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Bite Force in Subjects with Complete Dentition

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A B S T R A C T

Bite force is the condition, expression and measure of the masticatory function. The purpose of this study was to examine, by means of a newly constructed electronic gnathodynamometer, the values of maximal bite forces in subjects with complete dentition, the time in which they express 50% and 75% respectively of the total forces value, and the shape of the bite curve during testing. The obtained data was statistically analyzed with respect to gender and age. Analysis of the variance confirmed the finding that there was no statistically significant correlation between the values of forces and subjects' age, but there was a statistically significant difference between males and females in the values of the bite forces in the front segment, as well as between the values of the force on anterior and posterior teeth. The correlation between the time T_1 posterior right and T_1 posterior left, and between T_1 and T_2 for anterior teeth are statistically significant. Analysis of the bite curves suggests that males »bite« shorter than females with a sharper peak of the curve. Numerical values and bite curves should be a diagnostic factor in the further follow-up of subjects or in the choice of prosthodontic therapy.

Introduction

Assessment of the efficiency of masticatory function requires knowledge of the condition of all the parts of the stomatognathic system, as well as the magnitudes of bite forces that represent the condition, expression, and measure of the same function[1–3].

Mastication involves the orofacial muscles, and it is hypothesized that sensorial regulation resulting of mastication involves mechanoreceptors situated in the periodontium, temporomandibular joint, tongue, muscles and mucosa. The intensity of bite forces are determined mainly by muscle capacity[4–10], whereas masticatory forces depend on the number

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of motor units, muscle cross-sectional areas, the type of muscle cells, the angle at which the muscle acts to the bone, and on training. Bite forces correlate with anthropometric variables, such as height and weight[3,11–14]. However, the bite forces can be limited by other factors, such as by signals from C fibers from the dental pulp and/or periodontal ligament[15,16]. The forces are also controlled by proprioceptive signals from the periodontium, i. e. the limit of the physiological load is determined by the capacity of adaptation or physiological tolerance of the periodontium for bite force activity. Occlusal relations and the relation positions of teeth within the dental arch, as well as the loading of teeth, are important. Physiological tolerance is sooner exceeded by long-lasting static forces than by brief, dynamically rhythmical loads, such as during mastication and deglutition. Furthermore, teeth abrasions reduce the bite forces due to reduced vertical dimensions, while bruxism and parafunctions increase them due to uncontrolled practice[16–19]. On the other hand, abrasions of only anterior teeth increase bite forces, because contact surfaces of these teeth are larger and the associated muscles are stronger[18]. It is also important to mention the relation between the facial morphology and the values of bite forces in young adolescents[6,13,14,17,20,21]. The extent, direction and time of force action must correspond to the physiological area of tissue adaptation that can be disturbed by functional disorders, due to tooth loss or various diseases of soft or hard tooth tissues[22–24].

The purpose of this study was to measure the maximal bite forces in subjects with complete dentition, the masticatory muscles endurance time, as well as the storage of the recorded bite curves for further off line processing.

Subjects and Methods

The study included 47 subjects, 23 males and 24 females, age range 20–50 years. The bite forces were registered with a newly designed electronic gnathodynamometer (EGD) with a pressure-sensing element. The EGD was constructed thanking to the collaboration with the Faculty of Electrical Engineering and Computing (Zagreb, Croatia).

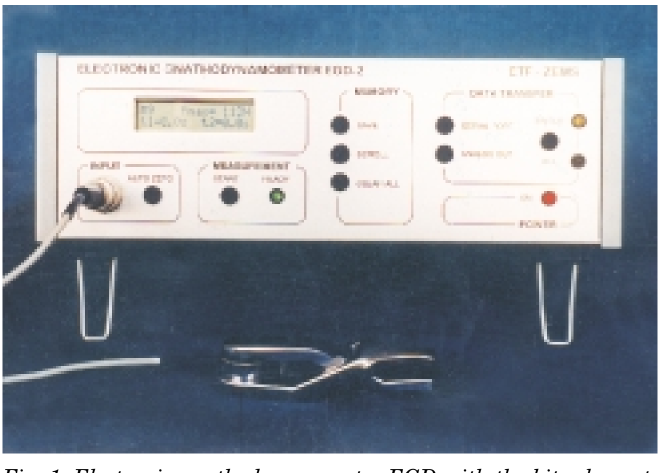

Fig. 1. Electronic gnathodynamometer EGD with the bite element.

