Assessment of the impact of temporomandibular disorders on maximum bite force

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Aim. Temporomandibular disorders (TMD) refer to functional disorders of the masticatory system, temporomandibular joint (TMJ) and masticatory muscles. The main objective of this study was to determine whether and to what extent temporomandibular disorders (TMD) affect the maximum bite force (MBF).
Methods. The present study included subjects with and without temporomandibular disorder. The presence of TMD was assessed by means of the Helkimo clinical dysfunction index analysis. We measured the maximum bite pressure (MBP) and occlusal contact area (OCA) by means of a Fuji Prescale Pressure measurement film. Based on the MBP and OCA values obtained, MBF values were determined.
Results. The MBF values were significantly lower in patients with TMD compared to subjects without TMD ($P<0.0005$). MBF values demonstrate a trend, with a tendency towards a decrease in values with the increase in the severity of TMD ($P <0.01$). OCA was significantly lower in patients with TMD ($P<0.05$). There was no significant difference between controls and patients with TMD in terms of the MBP ($P=0.135$).
Conclusion. TMDs have a significant impact on MBF and masticatory muscle action potential. More research is needed to determine the impact of reduced maximum bite force on the functional efficiency of the masticatory system.

Key words: temporomandibular disorders; maximum bite force, occlusal contact area, maximum bite pressure, pressure-sensitive film

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INTRODUCTION

Temporomandibular disorders (TMD) refer to functional disorders of the masticatory system, temporomandibular joint (TMJ) and masticatory muscles.

Epidemiological studies have established that 50-75% of the population during their lifetime experiences transient symptoms of TMD; however, only 3-4% of patients seek medical assistance[1].

Symptoms of the disorder include pain, restricted mandibular mobility and the noises from the TMJ during jaw movement. Pain is localised in masticatory muscles, temporomandibular joints and preauricular area, and may manifest in the form of otalgia or headache. Mandibular mobility disorders are reflected as single or multiple motion restrictions during jaw movement, which may be accompanied by irregularities in the progress and flow. The noise in the TMJ may be registered as a clicking, crepitus or a dull sound in the terminal stages of mouth opening.

Maximum bite force (MBF) is one of the indicators of the functional status of the masticatory system. It results from the jaw muscle activity regulated by craniomandibular mechanisms[2]. The values may be affected by physiological and morphological factors such as craniofacial morphology, gender, age, occlusal status and malocclusions[3-7].

Bite force measurements have found a wide application in dentistry, mainly for the examination of mastication mechanisms and assessment of the outcome of prosthetic restoration therapy[8]. Morphological and functional changes in individual orofacial system structures condition modification in the function of masticatory muscles in order to maintain the physiological balance of the masticatory apparatus. As masticatory muscles are the main bite force generators, their function and activity are directly proportional to the amount of bite force produced and vice versa[9].

The correlation between disorders in the function of the masticatory apparatus and the MBF has not been fully clarified. Many authors have obtained significantly lower values of bite force in patients with TMD compared to healthy subjects. Kogawa et al. indicate that the pain in patients suffering from TMD is the most common cause of decreased bite force[10]. Lower MBF values in patients with TMD are associated with reduced endurance of masticatory muscles during submaximal stress[11].

Pereira Cenci et al. argue that there are no differences between MBF in patients with TMD and healthy subjects[12]. Therefore, it is unclear how TMD affects MBF.

The main objective of this study was to determine whether and to what extent temporomandibular disorders affect the maximum bite force.

MATERIALS AND METHODS

The study was approved by the Ethics Committee of the Faculty of Medicine Pristina in Kosovska Mitrovica, and it was conducted by the researchers who had been previously trained and calibrated for registration signs and symptoms of TMD. Examiner reliability for the accurate diagnosis of TMD was tested on 10% of respondents of the total sample. A high inter-rater diagnostic accuracy of TMD ($\kappa = 0.97$) was achieved.

The research was conducted at the Clinic for Dental Prosthetics at the Faculty of Medicine Pristina in Kosovska Mitrovica. Three hundred and fifty subjects aged 18 to 25 years underwent clinical functional analysis by Helkimo[13], to register the presence or absence of TMD. The analysis consisted of an anamnestic questionnaire, clinical dysfunction index analysis of orofacial system and occlusal analysis.

