Original article

MedInform

DOI: 10.18044/MEDINFORM.2023101.1631

ISSUE 1, 2023

Effect of gender and age on the maximal bite force and the electromyographic activity of the masticatory muscles

Vladimir Bogdanov

Department of Orthodontics, Faculty of Dental Medicine, Medical University – Sofia

Abstract

Introduction: Chewing directly depends on the function of the masticatory muscles. Maximal bite force and surface EMG are important determinants for the masticatory function.

Aim: The aim of the study was to evaluate the relationship between gender and age and the bite force and electromyographic activity of the masticatory muscles in young subjects.

Material and Methods: The study included 110 individuals of mean age 17.08 ± 6.02 years: 43 males and 67 females. Surface EMG (s EMG) was performed on anterior temporalis and masseter muscles on the right and left side to all the 110 subjects. The bite force was assessed on 68 of them using strain-gauge transducer. The statistical analysis was performed using IBM SPSS Statistics, version 23.0.

Results: There was no significant difference between the maximal bite force between men and women both on the left and the right side. The bite force correlated significantly with age both on left and right. The values of the EMG potentials of the masseter muscle did not differ between male and female subjects both on left and right. As for the temporalis muscle the values on the left side in women were significantly higher than in men ($P<0.05$). The values of the right temporalis muscle did not differ. A significant positive correlation was found between the age and EMG activity of the left temporalis muscle ($P<0.01$) and of the left masseter muscle ($P<0.05$). On the right was not found significant correlation between EMG and age.

Conclusion: Both EMG and maximal bite force showed correlation with age. The left temporal muscle in women showed higher EMG values than in men.

Keywords: maximal bite force, surface electromyography, age, gender masticatory muscles

Introduction

The main aim of dental treatment is to provide normal oral function, and at first place, normal masticatory function. Normal mastication allows appropriate dietary intake and is closely related to the quality of life. Masticatory performance depends on many factors like dental status, salivary flow, health status including disorders of the temporomandibular joint and craniofacial pain (1). There is evidence, that age and gender also influence the normal masticatory function (2). Objective criteria for the estimation of the masticatory function are the bite force and the electromyographic activity of the masticatory muscles, which are closely interrelated. For this purpose measuring of the bite force and especially the maximal bite force (MBF) by gnathodynamometry (GDM) and the electromyographic activity of the masticatory muscles, performed by EMG are reliable methods for the estimation of the performance of the masticatory muscles (3,4).

Surface electromyography (sEMG) is an effective and safe tool for evaluation of the masticatory muscles in both children and adults (3). It is used for monitoring jaw-closing and facial muscles, and for evaluation of physiological and pathological conditions of the stomathognathic system.

The electromyographic (EMG) analysis enables the evaluation of the performance of the masticatory muscle activity in different clinical conditions. Data show, that with an increase of age a clear decrease of the muscle activity is observed, indicating that the changes in the stomathognathic system is a function of age (4). The measurement of the EMG activity of individuals from 7 to 80 years revealed that the children group (7-12 years) had the highest EMG activity both at rest and during maximal clenching compared to the other age groups. With the increase of age a clear decrease of the EMG activity was observed and during maximal clenching the highest values were observed in the temporalis muscle in all groups (4).

Age is an important sociomedical factor to consider when assessing muscle function. A correlation has been established between the age of individuals and the muscle activity of the various masticatory muscles. In twenty-four hour EMG monitoring of masticatory muscle activity in children, longer activity was reported in m. temporalis, while in adults the activity of m.masseter (5). Since m. temporalis positions the lower jaw, and in children the temporomandibular joint is not completely formed (shallow articular fossa), the prevalence of the tone of m. temporalis helps to position the lower jaw.

The influence of gender on the EMG muscle activity of the masticatory muscles has not been conclusively confirmed. Gender, according to various authors, is a factor influencing masticatory force, and the general opinion is that it is greater in men than in women (6,7,8). In healthy individuals differences of the EMG activity between the two sexes at a resting position were not found, while during maximum contraction in central occlusion the mean potentials of m. masseter and m. temporalis in males were higher than those in females. (7). Rilo B. et al., (1997) in subjects without temporo-mandibular disorders, found similar results for both sexes. This is contrary to the results obtained by Pinho J. et al., (2000), who reported higher resting values in women than in men. During maximal voluntary clench (MVC) in women again higher values were reported compared to men, respectively 65.17 μV versus 51.24 μV. Abu Alhaija E. et al., (2010) do not confirm these data, as they did not find differences in the masticatory force between the sexes.

