Research Article

Electromyographic Evaluation of Functional Adaptation of Patients with New Complete Dentures

Kujtim Sh. Shala, Linda J. Dula, Teuta Pustina-Krasniqi, Teuta Bicaj, Enis F. Ahmedi, Zana Lila-Krasniqi, and Arlinda Tmava-Dragusha

Department of Prosthetic Dentistry, School of Dentistry, Faculty of Medicine, University of Prishtina, Prishtina, Kosovo

Correspondence should be addressed to Linda J. Dula; linda.dula@uni-pr.edu

Received 13 August 2017; Revised 29 November 2017; Accepted 19 December 2017; Published 11 March 2018

Academic Editor: Manuel Lagravere

Copyright © 2018 Kujtim Sh. Shala et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Objective. The objective of this study was to evaluate the level of adaptation of patients to newly fitted complete dentures in their dominant and nondominant sides, by means of Electromyographic signals. Materials and Methods. Eighty-eight patients with complete dentures were evaluated in the study. Masticatory muscle (masseter and temporalis) bioelectric activity of the patients with complete dentures was recorded at maximum intercuspal relation. Parametric statistical data were analyzed with one-way repeated measures ANOVA test. Results. Measurement time was significantly different for both dominant (DS) and nondominant (NDS) sides: $F_{\Sigma}^{S-DS} = 21.51, p = 0.0001; F_{\Sigma}^{S-NDS} = 13.25, p = 0.0001$. Gender was also significantly different: $F_{\Sigma}^{S-DS-gender} = 41.53, p = 0.001; F_{\Sigma}^{S-NDS-gender} = 85.76, p = 0.0001$. The average surface area values showed significant difference in females. Prior experience with dentures showed no significant difference for both sides of mastication: $F_{\Sigma}^{S-DS-experiences} = 1.83, p = 0.1772; F_{\Sigma}^{S-NDS-experiences} = 3.30, p = 0.0697$. Conclusion. The planimetric indicators of bioelectric activity of masseter and temporalis muscles at maximum physiological loading conditions are significant discriminators of the level of functional adaptation of patients with new complete dentures.

1. Introduction

Tooth loss and the loss of periodontal afferent flow lead to changes in the masticatory neuromuscular patterns [1]. The Electromyographic (EMG) tests of masseter and temporalis muscles are utilized to determine the correlation between electromyographic activity of masticatory muscles and occlusal relations [2–3], craniofacial morphology [4, 5], and various therapeutic procedures [6, 7].

Electromyography (EMG) is defined as the Figureic recording of the electrical potential of muscle’s performance and their interrelation, based on the analysis of electrical signals produced during each muscle contraction [8]. It has been the only tool for the assessment of muscle activity of stomatognathic system since its first concerted use in dentistry by Moyers in 1949 [3]. Studies by Kemslay et al. [9] and Hagberg [10] have shown that masseter and temporalis muscles are preferred in EMG studies of masticatory function. Clinicians and researchers have historically used EMG to test the masticatory function of denture wearers.

EMG research suggests that the overall activity of mandibular elevator muscles in denture wearers does not significantly differ from patients with natural dentition [11]. However, there is no clear explanation as to why tooth loss reduces the capacity of masticatory muscles to perform [12]. In other words, as a result of tooth loss, although muscle activity is maintained, there is a significant reduction of masticatory efficiency in patients with complete dentures. The latter occurs due to the lack of adequate masticatory muscle activity (i.e., loss of periodontal receptors) and altered energy distribution within masticatory muscles. Pancherz [13] analyzed the integrated activity of masseter and temporalis muscles, with the help of standard electrode techniques, and compared the results between experimental homologous groups. Quantitative analysis of EMG activity between masseter and temporalis muscles was tested in
relation to the maximum bite forces in the intercuspial position and in relation to the masticatory cycle obtained during the crushing of a peanut grain. The results obtained in this research have shown that EMG activity of masseter muscle increases over time at maximum bite force and during mastication, while temporal muscle activity remains relatively constant. These results are consistent with the results of other human [2] and animal [14] studies.

One of the objectives of prosthetic rehabilitation is to ensure the best possible masticatory function of the patient.

