantly ($p \leq .01$) higher than the denture group.

During habitual chewing, the three groups had a similar muscles sEMG contraction pattern with a higher sEMG activity of a couple of masseter than temporalis. Not one intergroup statistical difference was found.

During rest, the All-on-Four and dentate groups again presented a higher sEMG activity of masseter than

TABLE 1 sEMG Variables Mean, Standard Error (±), and Paired *t*-Test Results during Clenching, Nonhabitual and Habitual Chewing, and Rest

	RM	LM	RT	LT	Significance
Clenching					
All on Four	188.2 ± 18.6	167.9 ± 22.5	133.8 ± 8.9	149.6 ± 16.2	n/s
Dentate	215.8 ± 40.4	166.4 ± 16.7	125.9 ± 7.0	130.8 ± 12.5	n/s
Denture	110.1 ± 9.5	110.6 ± 15.8	121.8 ± 9.7	131.5 ± 15.6	n/s
Nonhabitual chewing					
All on Four	245.0 ± 27.5	233.2 ± 32.8	171.9 ± 15.4	87.6 ± 9.3	n/s
Dentate	213.0 ± 44.2	180.2 ± 31.5	160.3 ± 16.4	165.1 ± 18.4	n/s
Denture	184.1 ± 23.6	157.0 ± 15.7	214.4 ± 25.0	242.8 ± 42.7	n/s
Habitual chewing					
All on Four®	322.0 ± 46.9	308.1 ± 51.6	199.8 ± 34.4	210.4 ± 37.4	n/s
Dentate	236.6 ± 59.5	209.4 ± 39.6	159.3 ± 20.9	200.1 ± 61.8	n/s
Denture	231.8 ± 37.3	202.1 ± 25.6	196.1 ± 18.6	185.7 ± 32.3	n/s
Rest					
All on Four	25.4 ± 8.3	21.9 ± 3.7	21.5 ± 3.5	20.4 ± 3.9	n/s
Dentate	14.4 ± 3.7	13.2 ± 2.4	13.5 ± 2.2	13.0 ± 2.5	n/s
Denture	15.6 ± 2.6	17.2 ± 2.0	37.3 ± 5.4	30.5 ± 5.0	n/s

Right and left masseter (RM and LM) and right and left temporalis (RT and LT) of All-on-Four ($n = 21$), dentate ($n = 21$), and denture groups ($n = 21$). All sEMG values are standardized as % of an MVC.
MVC = maximum voluntary contraction; n/s, no statistical significance; sEMG = surface electromyography.

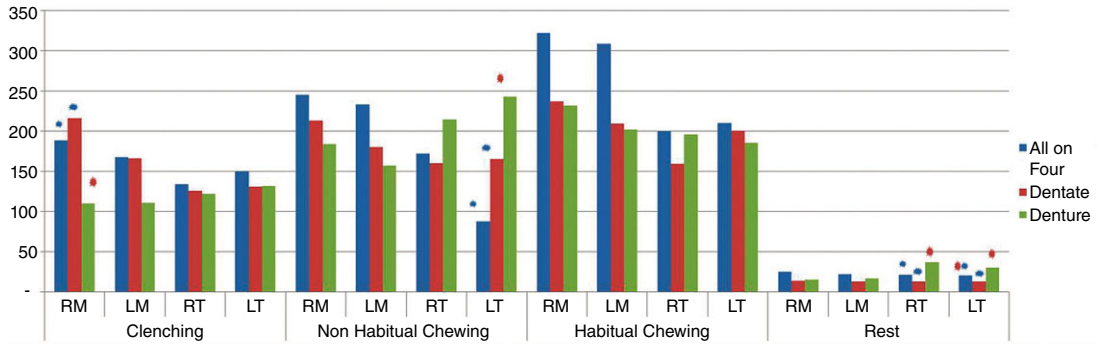

Figure 4 sEMG variables mean and one-way ANOVA/Duncan post hoc test results during clenching, nonhabitual and habitual chewing, and rest. Right and left masseter (RM and LM) and right and left temporalis (RT and LT) of All-on-Four ($n = 21$), dentate ($n = 21$), and denture groups ($n = 21$). All sEMG values are standardized as % of an MVC. Different asterisk (*) colors represent statistical differences. MVC, maximum voluntary contraction; sEMG = surface electromyography.

temporalis muscles, and the denture group had a higher temporalis than masseter muscles activity. Intergroup comparison showed that the All-on-Four and dentate groups had similar sEMG activity of couples of masseter and temporalis muscles. The left and right temporalis sEMG activity of All-on-Four and dentate groups was significantly ($p \leq .01$) more relaxed than the denture group.