Investigation of the masticatory force in relation to age and gender found significantly higher bite force in males than in females and in younger compared to older subjects (13). The authors did not find significant differences between right and left side MBF, and the bite force was significantly higher in males than in females regardless of the age, even below 18 years. Brown S. et al., (1996) on the contrary, showed no

correlation between MBF and gender up to 18 years of age. When the mandibular jaw-base line (ML-NL) was taken into consideration no gender differences in the bite force was registered up to 18 years, independently of the angle (15). Palinkas M. et al., (2010) in a study of five groups (7-80 years) found that the youngest group (7-12 y) had significantly lower bite force means at both sides as compared to all groups except the group from 61 to 80 years. In all groups gender was found to be a significant factor, associated with MBF. However, because of the differences in the patients' health status, age, gender, place of testing, it is difficult to compare the masticatory forces obtained by different researchers (16).

Aim

Therefore, it is of interest to investigate the influence of gender and age on the bite force and the electromyographic activity of the masticatory muscles.

Material And Methods

The study included 110 individuals of mean age 17.08 ± 6.02 years: 43 (39.1%) of them were males and 67 (60.9%) females. Surface EMG (s EMG) was performed to all the 110 subjects. The bite force was assessed on 68 of them. The inclusion criteria were: no temporo-mandibular disorders; no pain during clenching the teeth; no missing teeth in the lateral areas and no evidence of an acute inflammatory process. The study did not include individuals who underwent or are undergoing orthodontic treatment or have evidence of bruxism.

Assessment of bite force

The bite force was measured in 68 subjects with a mean age of 18.4 ± 6.1 years - 33 males and 35 females. A strain-gauge transducer was used – a gnatodynamometric system GD500.1 with a test range of 0-700 Newtons (N). The subjects sat on the dental chair with the head upright in natural position and unsupported. The horizontal planes of the gnathodynamometer were positioned in the area of the first permanent molars. Maximal voluntary clench was performed on the fork of the strain-gauge transducer. The study was performed bilaterally, sequentially to the left and right side with intervals of one minute. The patients were asked to bite with maximal strength to record maximal bite force. The results were measured in Newtons (N).

Assessment of the EMG Activity of the Masticatory Muscles

The sEMG examination was performed using a two-channel electromyograph (Neuro-EMG-Micro-2) with "Neuro-MEP-Ω" software. Electric potentials of two pairs of masticatory muscles were measured: temporalis anterior (TA) and the superficial part of the masseter muscle (MM). Before placing the surface electrodes (Ag/AgCl), the skin was cleaned with 90% ethyl alcohol over the most prominent part of the muscle palpated in contraction, parallel to the fibers according to the Surface EMG for Non-Invasive Assessment of Muscles program guidelines (SENIAM). Before sEMG measurement, all the subjects were instructed about the procedure and signed an informed consent. Maximal and mean EMG activity values of every contraction of the right and the left masseter and the anterior temporalis were recorded during maximal voluntary clenching for a 3-second period in microvolts (μV).

Statistical Analysis

The statistical analysis was performed using IBM SPSS Statistics version 23.0. The nonparametric test of Kolmogorov - Smirnov was used to check the normality of distribution. The statistical evaluation of the values of maximal bite force and the EMG values between the groups was performed by Mann-Whitney U–

test or Student's t-test depending on the normality of distribution, at the 95 per cent confidence interval (P<0.05). Spearman's correlation analysis was used to estimate the correlation between variables.

Results

Maximal bite force in males and females

On table 1 are presented the results of the maximal bite force on the right and left for both sexes.

Table 1. Maximal bite force on the right and left side of male and female subjects

Variable	Male (n=33)		Female (n=35)		P
	$\overline{X}$	SD	$\overline{X}$	SD	
MBF right	379,30	126,68	353,85	135,93	0,467
MBF left	409,61	121,12	383,20	135,11	0,400

The data show that there is no significant difference in bite force between men and women, both on the left, and on the right side.

Maximal bite force and its correlation with age

Correlation analysis was applied to examine the relationship between the age of the subjects and the MBF on the left and right.

As no difference was found in the maximum bite force between the two genders, when examining the correlation between age and MBF, the subjects were not divided by sex. The results are shown on Table 2.

Table 2. Relationship between age and maximal bite force on the right and the left side.

Variable	MBF right	MBF left
Age	0,282*	0,255*

* - P<0,05

From Table 2 it can be seen that there is a weak, but significant positive correlation between MBF and age on both the left and right sides.

EMG activity of the temporalis and masseter muscles

The maximum and mean values of the EMG activity of the two masticatory muscles on the left and right were measured and compared in both genders. Table 3 shows the maximum and mean values of each muscle in men and women.