2. Main Hypothesis

This study is part of a wide research with the following working hypothesis: “Optimum period of functional stability in Complete Denture Wearers, following the completion of the period of neuromuscular adjustment.” The hypothesis may be determined with the help of the following functional tests:

(i) Intercocular perception test
(ii) Maximum mastictory load test
(iii) Masticatory muscle bioelectric activity test
(iv) Masticatory efficiency test

The aim of this study was to evaluate the level of patients’ adaptation in experienced and nonexperienced denture wearers after the insertion of new complete dentures in dominant side (DS) and nondominant side (NDS). To do so, we used ElectromyoFigureic signals for a period of six months after fitting the dentures.

3. Materials and Methods

The research proposal was accepted and approved by the Ethics Committee of the University Dentistry Clinical Center of Kosovo, Pristina. Informed consent was obtained from each individual participant in this study.

Eighty-eight patients with complete dentures with eugnatic jaws in sagittal plain, and no signs of orofacial system dysfunction were examined. There were 42 females and 46 males. Forty-five patients belonged to the nonexperienced group which wore new complete dentures for the first time, while forty-three patients had been wearing complete dentures for a while (the experienced group) (Table 1).

All the examinees were subject to history taking and clinical examination of dominant masticatory side in function. All examinees have no signs of orofacial conditions.

Patients over 70 years of age with orthodontic anomalies in sagittal and transversal planes, dentofacial conditions, and significant resorption of alveolar ridge (i.e., negative alveolar ridge) were excluded from the study. Depending on their experience with denture wearing, the sample was divided into two groups:

(i) Group 1: patients fitted with dentures for the first time—complete denture wearers (nCDW)
(ii) Group 2: patients who had had previous experience with complete dentures—experienced complete denture wearers (eCDW)

The (convenient) random sample of patients was selected at the Department of Prosthodontics, University of Prishtina, Faculty of Medicine, Stomatology Branch, Prishtina, Kosovo.

In order to evaluate the masticatory muscle activity of CDW, EMG bioelectric activity of masseter and temporalis muscles was recorded, unilaterally, at maximum bite force (mBF). The successive measurement (observational) periods were at first week of fitting the complete dentures and five weeks, ten weeks, 15 weeks, 20 weeks, and 25 weeks after fitting the complete dentures.

During signal acquisition, the subject remained comfortably seated in a chair and was presented with the equipment and the movements to be performed, getting all the necessary instructions and information. EMG recording was carried out with the DynoFigureic Quadrant R 511 A, with the possibility of direct and integrated recording. The action potential was measured via bipolar electrodes. The electrodes were placed in the patients’ auricle or hand. Considering that a significant number of measurements are required at the time of observation, the constant position of the electrode was ensured. Specifically, a plastic template which contained the pressure of points of masseter and temporalis muscles in a coordinate system was used for each measurement. Within the earlier mentioned measurement (observation) periods, three consecutive mBF measurements were conducted lasting three seconds each with intermittent pauses of one minute of muscular relaxation time at the dominant side (DS) first and nondominant side (NDS) last. During initial isometric contraction time on clenching, in central relation (maximum intercuspal position), muscular tonus increased.

EMG recorded the amplitude and the sum of surfaces of the planimetric indicators of the bioelectric activity of masseter and temporalis muscles. The surface of the planimetric indicators of the bioelectric activities of masseter and temporalis muscles was measured with the aid of Reiss number 3005 and is presented as the mean value between the two measurements. The sum of the surfaces of planimetric indicators of bioelectric activity of masseter and temporalis muscles was obtained by the sum of constituent components (ΣP = Pmm + Pmt). For the analysis, the highest obtained value of the surface of planimetric indicators and bioelectric activity of masseter muscle was obtained at earlier defined time intervals. The corresponding sum of surfaces of the planimetric indicators of bioelectric activity of temporalis muscle was added to the latter value. Within the scope of this

| Table 1: Comparison of gender, age, and nonexperienced/experienced group. |
|-----------------|-----------------|-----------------|-----------------|-----------------|
|                  | Female          | Males           | Nonexperienced  | Experienced     |
| N                | 42              | 46              | 45              | 43              |
| X                | 54.6            | 55.7            | 52.7            | 57.8            |
| SD               | 5.4             | 6.1             | 5.7             | 4.1             |
| X, max           | 66              | 68              | 65              | 68              |
| X, min           | 42              | 44              | 42              | 49              |
scheme of bioelectric activities of masseter and temporalis muscles, maximal amplitude of each individual muscle was calculated and used in the analysis of the results.