The calibration was performed by laboratory tests with force values from 10–1,000 N and the achieved disregarded measurement error shows 1%. Measurements were carried out at an initial intraocclusal distance of 15 mm in three positions; between first molars on each side, and between both central incisors. The subjects sitting upright in a dental chair holed transducer by themselves. They were asked to bite as strongly as possible, up to the maximal bite force (MBF) and to release immediately after that, simulating biting into a hard bolus. The bite element was covered by vulcanized rubber and latex hygienic ring.

In one measuring cycle, the maximum force applied on the transducer was measured, as well as the total time T_1 and T_2 when 50% and 75% respectively of the maximum force value was expressed. The measurement parameters (F_{max}, T_1 and T_2) were shown on the display with liquid crystals (Figure 1). The numeric values and the bite curve were stored in the memory and transmitted to a personal computer via serial connection for permanent storage and/or further processing. The force signal can also be printed on an analogue printer connected to the force -measuring device as an external unit.

The results were statistically processed by descriptive statistics method, Pearson's coefficient, one-way analysis of variance, and Student's t-test for dependent variables.

Results

The subjects were persons aged from 20–50 (Mean = 24.89; SD = 5.658)). Table 1 shows the range between the measured values of bite forces. The mean maximum bite forces of sample were found to be 392.3 N with a standard deviation of 150.1. There was no correlation between age and bite forces values. Analysis of variance confirmed this finding (Table 2) and showed that no statistical significance was established in the sample between the values of bite forces for posterior teeth, i. e. on the first left and right molar, but there was between the anterior and posterior teeth (p<0.050). The maximum bite forces as related to gender are tabulated in Table 3. Females, 24 of them, exerted lower values of bite forces in relation to 23 male subjects. The differ-

TABLE 1
DESCRIPTIVE STATISTICAL ANALYSIS OF BITE FORCES (N)

	N	X	Median	Min.	Max.	Lower quartile	Upper quartile	Quartile range	SD
Right molar	47	387.79	377	102	836	263	512	249	167.64
Left molar	47	392.34	398	51	884	258	489	231	150.97
Incisors	47	255.79	270	28	605	155	318	163	116.78

TABLE 2
RESULTS OF ANALYSIS OF VARIANCE FOR GENDER (p<0.05)

	SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	p
Right molar	37981.61	1	37981.61	1254796.	45	27884.36	1.3621	0.2493
Left molar	4164.97	1	4164.97	1044276.	45	23206.12	0.1795	0.6738
Incisors	51788.04	1	51788.04	575504.	45	12788.97	4.0494	0.0502

ences were statistically significant for anterior teeth ($p<0.0500$), and between the posterior and anterior teeth. Statistical processing established that the distribution of forces did not mainly differ with respect to measuring places. Table 4 shows Pearson's correlation coefficient for all three measuring places. It can be seen that the differences between the mentioned correlation coefficients reach statistical significance. There are high, statistically significant correlations between the values of the bite forces posterior left and posterior right, while the correlation between the bite forces for anterior teeth and posterior right and left does not reach statistical significance. Such result points to a conclusion that the correlation between the values of forces for anterior and posterior teeth is lower. Student t-test confirms the mentioned facts, which means that there are statistically significant differences between the forces posterior and anterior, while the difference between the forces posterior left and right is not statistically significant (Table 5).

Endurance times T_1 and T_2 were statistically processed with respect to the range and mean values (Table 6). In order to estimate the significance of the mentioned variables, a correlation between the values of bite forces and times T_1 and T_2 was carried out (Table 7). Correlation is significant if they exceed 0.295. Analysis of variance confirmed statistically significant correlations between T_1 posterior right and T_1 posterior left, as well as between T_1 and T_2 for anterior teeth for both genders.