Table 3. Comparison of EMG potentials of left m. masseter and left m. temporalis between both sexes

	Males (n=43)		Females (n=67)		
	$\overline{X}$	SD	$\overline{X}$	SD	P
Left m.masseter					
Max	**1140,88**	**538,13**	**1087,10**	**526,00**	**0,752**
Mean	**339,30**	**108,18**	**323,93**	**107,28**	**0,466**
Left m.temporalis					
Max	**1114,33**	**442,28**	**1304,18**	**457,26**	**0,035***
Mean	**326,49**	**76,13**	**362,15**	**90,93**	**0,068**

* P<0.05

The data for the **left m. masseter** show that there is no significant difference of the maximum and mean EMG values between men and women.
The data for the **left m. temporalis** show that a statistically significant difference between the two sexes is found in the maximum value of the left m. temporalis, values being higher in female than in male subjects.
Table 4 shows the results of EMG recordings of the right m. masseter and m. temporalis.

Table 4. Comparison of EMG potentials of right m. masseter and m. temporalis in both sexes

	Males (n=43)		Females (n=67)		
	$\overline{X}$	SD	$\overline{X}$	SD	P
Right m.masseter					
Max	1072,23	516,26	1108,62	506,76	0,551
Mean	327,49	112,90	323,21	104,53	0,804
Right m.temporalis					
Max	1138,28	426,16	1306,33	545,38	0,177
Mean	335,86	86,66	367,43	108,36	0,306

There was no significant difference in the maximal and mean values of the muscle activity of the masseter and temporalis muscles on the right side between male and female individuals.
Data show, that no gender differences were observed in the EMG activity of the masticatory muscles of the examined subjects, except for the left m. temporalis that showed higher EMG potentials in women.

Correlation between EMG activity and age
Correlation analysis was used to examine the relationship between the EMG activity of the facial muscles and the age of the participants. The results are shown on table 5.

Table 5. Relationship between EMG activity and the age on the right and the left side

Muscle	Left m. masseter		Left m. temporalis		Right m. masseter		Right m. temporalis	
Value	Max	Mean	Max	Mean	Max	Mean	Max	Mean
Significance	0,191*	0,177	0,265**	0,271**	0,159	0,138	0,158	0,169

* - P<0,05, ** - P<0,01.

There is a significant, positive correlation between age and the EMG potentials of both muscles on the left being more pronounced for m. temporalis, while on the right no significant correlation is found.

Discussion

The influence of gender on the muscle activity of the masticatory muscles has not been conclusively confirmed.
For MVC in women higher values were reported compared to men, respectively 65.17 μV and 51.24 μV. Gender differences, according to various authors, are a factor influencing masticatory force, and the general opinion is that force is greater in men than in women. (6, 7, 8). Abu Alhaija E. et al., (2010) found no difference in masticatory force between the sexes.

Bite force is an important indicator of the function of the stomathognatic system, and its measurement is valuable to diagnose disorders of the musculoskeletal system of the facial skeleton (16). It is an important determinant of the dietary choices, which is closely related to the quality of life (1, 17). Data concerning the association between bite force with age and gender are controversial. Quindini P.R. et al., (2017) found that the bite force in men was higher compared to women both on the left and the right, regardless of the age, even in younger individuals, aged less than 18 years. In this study, however we did not find difference of the maximal bite force between male and female subjects both on the right and the left side in the age group 17±6 years. Brown S. et al., (1996) reported that the correlation between MBF and gender was not evident up to 18 years of age. Other data did not find correlation between the MBF and age (13, 18). Palinkas M. et al., (2010) found that in men the bite force was nearly 30% higher than in women. Moreover, age was found to be a determinant of muscle thickness of the masseter and temporalis muscles at rest and at maximal voluntary contraction with gradual increase to adulthood and a decrease in the age group of 61-80 years. In this study we examined the relationship between MBF and age and found a weak, but significant positive correlation between MBF and age both on the right and the left side. In this respect our results confirm the data of Brown S. et al., (1995) and do not confirm the data of Quindini P. et al., (2017). Our results confirm those of Szymanska J. et al., (2015), who report that gender has only a weak effect on the average bite force on the right, and conclude that there is a lack of clinical correlation between bite force and gender. Other studies also do not find correlation between values of the masticatory function and gender at different age groups (11, 19). In this study we found a significant positive correlation between maximal bite force and age both on the left and the right side, on the right being higher. These data are similar to the results of other studies that report that the increase in age by 1 year resulted in an increase of the maximum bite force on both sides, this increase being higher on the right side (14). Similar are the results of Usui T. et al., (2007), while Bakke M. et al., (2006) found that the bite force increases with age only up to 12 years of age, and then remains at a similar level up to adulthood (40-50 years). The mean age of the subjects in this study is 17± 6 years and yet we found significant positive correlation of the MBF with age. Our data show that in this age group there are no statistically significant differences in the MBF between genders, but there is significant positive correlation between age and the bite force.