4. Data Analysis

Statistical analysis was performed using the standard software package BMDP (Biomedical Statistical Package), dedicated to research in the biomedical sciences and including all methods of statistical procedures (Dixon, 62). Testing parametric data was done with one-way repeated measures ANOVA test.

5. Results

The tables present the average values of the electro-myographic activity of masseter and temporalis muscles in dominant side and nondominant side during maximum voluntary tooth compression at the intercuspidal position. The results presented in the tables are elaborated in the following:

(1) The amplitude dynamics of the planimetric indicators of bioelectric activity of m. masseter during maximum voluntary tooth compression at the intercuspidal position presented with these values: by analysis of variation, the influence of the time of measurement in the change of the amplitude of m. masseter was more significant in dominant side (DS) compared to the nondominant side (NDS): Fa.m.m.-DS = 16.06, p = 0.0001; Fa.m.m.-NDS = 9.39, p = 0.0001.

In DS, the amplitude of the m. masseter increased steadily from the initial values to the third measurement. However, it marked a collapse in the fourth measurement and then reached maximum value again, which it sustained throughout the fifth and sixth measurements. In NDS, the value of the amplitude conveys the same dynamics but with less pronounced changes. In addition, the stationary state (when there is no muscular contraction activity) is reached after the fourth measurement (Table 2).

Gender influences the average values of the amplitude of m. masseter: Fa.m.m-DS-gender = 34.4, p = 0.0001; Fa.m.m-NDS-gender = 239.59; p = 0.001. In addition, gender interacts with the time of measurement to lead to different results. Fa.m.m-DS-interaction = 7.06, p = 0.0001; Fa.m.m-NDS-interactions = 10.65, p = 0.0001 (Table 2 and Figure 1).

The amplitude values of m. masseter in the DS and the NDS do not vary depending on the variables of the previous experience with complete dentures. Fa.m.m.-experience DS = 1.25, p = 0.2648; Fa.m.m.-experience NDS = 3.23, p = 0.0729 (Table 2 and Figure 2).

(2) The amplitude dynamics of the planimetric indicators of bioelectric activity of m. temporalis during maximum voluntary tooth compression at the intercuspidal position presented with these values: the significant differences only on the dominant side (DS) compared to the nondominant side (NDS): Fa.m.t-DS = 3.28, p = 0.0063; Fa.m.t-NDS = 1.62, p = 0.1518. While the amplitude values in the first three measurements are approximately the same, in the fourth measurement, there is a noticeable reduction of the amplitude values. Further, in the last two measurements, they approach the initial values again. Analysis suggests that there is no reaction in NDS, except for the natural variation between the values of the amplitude between successive measurements (Table 3).

The gender of the researchers and the interaction of time with gender affect the change of the values of the amplitude of m. temporalis: Fa.m.t-DS-gender = 282.6, p = 0.0001; Fa.m.t-NDS-gender = 112.63, p = 0.0001; Fa.m.t-NDS-interaction = 5.60, p = 0.0001 (Table 3 and Figure 3). Significant differences in the amplitude of the m. temporal also occur as a result of the influence of the prior experience in both DS and NDS: Fa.m.t-DS-experience = 7.81 p = 0.0054; Fa.m.t-NDS-experiences = 25.07, p = 0.0001 (Table 3 and Figure 4).

(3) The values of the sum of the surfaces of the planimetric indicators of the bioelectric activity of m. masseter and m. temporalis presented with these values: the influence of the measurement time on the values of the amount of surfaces is important both in DS and in NDS: FΣs-DS = 21.51, p = 0.0001; FΣs-NDS = 13.25, p = 0.0001. The initial values of DS amounts are lower than the others. The stationary is measured in the fifth measurement, suggesting that, in the NDS, the first four measurements did not differ, but in the fifth and sixth measurements, there were approximate values of the sum of the surfaces (Table 4).