The results of the clinical dysfunction index analysis were evaluated from 0 to 5 on a scale according to severity. A summary of the results obtained during the clinical dysfunction analysis was ranked on the clinical dysfunction index (Di) scale. Index values ranging from 0 to 25 indicate the severity of TMD.

Group Formation

Subjects were selected and divided into two observation groups: the TMD group consisting of patients suffering from TMD and control group involving healthy subjects. Eligibility criteria for the TMD group formation included the following: 1. TMD signs and symptoms presence (Di>0), 2. Intact dental arch (excluding third molars), 3. Presence of dental fillings not exceeding four, 4. First class occlusion according to Angle, 5. Subjects with a clear prosthetic or orthodontic treatment record. The control group was adjusted to the experimental one, except for the criterion referring to the presence of TMD signs and symptoms (Di=0). Criteria governing the exclusion of subjects from the study implied irritating pain in the surrounding structures (ear, nose, sinuses), inflammatory processes in the orofacial area, neurogenic and muscular diseases and subjects with chronic diseases or general health impairment.

The TMD group consisted of 41 respondents (27 female and 14 male), while the control group included 36 respondents (23 female and 13 male) in total.

Maximum Bite Force (MBF) Registration

All respondents were subjected to the registration of maximum bite pressure, occlusal contact area and maximum bite force calculation.

Maximum bite pressure (MBP) was registered by means of MS Type mono-sheet pressure sensitive films (Prescale Fuji film, Tokyo). MS-Type Films can register the pressure ranging from 10 to 50 MPa. The principle of operation of the Fuji Prescale Films is based on the development of red colour on the film surface at the point of pressure. Through PSC technology (Particle Size Control), microcapsule layers within the films are designed to react to different values of pressure, releasing the colour in the intensity directly proportional to the applied pressure.

The subjects were instructed to assume an erect head and upper body position. Following a thorough drying, to ensure relatively dry environment on the occlusal surfaces of the teeth, the horseshoe-shaped registration film was placed between dental arches. The subjects were instructed to bite using their greatest efforts in the maximum intercuspation position and to keep the bite force applied for the following 10s. MBP registration was conducted using MS and HS-Type Films in all subjects, with a 2-min break between the two registration protocols, to allow the subject the time to relax the masticatory muscles.

Upon completion, the image records were scanned using a Canon scanner in A4 format at 300 dpi resolution (Fig. 1). Visual comparison of the colour of occlusal contact area against the scale of different intensity colours enabled the determination of the density (intensity) of the colour for each occlusal contact registered (Fig. 2).

Based on the colour density, the corresponding readouts of the bite pressure values in the registered occlusal contact were obtained accordingly (Fig. 3).

The occlusal contact surface area (OCA) was measured in Photoshop (Adobe Photoshop CC) using the pre-scanned film images.

Multiplying the value of the maximum bite pressure by occlusal contact area, the value of bite force was obtained for each occlusal contact observed:

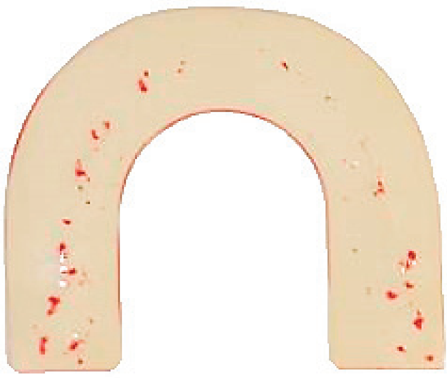

Fig. 1. Occlusal contacts registered on a prescale film.

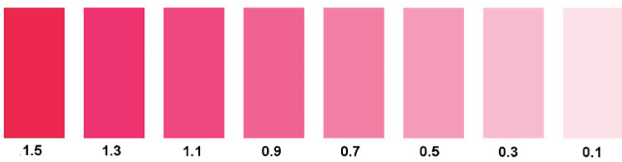

Fig. 2. Scale for reading colour of the occlusal contact intensity registered.