DISCUSSION

The edentulism is a clinical condition that, in addition to the loss of structural components like alveolar bone, results in serious functional damages, such as poor masticatory function and deficient nutrition.[18] Thus, besides filling the loose structural components, the treatment of these patients may include functional rehabilitation also. The use of sEMG to evaluate the masticatory muscles of All-on-Four rehabilitated patients, like the one in this study, was essential to provide an integral evaluation and a complete diagnosis of the individuals.

Taking into account special methodological recommendations,[13] the sEMG is a method of detecting and registering electrical activity of muscle fibers that appear to be able to deliver additional information for diagnosis and therapy,[19] as performed in the present study. The sEMG assessments involve several variability sources, both technical and biological. In the present study, the technical variability were reduced by using all special methodology recommended by the European Recommendations for Surface Electromyography.[13] Biological variability was reduced by assessing values relative to maximum voluntary contraction.[13,14,19] The evaluated patients of the present study were using definitive prosthesis for at least 6 months because at this stage the patients had adapted well to chewing with the denture.[20]

When the muscular masticatory function is analyzed, it is expected that both sides work similarly. The bilateral mastication is important to the good stimulus of the support structures.[21,22] The present study verified that All-on-Four, dentate, and denture groups had a symmetric function of masticatory muscles. The inclusion criteria of satisfactorily rehabilitated patients proposed by Misch,[16] and used in the present study, may explain these results. These findings show the clinical importance of well rehabilitation establishment, using occlusal and functional criteria. A different sample composed of patients using prosthesis with inadequate rehabilitation criteria may result in different a finding. The teeth are important in the masticatory system,[18] and occlusal factors, like change in occlusal contacting pattern, can generate the asymmetry of masticatory muscles.[23,24]

The present study showed that All-on-Four group presented masticatory muscles contraction pattern similar to dentate. Both groups revealed a great sEMG activation of the masseter in comparison with temporalis muscle. This is an expected condition in individuals that present an adequate activity of the stomatognatic system. Masseter is a muscle of power, actively acting in the masticatory process. The temporalis muscle is faster, being the first to contract in mandible elevation, coordinating the movement as a mandibular positioner, and acting less intensely during mastication.[25] The muscular activation of All-on-Four group was similar to dentate during clenching, nonhabitual chewing, habitual chewing, and rest. This similarity of function can be

explained by the presence of osseoperception in patients with implant-supported denture, despite the absence of periodontal afferent input.

The periodontal receptors play a significant role in the masticatory system because of it somatosensory cortex stimulation.[26] The sensory and motor feedback of the central nervous system in patients with implant-supported full dentures is closer to that of the natural dentition.[27] The bone in the peri-implant regions contain nerve fibers which may serve as a source of sensory feedback instead of the periodontal ligament.[28] Activation of oral facial representative areas in sensorial and motor cortex may explain the improved tactile, stereognosticability, and mastication function, which might be the underlying physiologic mechanism of osseoperception.[27]

The functional effect of All-on-Four was not previously considered, thus limiting direct comparison of our results. Some function-positive results regarding the use of oral implant were made in overdenture studies. The sEMG patterns of muscle activation in implant-retained overdentures showed that this treatment can be considered as a good option for oral rehabilitation.[15] Implant treatment was shown to have a significant positive effect on both bite force and masticatory performance.[18] Also, patient satisfaction with an implant-retained prosthesis was high in comparison with the situation before implant treatment.[18]