The gender impact is of great importance on both sides and in the interaction with the time of measurement: FΣs-DS-gender = 41.53, p = 0.001; FΣs-NDS-gender = 85.76, p = 0.0001; FΣs-DS-interactions = 34.6, p = 0.001; and FΣs-NDS-interactions = 8.37, p = 0.0001. The average value of the surface area has significant differences in females and rose with the time of measurement (Figure 5).

The impact of the preliminary experience with the complete dentures did not matter either in DS and NDS: FΣs-DS-experiences = 1.83, p = 0.1772; FΣs-NDS-experiences = 3.30, p = 0.0697 (Figure 6).

6. Discussion

This study investigated the behavior of EMG parameters during maximal voluntary tooth compression in the intercuspidal position. We paid special attention to how the main mandibular elevator, under maximum load conditions, expressed their activity in the intercuspidal position. This is the activity that affects the dynamics of functional adaptation to the new complete dentures. New prostheses have positive effect on the patient’s muscular activity. However, an adaptation period of the muscle fibers to the new prosthesis is needed [15]. Goiato et al. concluded that a new complete denture allows for neuromuscular reprogramming, which contributes to muscular balance of the masticatory system [16]. Moller and Hannam et al. have proved
that the stability of the intercuspidal position is of great clinical significance because this position can generate large masticatory forces, as the muscular activity in this position is maximally expressed [5, 17]. During the period of initial isometric contraction in conditions of tightness of the teeth in the maximal intercuspidation, there is an increase in muscle tone. This increase is in a positive linear relationship with the number of planes of EMG (quantitative parameter) of the muscles involved [18].

The maximum amplitude within the planimetric indicators is of qualitative importance as it is the result of the bioelectric activity of the recruited motor units during the generation of a masticatory force. The planimetric indicators were analyzed separately in relation to the dynamics of the component: the amount of surfaces and the amplitude of bioelectric activity of m. masseter and m. temporalis during under maximum load conditions. The amplitude average values of m. masseter and m. temporalis during maximum voluntary tooth compression are about 1/3 lower in the DS than in NDS, while in the NDS, it is detected at several defined time intervals. No significant difference was found in the amplitude values of m. masseter and m. temporalis during maximum voluntary tooth compression at the intercuspidal position between DS and NDS.

Edentulous subjects also produced significantly less EMG activity and had significantly lower estimated jaw muscle strength. Weakened jaw muscles are one factor contributing to lower maximum bite forces among users of conventional dentures [19]. A previous study of elevator muscle activity in patients before and after complete dentures suggested that the use of complete dentures provokes electromyographic changes by increasing the occlusal vertical dimension [20].

The behavior of the research determines functional adaptation to new complete denture, and it oscillates around the balancing position. This result is also supported by Karakazis and Kossion, who reported that the chewing efficiency showed a noticeable increase with time. This is because improving denture adaptation may be due to the neuromuscular control which is gradually generated by time [21].

Our findings suggest that there is a difference due to gender, thus aligning with previous research. Gender influences the average values of the amplitude of m. masseter. According to previous research, females have lower amplitude

Table 2: The amplitude dynamics of the planimetric indicators of bioelectric activity of m. masseter (μV) during maximum voluntary tooth compression at the intercuspidal position.

| Measurement | Gender | Experience | Total |
|-------------|--------|------------|-------|
|             | F      | M          |       |
|             | DS     | NDS        |       |
|             | Male   |            |       |
| N           | 42     | 42         | 46    |
| 1x          | 418    | 287        | 509   |
| 2x          | 27.6   | 18.7        | 19.2  |
| 3x          | 586    | 449        | 537   |
| 4x          | 37.2   | 21.5        | 26.3  |
| 5x          | 588    | 557        | 605   |
| 6x          | 734    | 535        | 609   |

Figure 1: The amplitude of m. masseter according to gender with complete dentures (dominant side/nondominant side).

Figure 2: The amplitude of m. masseter according to experience with complete dentures (dominant side/nondominant side).