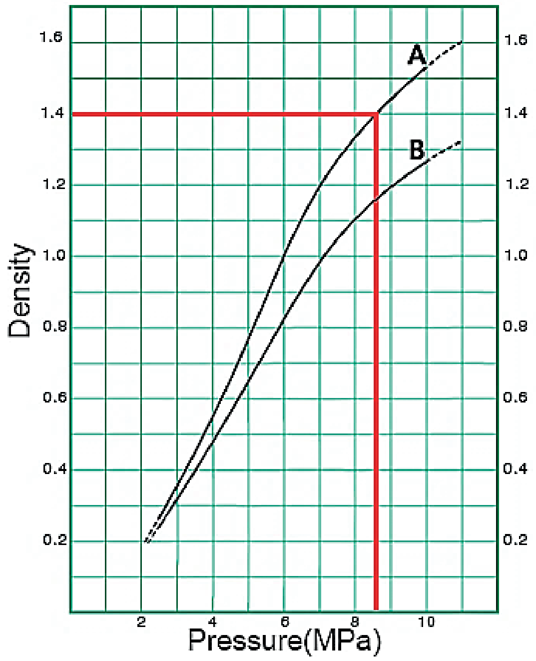

Fig. 3. Graph used for the determination of values of bite pressure.

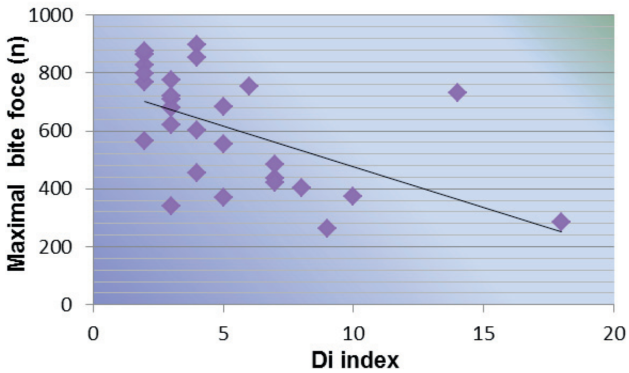

Fig. 4. Correlation between maximum bite force and dysfunction index (Di).

$$F\ (N) = P\ (MPa) \times A\ (mm^2)$$

The sum of all occlusal contact bite forces registered in one patient determined the maximum bite force (MBF) per patient, for each one separately:

$$\Sigma\ Fn = F_1 + F_2 + F_{3+ \ldots}\ F_n$$

Descriptive statistics included means standard deviation and frequency. To respond to the tasks assigned, relating to determination of the influence of TMD on the value of the MBF, the Student t-test was used, along with the Pearson's correlation analysis and linear regression analysis. The statistical hypotheses were tested at the significance levels of 0.01, 0.05 and 0.0005.

RESULTS

Average values of MBP, OCA and MBF were compared between the TMD group and the control group subjects respecting the gender distinction thereof accordingly.

A comparative analysis (t-test) demonstrated no statistically significant difference in the values of MBP between same gender TMD and control group subjects (*P*=0.135; *P*=0.309) (Table 1).

The comparative analysis of the average values of OCA between female and male subjects of the observed groups showed statistically significant differences (Table 2).

By testing the statistical significance of the difference (t-test), it was established that the average values of OCA were significantly higher in the control group compared to the TMD group (*P*<0.05).

A comparative analysis was used to test the average values of MBF in subjects of the observed groups with respect to the gender distinction (Table 3).

The analysis established that the average values of MBF were significantly higher in the control group com-

Table 1. Comparative analysis of MBP between female and male subjects of the observed group.

	Maximum bite pressure (MBP)		
Gender	Control group	TMD group	*P*
Female subjects	38.0±3.3	36.7±2.7	0.135
Male subjects	40.8±7.7	38.5±2.7	0.309

Table 2. Comparative analysis of OCA between female and male subjects of the observed group.

	Occlusal contact area (OCA) (mm²)		
Gender	Control group	TMD group	*P*
Female subjects	16.6±5.2	11.2±4.5	<0.05
Male subjects	22.7± 4.1	17.6±4.7	<0.05

Table 3. Comparative analysis of MBF between female and male subjects of the observed group.

	Maximum bite force (n)		
Gender	Control group	TMD group	*P*
Female subjects	743.6±138.0	506.3±174.7	<0.0005
Male subjects	939.8±109.7	745.5±129.8	<0.0005

pared to the TMD group ($P<0.0005$). MBF was significantly decreased in patients suffering from TMD.