Values of bite endurance T_1 and T_2 are shorter in men on all measured places (Table 8). However, the endurance of the bite up to the maximum force is not correlated with subjects' age (Figures 2 and 3), but with the feeling of pain (22.6%), tooth numbness (4.6%), muscle pain (2.7%) or fear of break of tooth (23.4%) (Figure 4). Other subjects did not state any reasons for interruption the bite.

TABLE 3
RANGE OF BITE FORCES (N) ACCORDING TO GENDER

	Right molar	Left molar	Incisors
Female	359.96	383.13	223.29
Male	416.83	401.96	289.70
All	387.79	392.34	255.79

TABLE 4
PEARSON'S COEFFICIENT OF CORRELATION BETWEEN BITE FORCES AND MEASURING PLACES ($p < 0.05$)

	Right molar	Left molar	Incisors
Right molar	1.00	0.80	0.26
Left molar	0.80	1.00	0.24
Incisors	0.26	0.24	1.00

TABLE 5
STUDENT T-TEST FOR DEPENDENT VARIABLES ON THREE MEASURING PLACES

	X	SD	N	Diff.	SD Diff.	t	df	p
Right molar	387.79	167.64						
Left molar	392.34	150.97	47	–4.55	102.72	–0.30	46	0.7626
Right molar	387.79	167.64						
Incisors	255.79	116.78	47	132.00	177.36	5.10	46	0.0001
Left molar	392.34	150.97						
Incisors	255.79	116.78	47	136.55	167.06	5.60	46	0.0001

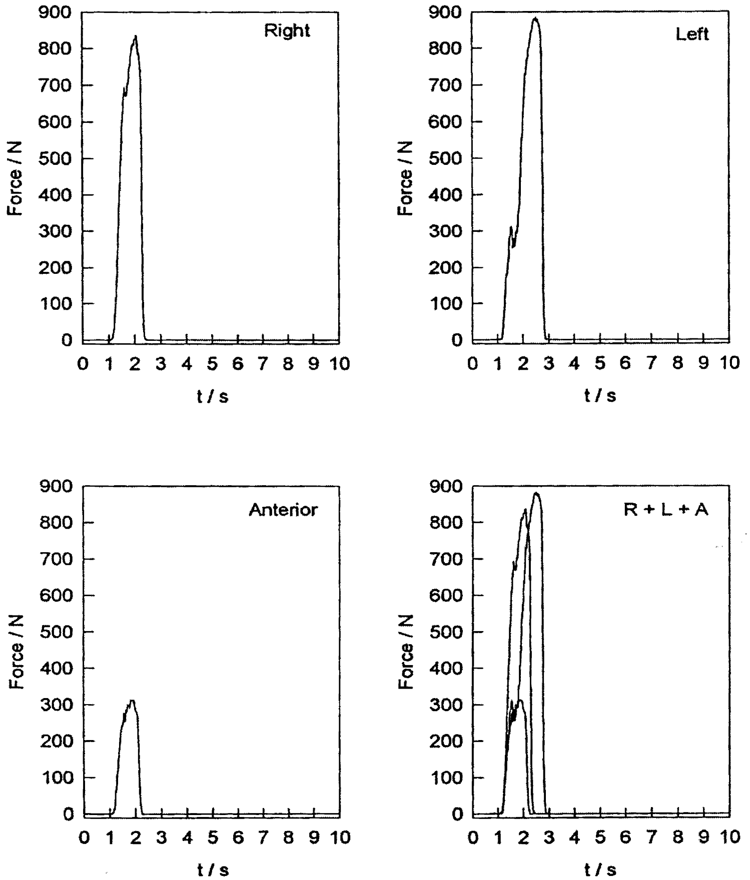

Fig. 2. Bite curve – male, 24 years old.