Table 3: The amplitude dynamics of the planimetric indicators of bioelectric activity of m. temporalis during maximum voluntary tooth compression at the intercuspidal position.

| Measurement | Gender | Experience | Total       |
|-------------|--------|------------|-------------|
|             |        | Without    | With        |
|             | DS     | NDS        | DS          | NDS        | DS  | NDS        | DS          | NDS        |
| N           | 42     | 42         | 46          | 46         | 45       | 45         | 43          | 43         | 88           | 88           |
| 1x          | 395    | 342        | 726         | 531        | 612      | 511        | 522         | 389        | 389          | 568          | 451          |
| SD          | 22.1   | 25.7       | 43.8        | 26.2       | 46.7     | 31.5       | 38.8        | 26.0       | 30.7         | 21.4         |              |
| 2x          | 371    | 264        | 745         | 516        | 609      | 433        | 522         | 356        | 356          | 566          | 396          |
| SD          | 16.9   | 13.8       | 37.2        | 33.3       | 41.6     | 35.3       | 39.4        | 28.1       | 28.9         | 22.9         |              |
| 3x          | 577    | 374        | 633         | 445        | 641      | 451        | 570         | 369        | 360          | 410          |              |
| SD          | 22.4   | 26.1       | 31.3        | 25.5       | 31.6     | 26.9       | 21.6        | 24.0       | 19.6         | 18.5         |              |
| 4x          | 430    | 366        | 522         | 424        | 496      | 428        | 459         | 363        | 478          | 396          |              |
| SD          | 13.9   | 23.1       | 14.6        | 17.0       | 16.1     | 21.2       | 15.3        | 18.5       | 11.2         | 14.4         |              |
| 5x          | 345    | 348        | 698         | 453        | 539      | 428        | 520         | 377        | 530          | 403          |              |
| SD          | 8.1    | 15.4       | 28.6        | 19.8       | 36.1     | 21.3       | 32.7        | 16.8       | 24.3         | 13.8         |              |
| 6x          | 384    | 354        | 758         | 517        | 596      | 463        | 562         | 415        | 579          | 440          |              |
| SD          | 9.5    | 23.4       | 36.9        | 21.7       | 40.6     | 27.1       | 39.0        | 23.6       | 28.1         | 18.1         |              |

![Figure 3: The amplitude of m. temporalis according to gender with complete dentures (dominant side/nondominant side).](image)

![Figure 4: The amplitude of m. temporalis according to experience with complete dentures (dominant side/nondominant side).](image)

The experience of patient’s wearing complete dentures is the most important factor in which intensive reactions are observed during the observational period. The amplitude values of m. masseter in DS and the NDS do not vary depending on the variables of the previous experience complete dentures. On the contrary, patients with no experience with complete denture have higher amplitude of m. temporalis compared to experienced patients. This report confirms Moller’s opinion that m. temporalis is the main postural mandibular muscle [26]. Electrical activity during tooth clenching exhibited a statistically significant reduction only in the right m. temporal after five months of wearing the new complete dentures [18]. It is interesting that previous experience has not been shown as a factor which affects change in the value of the surface area of the planimetric indicators on both the dominant side and the nondominant side. These observations confirm that wavelet-based EMG analysis is instrumental in evaluating denture adaptation for patients with complete dentures replacement, and denture adaptation increases with time [27].

The fact is that some studies observed differences in the proportion of fiber types between denture wearers, and dentate subjects cannot be ascribed to degenerative changes intrinsic to the ageing muscle. Instead, this is caused by functional differences in muscle activity and morphological alterations of stomatognathic system accompanying the complete teeth loss [28]. Tooth loss and use of complete dentures affect the motor and sensorial aspects involved in
the masticatory process. Information received centrally is not sufficiently accurate to allow adaptation of mastication patterns to the food texture in denture wearers [29]. Treatment by implant-supported oral rehabilitation in the elderly individual revealed a decrease in electromyographic amplitude for the masseter muscles during swallowing of pasty and liquid foods [30]. Edentulous patients with implant-supported fixed dental prostheses are a very invasive, expensive, long treatment option but at the same time a valuable treatment option for restoring edentulous patients [31]. These data will allow clinicians to objectively make clinical decisions and predict future treatment outcomes.