Besides the bite force the evaluation of the activity of the masticatory muscles by a sEMG is another valuable and reliable method to investigate the masticatory function. While in a resting position are not reported gender differences of the EMG activity, during maximal contraction EMG activity of masseter and temporalis muscles were higher in men than in women (7, 9). In this study we measured maximal and mean values of the electromyographic activity of the temporalis and the masseter muscles of 110 subjects. Our data show that on the right side there is no difference in the maximal and mean values of the EMG potentials of the m. masseter and m temporalis between males and females. On the left side, however the maximum values of EMG of temporalis muscles in women were significantly higher than in men, while the potentials of m. masseter did not differ. We did not find difference in men and women of the mean values of EMG potentials both on right and left side of both muscles. Data concerning the comparison between the temporalis and masseter muscles are also conflicting. Some studies report that during maximal clenching the maximal EMG activity is registered in the masseter muscle (23), while others find higher values in the temporalis muscles (4). The authors also found age-related changes of the EMG muscle activity with children having higher EMG values for all clinical settings, and as age increases from youth to adults and from adults to elderly a decrease of the EMG activity is recorded. In our study a significant positive correlation is found between EMG and age on the left side (of both m. masseter and m. temporalis while on the right side no such relationship was detected. Manfredini D. et al., (2011) found that the right side muscles had higher voltages

during clenching, however our data did not prove asymmetry between left and right EMG potentials. Our data support the results of Wieczorek A. et al., (2015), that in females the EMG activity of m. temporalis is higher than in men, but do not support their finding that in men the activity of m. masseter is higher than in women, we found the difference insignificant.

Conclusions

In conclusion we found that the maximal bite force does not differ between male and female subjects, but the MBF is significantly positively correlated with age. As to the EMG activity of the temporalis and masseter muscles, the EMG potentials during maximal clenching of m. temporalis on the left side is significantly higher in women than in men. As to m. masseter no gender differences were detected both on the left and the right side during maximal clenching. Concerning the relationship between age and EMG activity, there was a clear significant positive correlation between EMG and age, of both temporalis and masseter muscles, but only on the left side.

References

1. Ikebe K, Nokubi T, Morii K, Kashiwagi J, Furuya M. Association of bite force with ageing and occlusal support in older adults. J Dent. 2005 Feb;33(2):131-7. doi: 10.1016/j.jdent.2004.09.002. Epub 2004 Nov 19. PMID: 15683894.
2. Quiudini PR Jr, Pozza DH, Pinto ADS, de Arruda MF, Guimarães AS. Differences in bite force between dolichofacial and brachyfacial individuals: Side of mastication, gender, weight and height. J Prosthodont Res. 2017 Jul;61(3):283-289. doi: 10.1016/j.jpor.2016.10.003. Epub 2016 Nov 17. PMID: 27866879.
3. Galo R, Vitti M, Santos CM, Hallak JE, Regalo SC. The effect of age on the function of the masticatory system--an electromyographical analysis. *Gerodontology*. 2006;23(3):177-182. doi:10.1111/j.1741-2358.2006.00113.x
4. Cecílio FA, Regalo SC, Palinkas M, et al. Ageing and surface EMG activity patterns of masticatory muscles. *J Oral Rehabil*. 2010;37(4):248-255. doi:10.1111/j.1365-2842.2010.02051.x
5. Ueda HM, Miyamoto K, Saifuddin M et al: Masticatory muscle activity in children and adults with different facial types. Am J Orthod Dentofacial Orthop, 2000; 118(1): 63–68
6. Calderon PS, Kogawa EM, Lauris JRP, Conti PCR. The influence of gender and bruxism on the human maximum bite force. J Appl Oral Sci. 2006;14:448-53.
7. Ferrario V., Sforza C., Zanotti G., Tartaglia G. Maximal bite force in healthy young adults as predicted by surface electromyography. Journal of Dentistry, 2004;32:451-457.
8. Regalo SCH, Santos CM, Vitti M, Regalo CA, Vasconcelos PB, Mestriner J, et al. Evaluation of molar and incisor bite force in indigenous compared with white population in Brazil. Arch Oral Biol. 2008;53:282-6.
9. Rilo B, Santana U, Mora MJ, Cadarso CM. Myoelectrical activity of clinical rest position and jaw muscle activity in young adults. J Oral Rehabil, 1997; 24(10): 735–40
10. Pinho JC, Caldas FM, Mora MJ, Santana-Penin U. Electromyographic activity in patients with temporomandibular disorders. J Oral Rehabil, 2000; 27(11): 985–90
11. Abu Alhaija ES, Al Zo'ubi IA, Al Rousan ME, Hammad MM Maximum occlusal bite forces in Jordanian individuals with different dentofacial vertical skeletal patterns. Eur J Orthod. 2010 Feb;32(1):71-7
12. Poli O., Manzon L., Niglio T., Ettore E., Vozza I. Masticatory force in relation with age in subjects with full permanent dentition: a cross –sectional study. Healthcale, 2021; 9:700.
13. Braun S, Hnat WP, Freudenthaler JW, Marcotte MR, Hönigle K, Johnson BE. A study of maximum bite force during growth and development. Angle Orthod. 1996;66(4):261-4. doi: 10.1043/0003-3219(1996)066<0261:ASOMBF>2.3.CO;2. PMID: 8863960.