In contrast to All-on-Four® group, the complete denture group presented a higher temporalis activity in comparison with masseter, showing that this type of complete rehabilitation does not promote a correct functional reestablishment in edentulous patients.[29,30] The reduced functional performance may be related to retention and stability problems,[18] discomfort, and patient's adaptive nonability characteristics inherent to this kind of rehabilitation. Previous studies showed that the majority of individual wearers of complete denture reported painful symptomatology, less regular and uniform chewing cycles; and a minority of individual prosthesis on implant wearers reported this symptomatology.[31–33]

Any alteration in the equilibrium of stomatognatic system could cause changes in the muscular tension that are more clearly observed in the temporalis muscles,[29,30] a fact verified in the results of the present research, in which the wearers of complete dentures presented a higher electromyographic activity of temporalis muscles than the dentate and All-on-Four individuals. The electromyographic activity of masticatory muscles in rest is higher in individuals with dysfunctions in the stomatognatic system, in comparison with healthy individuals, indicating an increase in the basal tonus.[29,34]

The similarity between All-on-Four and dentate as well the significant difference of those with the complete denture rehabilitation may show that the All-on-Four rehabilitation is a good option to reestablish a muscular function of edentulous patients, being better than removable rehabilitation like complete denture.

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REFERENCES

1. Allen PF, McMillan AS, Walshaw D. A patient-based assessment of implant-stabilized and conventional complete dentures. J Prosthet Dent 2001; 85:141–147.
2. Brånemark PI, Hansson BO, Adell R, et al. Osseointegrated implants in the treatment of the edentulous jaw. Experience from a 10-year period. Scand J Plast Reconstr Surg Suppl 1977; 16:1–132.
3. Malo P, Rangert B, Nobre M. "All-on-Four" immediate-function concept with Branemark System implants for completely dentulous mandibles: a retrospective clinical study. Clinical Implant Dentistry and Related Research 2003; 5(Suppl 1):2–9.
4. Maló P, de Araújo Nobre M, Lopes A, et al. "All-on-4" immediate-function concept for completely edentulous maxillae: a clinical report on the medium (3 years) and long-term (5 years) outcomes. Clin Implant Dent Relat Res 2012; 14(Suppl 1):e139–e150. doi: 10.1111/j.1708-8208.2011.00395.x. Epub 2011 Oct 18.
5. Armellini D, von Fraunhofer JA. The shortened dental arch: a review of the literature. J Prosthet Dent 2004; 92:531–535.
6. Agliardi E, Clericò M, Ciancio P, Massironi D. Immediate loading of full-arch fixed prostheses supported by axial and tilted implants for the treatment of edentulous atrophic mandibles. Quintessence Int 2010; 41:285–293.
7. Aparicio C, Perales P, Rangert B. Tilted implants as an alternative to maxillary sinus grafting: a clinical, radiologic, and periotest study. Clinical Implant Dentistry and Related Research 2001; 3:39–49.
8. Malo P, Rangert B, Nobre M. All-on-4 immediate-function concept with Branemark System implants for completely edentulous maxillae: a 1-year retrospective clinical study. Clin Implant Dent Relat Res 2005; 7(Suppl 1):S88–S94.