7. Conclusions

Components of planimetric indicators of bioelectric activity of masseter and temporalis muscles at maximum physiological load are an important discriminator of the level of functional adjustment to newly fitted complete dentures. The dynamics of this indicator is featured by marked oscillation in relation to initial values with a tendency to reestablish stability after week 20 from the baseline.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors’ Contributions

All authors contributed equally to this work.

References

[1] I. Z. Alajbeg, M. Valentic-Peruzovic, I. Alajbeg, D. Illes, and A. Celebic, "The influence of dental status on masticatory muscle activity in elderly patients," International Journal of Prosthodontics, vol. 18, no. 4, pp. 333–338, 2005.
[2] C. M. Moses and C. P. Clamerras, "An EMG investigation of patients with normal jaw relationships and Class III jaw relationship," American Journal of Orthodontics, vol. 66, no. 5, pp. 538–556, 1996.
[3] R. E. Moyers, "Temporomandibular muscle contraction patterns in Angle Class II, Division 1 malocclusions: an electromyographic analysis," American Journal of Orthodontics, vol. 35, no. 11, pp. 837–857, 1999.
[4] J. Ahlgren, B. Ingervall, and B. Thilander, "Muscle activity in normal and postnormal occlusion," *American Journal of Orthodontics*, vol. 64, no. 5, pp. 445–456, 1993.

[5] E. Møller, "The chewing apparatus: electromyographic study of the muscle of the mastication and its correlation to fascial morphology," *Acta Physiologica Scandinavica*, vol. 69, p. 280, 2003.

[6] O. Grosfeld, "Changes of muscle activity patterns as results of orthodontic treatments," *European Orthodontic Society Transactions*, vol. 41, pp. 203–213, 1998.

[7] J. Ahlgren, "Early and late electromyographic response to treatment with activators," *American Journal of Orthodontics*, vol. 74, no. 1, pp. 88–92, 1994.

[8] M. Farella, S. Palla, S. Erni, A. Michelotti, and L. M. Gallo, "Masticatory muscle activity during deliberately performed oral tasks," *Physiological Measurement*, vol. 29, no. 12, pp. 1397–1410, 2008.

[9] E. K. Kemsley, J. C. Sprunt, M. Defernez, and A. C. Smith, "Electromyographic responses to prescribed mastication," *Journal of Electromyography and Kinesiology*, vol. 13, no. 2, pp. 197–207, 2003.

[10] C. Hagberg, "The amplitude distribution of electromyographic activity of masticatory muscles during unilateral chewing," *Journal of Oral Rehabilitation*, vol. 13, no. 6, pp. 567–574, 1986.

[11] T. Harldson, U. Karlsson, and G. Carlsuus, "Chewing efficiency in patients with osteointernal bridges," *Swedish Dental Journal*, vol. 3, pp. 183–189, 2001.

[12] P. Glantz and G. Stafford, "Bite force and functional loading levels in maxillary complete dentures," *Dental Materials*, vol. 1, no. 2, pp. 66–70, 1995.

[13] H. Pancherz, "Temporal and masseter muscle activity in children and adults with normal occlusion. An electromyographic investigation," *Acta Odontologica Scandinavica*, vol. 38, no. 6, pp. 343–348, 1990.

[14] S. W. Herring, "Mastication and maturity. A longitudinal study in pigs," *Journal of Dental Research*, vol. 56, no. 11, pp. 1377–1382, 2001.

[15] J. B. O. Amorim, S. B. Rabelo, A. C. Souza et al., "Masticatory muscle activity evaluation by electromyography in removable partial denture users," *Brazilian Dental Science*, vol. 16, no. 4, p. 41, 2013.

[16] M. C. Goiato, A. R. Garcia, and D. M. Santos, "Electromyographic evaluation of masseter and anterior temporalis muscles in resting position and during maximum tooth clenching of edentulous patients before and after new complete dentures," *Acta Odontológica Latinoamericana*, vol. 20, no. 2, pp. 67–72, 2007.