Discussion

Interest for measuring bite forces lasts almost two centuries, starting from Black and his construction of a mechanic gnathodynamometer. In 1923 Wustrow claimed that measurement of practically possible values of bite forces is a precondition for loading of oral tissues within the limits of physiological tolerance[25]. Hundred-odd measuring devices have been constructed up to now, applying various measuring principles, with the aim of examining various factors with a proven influence on the values of bite forces. These are gender and age, location of bite point (muscle tension changes with the bite point), degree of mouth opening, attitude of the investigator and subject, psychological and mental condition during effort, vertical dimension of the face, histochemical type of muscles, dentition, state of the surrounding hard and soft tissues, etc. The bite force may be a reflection of the form. The change of facial proportions may be the result and not the cause of altered bite forces. Painful decayed teeth or just fear of pain or

TABLE 6
DESCRIPTIVE STATISTICS FOR THE TIMES T_1 AND T_2 (s)

	N	X	Sum	Min.	Max.	Range	SD
T_1R	47	1.41	66.10	0.20	4	3.80	0.99
T_2R	47	1.06	49.90	0.20	3.80	3.60	0.86
T_1L	47	1.09	51.40	0	3.60	3.60	0.90
T_2L	47	0.93	43.70	0	3.20	3.20	0.83
T_1I	47	1.15	54.20	0.10	4.30	4.20	0.83
T_2I	47	0.99	46.50	0	3.80	3.80	0.79

TABLE 7
CORRELATION BETWEEN BITE FORCES AND THE TIMES T_1 AND T_2

	Right molar	Left molar	Incisors	T_1R	T_2R	T_1L	T_2L	T_1I	T_2I
Right molar	1.00	0.80	0.26	0.04	0.32	0.19	0.27	0.12	0.16
Left molar	0.80	1.00	0.24	0.05	0.22	0.24	0.28	0.03	0.06
Incisors	0.26	0.24	1.00	–0.17	0.02	0.02	0.01	0.10	–0.05
T_1R	0.04	0.05	–0.17	1.00	0.81	0.71	0.69	0.61	0.61
T_2R	0.32	0.22	–0.02	0.81	1.00	0.58	0.71	0.49	0.51
T_1L	0.19	0.24	–0.02	0.71	0.58	1.00	0.87	0.63	0.62
T_2L	0.27	0.28	0.01	0.69	0.71	0.87	1.00	0.50	0.53
T_1I	0.12	0.03	–0.10	0.61	0.49	0.63	0.50	1.00	0.98
T_2I	0.16	0.06	0.05	0.61	0.51	0.62	0.53	0.98	1.00

TABLE 8
COVALUES OF BITE ENDURANCE (T_1 AND T_2 (s))

	T_1R	T_2R	T_1L	T_2L	T_1I	T_2I
Female	1.78	1.24	1.38	1.10	1.43	1.25
Male	1.02	0.87	0.80	0.75	0.87	0.72
All	1.41	1.06	1.09	0.93	1.15	0.99

break of tooth may weaken the bite force of the same regulating reflex system, i. e. of the negative feedback reflex from the periodontal receptors. Ivaniš found bite forces of high intensity for anterior teeth in young adolescents with a high number of intact teeth[26]. The findings of Shian and Wang are similar[14]. Some authors give advantage to measuring of bite forces during clenching in the belief that the number of occlusal contacts increases the values of bite forces[6,7,27–33]. This opinion is in accordance with the standpoint that dental status has a direct influence on the values of forces[14,34]. Since not all teeth are loaded in majority of cases, except in the stage of deglutition, we believe that the data on the loading capacity of one or more pairs of antagonists is more important. Therefore, most devices are designed to record uniaxial forces between single teeth, or a small group of op-