9. Malo P, Nobre Mde A, Petersson U, et al. A pilot study of complete edentulous rehabilitation with immediate function using a new implant design: case series. Clin Implant Dent Relat Res 2006; 8:223–232.
10. Malo P, de Araújo Nobre M, Lopes A, et al. A longitudinal study of the survival of All-on-4 implants in the mandible with up to 10 years of follow-up. J Am Dent Assoc 2011; 142:310–320.
11. Francetti L, Agliardi E, Testori T, Romeo D, Taschieri S, Fabbro MD. Immediate rehabilitation of the mandible with fixed full prosthesis supported by axial and tilted implants: interim results of a single cohort prospective study. Clin Implant Dent Relat Res 2008; 10:255–263.
12. Khatami AH, Smith CR. "All-on-four" immediate function concept and clinical report of treatment of an edentulous mandible with a fixed complete denture and milled titanium framework. J Prosthodont 2008; 17:47–51.
13. Hermens HJ, Freriks B, Merletti R. European recommendations for surface electromyography – results of the SENIAN project. 1999: 13–58.
14. De Rossi M, De Rossi A, Hallak JEC, et al. Electromyographic evaluation in children having rapid maxillary expansion. Am J Orthod Dentofacial Orthop 2009; 136:355–360.
15. Bersani E, Regalo SC, Siéssere S, et al. Implant-supported prosthesis following Brånemark protocol on electromyography of masticatory muscles. J Oral Rehabil 2011; 38:668–673.
16. Misch CE. Clinical indications for altering vertical dimension of occlusion. Objective vs subjective methods for determining vertical dimension of occlusion. Quintessence Int 2000; 31:280–282.
17. Criswell E, ed. Cram's introduction to surface electromyography. 2nd ed. Sudbury, MA: Jones and Bartlett Publishers, 2011:436.
18. Polzer I, Schimmel M, Müller F, et al. Edentulism as part of the general health problems of elderly adults. Int Dent J 2010; 60:143–155.
19. Hugger A, Hugger S, Schindler HJ. Surface electromyography of the masticatory muscles for application in dental practice. Current evidence and future developments. Int J Comput Dent 2008; 11:81–106.
20. Tallgren A, Tryde G. Chewing and swallowing activity of masticatory muscles in patients with a complete upper and a partial lower denture. J Oral Rehabil 1991; 18:285–299.
21. Farias Gomes SG, Custodio W, Moura Jufer JS, et al. Correlation of mastication and masticatory movements and effect of chewing side preference. Braz Dent J 2010; 21:351–355.
22. Van Der Bilt A. Assessment of mastication with implications for oral rehabilitation: a review. J Oral Rehabil 2011; 38:754–780.
23. Ferrario VF, Sforza C, Serrão G, et al. The effects of a single intercuspal interference on electromyographic characteristics of human masticatory muscles during maximal voluntary teeth clenching. Cranio 1999; 17:184–188.
24. Adhikari H, Kapoor A, Prakash U, et al. "Electromyographic pattern of masticatory muscles in altered dentition" Part II. J Conserv Dent 2011; 14:120–127.
25. Koolstra JH. Dynamics of the human masticatory system. Crit Rev Oral Biol Med 2002; 13:366–376.
26. Trulsson M, Francis ST, Bowtell R, et al. Brain activations in response to vibrotactile tooth stimulation: a psychophysical and fMRI study. Neurophysiol 2010; 104:2257–2265.
27. Yan C, Ye L, Zhen J, et al. Neuroplasticity of edentulous patients with implant-supported full dentures. Eur J Oral Sci 2008; 116:387–393.
28. Weiner S, Sirois D, Ehrenberg D, et al. Sensory responses from loading of implants: a pilot study. Int J Oral Maxillofac Implants 2004; 19:44–51.
29. Liu ZJ, Yamagata K, Kasahara Y, et al. Electromyographic examination of jaw muscles in relation to symptoms and occlusion of patients with temporomandibular joint disorders. J Oral Rehabil 1999; 26:33–47.
30. Landulpho AB, Silva WA, Vitti M. Electromyographic evaluation of masseter and anterior temporalis muscles in patients with temporomandibular disorders following interocclusal appliance treatment. J Oral Rehabil 2004; 31:95–98.
31. Fontijn-Tekamp FA, Slagter AP, van 't Hof MA, et al. Pain and instability during biting with mandibular implant-retained overdentures. Clin Oral Implants Res 2001; 12: 46–51.
32. Veyrune JL, Lassauzay C, Nicolas E, et al. Mastication of model products in complete denture wearers. Arch Oral Biol 2007; 52:1180–1185.
33. Mishellany-Dutour A, Renaud J, Peyron MA, et al. Is the goal of mastication reached in young dentates, aged dentates and aged denture wearers? Br J Nutr 2008; 99:121–128.
34. Pinho JC, Caldas FM, Mora MJ, et al. Electromyographic activity in patients with temporomandibular disorders. J Oral Rehabil 2000; 27:985–990.

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