[17] A. G. Hannam, R. E. De Cou, J. D. Scott, and W. W. Wood, "The relationship between dental occlusion, muscle activity and associated jaw movement in man," *Archives of Oral Biology*, vol. 22, no. 1, pp. 25–34, 1998.

[18] Y. Kamazoe, H. Kotani, T. Maetani, H. Yatani, and T. Hamada, "Integrated electromyographic activity and biting force during rapid isometric contraction of fadigued masseter muscle in man," *Archives of Oral Biology*, vol. 26, no. 10, pp. 801–809, 1981.

[19] R. Caloss, M. Al-Arab, R. A. Finn, O. Lonergan, and G. S. Throckmorton, "Does long-term use of unstable dentures weaken jaw muscles?" *Journal of Oral Rehabilitation*, vol. 37, no. 4, pp. 256–261, 2010.

[20] Z. J. Liu, K. Yamagata, Y. Kasahara, and G. Ito, "Electromyographic examination of jaw muscles in relation to symptoms and occlusion of patients with temporomandibular joint disorders," *Journal of Oral Rehabilitation*, vol. 26, no. 1, pp. 33–47, 1999.

[21] H. C. Karakazis and A. E. Kossion, "Surface EMG activity of the masseter muscle in denture wearers during chewing of hard and soft food," *Journal of Oral Rehabilitation*, vol. 25, no. 1, pp. 8–14, 1998.

[22] T. Shinogaya, M. Bakke, C. E. Thomsen, A. Vilmann, A. Sodeyama, and M. Matsumoto, "Effects of ethnicity, gender and age on clenching force and load distribution," *Clinical Oral Investigations*, vol. 5, no. 1, pp. 63–68, 2001.

[23] M. Bonakdarchian, N. Askari, and M. Askari, "Effect of face form on maximal molar bite force with natural dentition," *Archives of Oral Biology*, vol. 54, no. 3, pp. 201–204, 2009.

[24] L. W. Olthoff, W. Van Der Glas, and A. Van Der Blit, "Influence of occlusal vertical dimension on the masticatory performance during chewing with maxillary splints," *Journal of Oral Rehabilitation*, vol. 34, no. 8, pp. 560–565, 2007.

[25] R. A. Pizolato, M. B. D. Gavião, G. Berretin-Felix, A. C. M. Sampaio, and A. S. T. Junior, "Maximal bite force in young adults temporomandibular disorders and bruxism," *Brazilian Oral Research*, vol. 21, no. 3, pp. 278–283, 2007.

[26] M. Bakke, L. Michler, and E. Möller, "Occlusal control of mandibular elevator muscles," *European Journal of Oral Sciences*, vol. 100, no. 5, pp. 284–291, 1992.

[27] M. Tokmakci, M. Zortuk, M. H. Asyali, Y. Sisman, H. I. Kilinc, and E. T. Ertas, "Effect of chewing on dental patients with total denture: an experimental study." *SpringerPlus*, vol. 2, no. 1, p. 40, 2013.

[28] E. Cvetko, P. Karen, and I. Erzen, "Wearing of complete dentures reduces slow fibre and enhances hybrid fibre fraction in masseter muscle," *Journal of Oral Rehabilitation*, vol. 39, no. 8, pp. 608–614, 2012.

[29] J. L. Veyrune and L. Mioche, "Complete denture wears: electromyography of mastication and texture perception whilst eating meat," *European Journal of Oral Sciences*, vol. 108, no. 2, pp. 83–92, 2000.

[30] G. Berretin-Felix, H. Nary Filho, C. R. Padovani, A. S. Trindade Junior, and W. M. Machado, "Electromyographic evaluation of mastication and swallowing in elderly individuals with mandibular fixed implant-supported prostheses," *Journal of Applied Oral Science*, vol. 16, no. 2, pp. 116–121, 2008.

[31] G. O. Gallucci, J. P. Bernard, and U. C. Belser, "Treatment of completely edentulous patients with fixed implant-supported restorations: three consecutive cases of simultaneous immediate loading in both maxilla and mandible," *International Journal of Periodontics & Restorative Dentistry*, vol. 25, pp. 27–37, 2005.