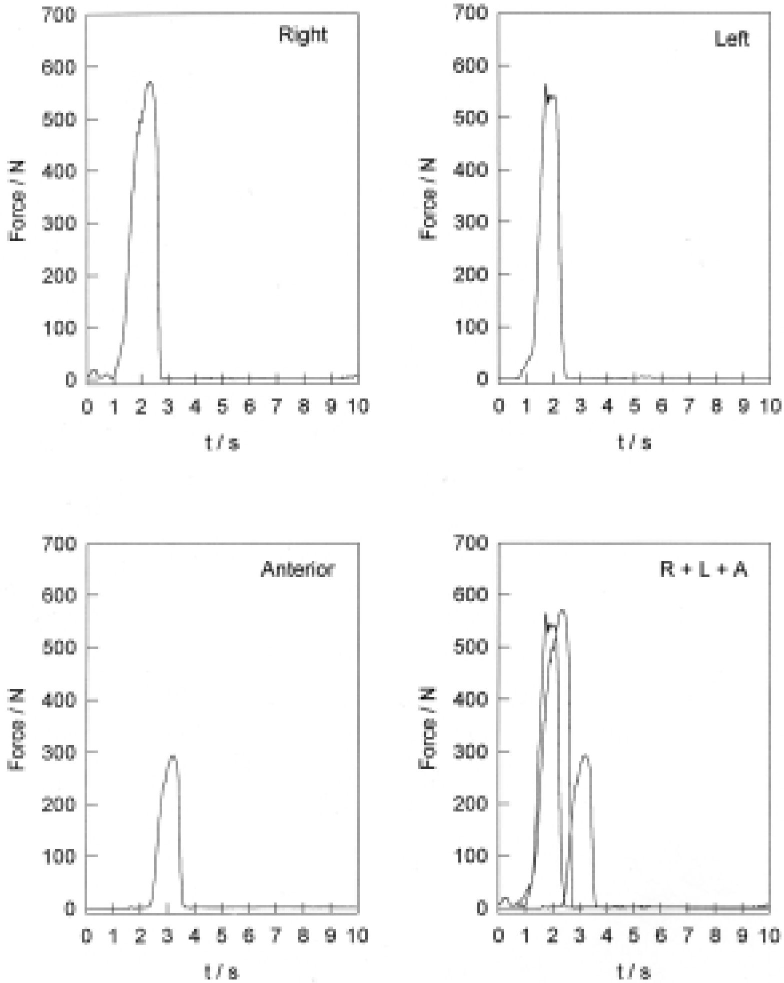

Fig. 3. Bite curve – female, 48 years old.

posing teeth. The gnathodynamometer used in our investigation is one the many based on a strain gauge as a sensor. The width of the biting element comprises one molar or first two incisors. The results we obtained with EGD proved this device to be a highly sensitive instrument for measuring bite forces. There was the same number of subjects according to gender, but not according to age. The largest number of subjects was aged between 20–26, and therefore, no correlation was found between age and bite forces. This, however, does not mean that they would not have been correlated if a larger sample had been taken. Braun et al[13], Waltimo and Könenen[15] and Miyaura et al[34] confirm our result on a similar age group. Voeiker and Sonnenburg argue that the differences in bite forces between sexes become significant in older age[35]. Shian and Wang[14] and Julien et al[28] es-