The correlation analysis revealed the interdependence between MBF value and dysfunction index (Di) (Pearson correlation r = –0.509; $P<0.01$) (Fig. 4).

The correlation was negative, implying that MBF values demonstrate a downward trend with increasing severity of TMD.

Linear regression analysis of available data revealed a regularity in the influence of gender and TMD on MBF. The ratios determined are shown in the linear regression equation given below:

$$\text{Maximum bite force (N)} = 618 + 242 \times \text{gender} - 244 \times \text{group}$$

Gender (0-female, 1-male)
Group (0-control, 1-TMD group)

The regression equation represents the simplest method used to calculate the estimated value of MBF provided that available data used for these purposes include gender and TMD presence/absence.

DISCUSSION

Maximum bite force is one of the indicators of the functional status of the masticatory system. This study determined whether the functional capacity of muscles, and thus MBF, in patients with TMD, was significantly changed compared to that observed in healthy subjects.

Gender is an important determinant of the MBF. It is found to be much higher in men than in women. Therefore, the analysis of MBP, OCA and MBF was carried out with respect to gender. The difference in muscular potential may be attributed to the structural difference between the masticatory muscles in men and women[14]. These structural differences in maseteric muscles can be explained by the hormonal status differences in male and female subjects[15]. Ferrario V. et al. also found higher bite force in men than in women. The authors explain this difference by size of the teeth, periodontal attachment surface and occlusal contact area, which is undoubtedly higher in males[16].

Our study included the analysis of maximum bite pressure (MBP) and occlusal contact area (OCA) as the major determining factors of the MBF. This study showed no significant differences in mean MBP between patients with and without TMD. The results are consistent with the results of the study conducted by Sato et al. indicating that bite pressure was not significantly altered in patients with TMD, even though the bite force was significantly reduced[17]. Hidaka et al. argue that the increase in the intensity of tightening the teeth increases the value bite force and occlusal contact area proportionally, and that the value of bite pressure remains unaltered[18]. Similarly, Kitafusa et al. observed significant differences in bite force values in the subjects with different craniofacial morphology, but not in bite pressure values determined[19]. These findings indicate that bite pressure is a weaker determinant of bite force in relation to the occlusal contact area, which partly explains the findings of this study.

The results of our study indicate that OCA is significantly lower in patients with TMD compared to healthy subjects. Similar results have been reported by other authors[16]. Some researchers have found that the values of maximum bite force depend on the position, the number of teeth and occlusal contact[18,20]. The correlation between occlusal contact and MBF can be explained by a favourable occlusal support enabling a more powerful and greater activity of elevator muscles, which develop a higher bite force. This explanation, from another point of view, may also suggest that stronger elevator muscles enable a more favourable occlusal support and a greater number of occlusal contacts[2]. Some studies indicate a positive correlation between the number of occlusal contacts and electromyographic activity amplitude in maseteric muscles during maximum voluntary contraction and occlusal mastication stage[21]. Changes in the values of MBF may significantly influence the number and the surface area of occlusal contacts, as confirmed by our study.

Data analysis showed that MBF is significantly lower in patients with TMD compared to healthy subjects. The results of our study concur with the results of other studies, and the most common cause of decreased muscle function reported accordingly is the pain of myogenic and/or arthrogenic origin[22,23]. However, Kim et al found that the MBF significantly decreased in the patients with non-painful TMD. This study showed that OCA was decreased in TMD subjects and that MBP did not show significant changes[24], which is consistent with the results of our study. Inflammation in TMJ structures is also one of the factors that contribute to impairment of muscle efficiency[25]. Ikebe et al. determined that the subjects with a noise in TMJ and restricted occlusal support demonstrate lower valued MBF (ref.[26]). Also, Ow et al. found that patients with TMD demonstrate significant variations in the values of MBF at multiple repeated registrations, which indicates the loss of sensory acuity in regulating the masticatory muscle function[27]. Bavia et al. reported that in patients with different craniofacial morphology and painful TMD, the maximum bite force was reduced, but this did not affect the mastication performance of the respondents[28]. However, the results of some studies show that there is no change observed in MBF in patients suffering from TMD (ref.[12,28]). These findings are probably the result of different measurement techniques applied. Measuring instruments causing jaw separation lead to masticatory muscle stretching, thus changing the position of the condyle in the fossa articularis and consequently triggering the variations in muscular activity[29]. During our research, the above referenced Prescale films were used, enabling MBF registration in natural conditions with minimum alterations in the vertical dimension of occlusion. Our study, in addition to decreased MBF arguments presented, has established a downward trend reflecting a decline in the values with increasing severity of TMD. Similar results were obtained by Bonjardim et al. who found a negative correlation between the MBF and craniomandibular indices in patients with TMD (ref.[30]).