14. Szymanska J., Sidorowicz L. Bite force and its correlation with long face in children and youth. Folia Morphol., 2015; 75:513-517.
15. Palinkas M., Nassar MS, Cecílio FA, Siéssere S, Semprini M, Machado-de-Sousa JP, Hallak JE, Regalo SC. Age and gender influence on maximal bite force and masticatory muscles thickness. Arch Oral Biol. 2010 Oct;55(10):797-802. doi: 10.1016/j.archoralbio.2010.06.016. Epub 2010 Jul 27. PMID: 20667521.
16. Koc D., Dogan A., Bek B. Bite force and influential factors on bite force measurements:a literature review. Eur J.Dent, 2010;4:223-232.
17. Hiiemae K, Heath MR, Heath G, Kazazoglu E, Murray J, Sapper D, Hamblett K. Natural bites, food consistency and feeding behaviour in man. Arch Oral Biol. 1996 Feb;41(2):175-89. doi: 10.1016/0003-9969(95)00112-3. PMID: 8712974.
18. 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. doi: 10.1043/0003-3219(1995)065<0367:ASOBFP>2.0.CO;2. PMID: 8526296.
19. Pereira LJ, Pastore MG, Bonjardim LR, Castelo PM, Gavião MB. Molar bite force and its correlation with signs of temporomandibular dysfunction in mixed and permanent dentition. J Oral Rehabil. 2007 Oct;34(10):759-66. doi: 10.1111/j.1365-2842.2006.01697.x. PMID: 17824888.
20. Usui T, Uematsu S, Kanegae H, Morimoto T, Kurihara S. Change in maximum occlusal force in association with maxillofacial growth. Orthod Craniofac Res. 2007 Nov;10(4):226-34. doi: 10.1111/j.1601-6343.2007.00405.x. PMID: 17973690.
21. Bakke M. Bite force and occlusion. Semin Orthod, 2006;12:120-126.
22. Ferrario V.F., Sforza C, Miani A et al. Electromyographic activity of human masticatory muscles in normal young people. Statistical evaluation of reference values for clinical applications. J Oral Rehabil, 1993; 20(3): 271–80
23. Gameiro GH, da Silva Andrade A, Nouer DF, Ferraz de Arruda Veiga MC. How may stressful experiences contribute to the development of temporomandibular disorders? Clin Oral Investig. 2006 Dec;10(4):261-8. doi: 10.1007/s00784-006-0064-1. Epub 2006 Aug 22. PMID: 16924558.
24. Manfredini D, Cocilovo F, Favero L, Ferronato G, Tonello S, Guarda-Nardini L. Surface electromyography of jaw muscles and kinesiographic recordings: diagnostic accuracy for myofascial pain. J Oral Rehabil. 2011 Nov;38(11):791-9. doi: 10.1111/j.1365-2842.2011.02218.x. Epub 2011 Apr 11. PMID: 21480942.
25. Wieczorek A., Loster J. Activity of the masticatory muscles and occlusal contacts in young adults with and without orthodontic treatment. BMC Oral Health , 2015; 15:116

Corresponding author:
Vladimir Bogdanov,
Sv Georgi Sofiyski blvd 1,
Department of Orthodontics, Faculty of Dental Medicine,
Medical University - Sofia
e-mail: vladbogdanov@yahoo.com

Bogdanov Vl, Effect of gender and age on the maximal bite force and the electromyographic activity of the masticatory muscles. Medinform 2023; 10(1):1631-1638.