However, from the interpretation of the results of our study, it has to be considered that the focus was to register voluntary MBF in the subjects observed. Studies suggest that the controlled submaximal level of bite force correlates with the electrical muscle activity[31]. Our study did not cover the electrical activity of the muscle, which is one of the limitations of this study. In addition, the study included subjects with intact dental arches but with dental restorations (maximum four fillings). The results of the present study indicate that bite force is significantly reduced in subjects with dental fillings in incisal and molar sectors[32,33]. The presence of dental fillings may have affected the value of the bite force, which can also be considered as the relative limitation of the study.

CONCLUSION

TMD significantly affects the potential of masticatory muscle action. This was confirmed by the analysis of MBF with significantly lower values in patients with TMD. Moreover, MBF values decrease with the increase in the severity of TMD. In addition, the average value of OCA established was lower in patients with TMD, though no significant variations have been reported for MBP. Nevertheless, future research is necessary to analyse the impact of reduced maximum bite force on the functional efficiency of the masticatory system.

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REFERENCES

1. Okeson JP. Menagement of temporomandibular disorders and Occlusion. 7nd ed. Missouri: The C.V. Mosby CoSt. Louis, 2013
2. Bakke M. Bite force and occlusion. Semin Orthod 2006;12(2):120-6.
3. Sonnesen L, Bakke M, Solow M. Temporomandibular disorders in relation to craniofacial dimension, head posture and bite force in children selected orthodontic treatment. Eur J Orthod 2001;23(2):179-92.
4. Calderon PS, Kogawa EM, Lauris JR, Conti PC. The influence of gender and bruxism on the human maximum bite force. J Appl Oral Sci 2006;14(6):448-53.
5. Koc D, Dogan A, Bek B. Bite force and influential factors on bite force measurements: A literature revew. Eur J Dent 2010;4(2):223-32.
6. Varga S, Spalj S, Varga M, Anic S, Milosevic S, Mestrovic S, Slaj M. Maximum voluntary molar bite force in subjects with normal occlusion. Eur J Orthod 2011;33(4):427-33.
7. Castelo PM, Gavião MB, Pereira LJ, Bonjardim LR. Masticatory muscle thickness, bite force, and occlusal contacts in young children with unilateral posterior crossbite. Eur J Orthod 2007;29(2):149-56.
8. Fernandes CP, Glantz PJ, Svensson SA, Bergmark A. A novel sensor for bite force determinations. Dent Mater 2003;19(2):118-26.
9. Braun S, Bantleon HP, Hnat WP, Freudenthaler JW, Marcotte MR, Johnson BE. A study of bite force, part 1: Relationship to various physical characteristics. Angle Orthod 1995;65(5):367-72.
10. Kogawa EM, Calderon PS, Laurus JR, Araujo CR, Conti PC. Evaluation of maximal bite force in temporomandibular disorders patients. J Oral Rehabil 2006;33(8):559-65.
11. Tortopidis D, Lzons MF, Baxendale RH. Bite force, endurance and masseter muscle fatigue in healthy edentulous subjects and those with TMD. J Oral Rehabil 1999;26(4):321-8.
12. Pereira-Cenci T, Pereira LJ, Cenci MS, Bonachela WC, Del Bel Cury AA. Maximal bite force and its association with temporomandibular disorders. Braz Dent J 2007;18(1):65-8.
13. Helkimo M. Studies of function and dysfunction of the masticatory system. Index for anamnestic and clinical dysfunction and occlusal state. Sweden Dent J 1974;67(2):101-21.
14. Shinogaya T, Bakke M, Thomsen CE, Vilmann A, Sodeyama A, Matsumoto M. Effects of ethnicity, gender and age on clenching force and load distribution. Clin Oral Invest 2001;5:63-8.
15. Pizolato RA, Gavião MB, Berretin-Felix G, Sampaio ACM, Trindade Junior AST. Maximal bite force in young adults temporomandibular disorders and bruxism. Braz Oral Res 2007;21(3):278-83.
16. Ferrario VF, Sforza C, Serrao G, Dellavia C, Tartagilia GM. Single tooth bite forces in healthy young adults. J Oral Rehabil 2004;31(1):18-22.
17. Sato S, Ohta M, Sawatari M, Kawamura H, Motegi K. Occlusal contact area, occlusal pressure, bite force, and masticatory efficiency in patients with anterior disc displacement of the temporomandibular joint. J Oral Rehabil 2001;26(11):906-11.
18. Hidaka O, Iwasaki M, Saito M, Morimoto T. Influence of clenching intensity on bite force balance, occlusal contact area, and average bite pressure. J Dent Res 1999;78(7):1336-44.
19. Kitafusa Y. Application of „Prescale" as an aid to clinical diagnosis in Orthodontics. Bull Tokyo Dent 2002;45(2):99-108.
20. Lasilla V, Holmlund I, Koivumaa KK. Bite force and its correlations in different denture types. Acta Odontol Scand 1985;43:127-32.
21. Bakke M, Michler L, Möller E Bakke M, Michler L, Moller E. Occlusal control of mandibular elevator muscles. Scand J Dent Res 1992;100(5):284-91.
22. Pereira LJ, Gaviao MBD, Bonjardim LR, Castelo PM, van Der Bilt A. Muscle thickness, bite force, and cranio-facial dimensions in adolescents with signs and symptoms of temporomandibular dysfunction. Eur J Orthod 2007;29(1):72-8.
23. Ahlberg JP, Kovero OA, Humerinta KA, Zepa I, Nissinen MJ, Könönen MH. Maximal bite force and its association with signs and symptoms of TMD, occlusion, and body mass index in a cohort of young adults. Cranio 2003;21(4):248-52.
24. Ki-Seo K, Jong-Hoon C, Seong-Taek K, Chong-Youl K, Hyung-Joon A. Bite force, occlusal contact area and occlusal pressure of patients with temporomandibular joint internal derangement. Korean Journal of Oral Medicine 2006;31:265-74.
25. Wenneberg B, Kjellberg H, Kiliaridis S. Bite force and temporomandibular disorder in juvenile chronic arthritis. J Oral Rehabil 1995;22(8):633-41.
26. Ikebe K, Hazeyama T, Iwase K, Sajima H, Gonda T, Maeda Y, Nokubi T. Association of symptomless TMJ sounds with occlusal force and masticatory performance in older adults. J Oral Rehabil 2008;35(5):317-23.
27. Ow RK, Carlsson GE, Jemt T. Biting forces in patients with craniomandibular disorders. Cranio 1989;7(2):119-25.
28. Bavia PF, Vilanova LS, Garcia RC. Craniofacial Morphology Affects Bite Force in Patients with Painful Temporomandibular Disorders. Braz Dent J 2016;27:619-24.
29. Shinsuke S, Hiroo K, Hitoshi A, Taizo H. Quantitative analysis of occlusal force balance in intercuspal position using Dental Prescal system in pacient with temporomandibular disorders. Int Chin J Dent 2007;7(2):43-7.
30. Olthoff LW, van Der Glas WH, van Der Blit A. Influence of occlusal vertical dimension on the masticatory performance during chewing with maxillary splints. J Oral Rehabil 2007;34(3):560-5.
31. Bonjardim LR., Gavião MBD, Pereira LJ, Castelo PM. Bite force determination in adolescents with and without temporomandibular dysfunction. J Oral Rehabil 2005;32(8):577-83.
32. Ferrario VF, Sforza C, Zanotti G, Tartaglia GM. Maximal bite forces in healthy young adults as predicted by surface electromyography. J Dent 2004;32(6):451-7.
33. Kampe T, Haraldson T, Hannerz H, Carlsson GE. Occlusal perception and bite force in young subjects with and without dental fillings. Acta Odontol Scand 1987;45(2):101-7.
34. Babic Z, Panduric J, Jerolimov V, Mioc M, Pizeta I, Jakovac M. Bite force in subjects with complete dentition. Coll Antropol 2002;26(1):293-302.