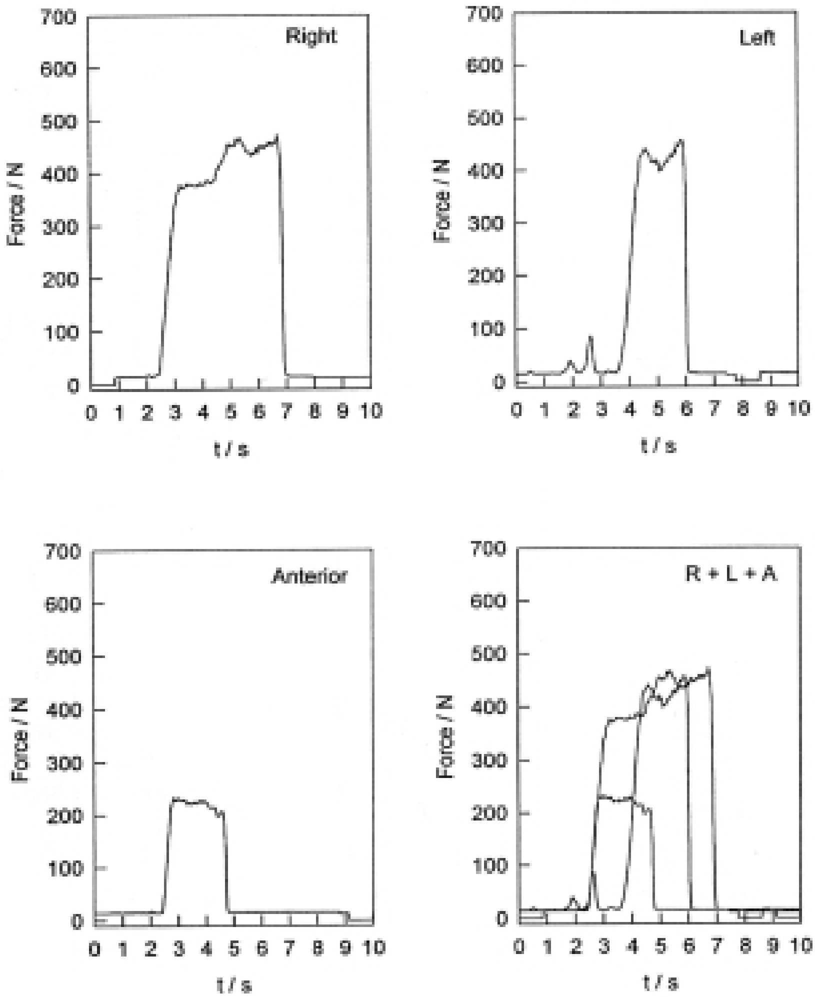

Fig. 4. Bite curve – female, 24 years old.

tablished this correlation in young adolescents, as well as differences in the values of bite forces between sexes. According to Shian and Wang boys exerted stronger bite forces in each age, while Garner and Kotwal[36] obtained stronger forces in girls aged between 11–16 than in boys, explaining this with faster growing up in this age. In her study Živko[37] found an increase in bite forces up to 45 years of life, and then a decrease of these values, probably as a consequence of tooth loss. It is very hard to compare numerical values of measurement due to all the mentioned factors. They are important primarily as individual values that can be compared only in the same measuring conditions. However, our results confirm the findings of other authors that forces in the molar area are considerably stronger than for anterior teeth, that males usually have higher values of forces and that there is no significant difference in posterior teeth forces, regardless of the working masticatory side. The most common limiting factor of higher values of forces is fear of break of tooth, as well as tooth and muscle pain. Pain or impossibility of muscles for subjects to be able to bite more strongly suggests that measurement recorded the actual muscle potential.

The times T_1 and T_2 are shorter in the group of male subjects, and they are not correlated with subjects' age. This shorter time of biting until the maximum force indicates the real potential of closing muscles to maintain maximal contraction between teeth, as well as certain safety of subjects. It is an expression of a desire for superiority and a sign of health and a higher masticatory potential, which is confirmed also by the numerical values of forces. No correlation between T_2 posterior right and T_2 posterior left was noticeable found, due to insecurity in biting, in that part of measured time. That is evident in smaller or stronger shift of the upward part of the bite curves and in different level of the pick showing the MBF.

Conclusion

There are many experimental factors that determine maximum bite force, including methodological, functional, physical and psychological influences.

In the present study no correlation between bite forces and age was established in the subject with complete dentition. The differences in bite forces values for posterior and anterior teeth are statistically significant, while there is no such correlation between the left and right side of the jaw. Bite forces are significantly different in the values for anterior teeth, as well as between anterior and posterior teeth, according to the genders. High correlation between the values on left and right posterior teeth were established, while the correlation between the forces for posterior and anterior teeth is low. For both sexes positive correlations between the time T_1 posterior right and T_1 posterior left, as well as between T_1 and T_2 for anterior teeth, were found.

Based on the storage of the numerical values of bite forces and bite curves, the described method of study enables observation of subjects through a certain time period, as well as taking into account individual values of bite forces in planning, implementation and control of treatment within the orofacial system.

REFERENCES

1. ŽIVKO, J., Z. KOSOVEL, Rekonstruktivni zahvati i žvačne sile. In: SUVIN, M., D. BRANOVAČKI (Eds.): Dostignuća u stomatološkoj protetici 2. (Liber, Zagreb, 1985). — 2. IVANIŠ, T.: Relacije određenih konstitucijskih faktora s intenzitetom žvačnih sila. In Croat. Ph.D. Thesis. (School of Dental Medicine, University of Zagreb, Zagreb, 1986). — 3. IVANIŠ, T., J. ŽIVKO-BABIĆ, D. KOMAR, A. ĆATOVIĆ, Coll. Antropol., 2 (1996) 377. — 4. PRÖSCHEL, P. A., J. RAUM, Int. J. Prosthodont., 14 (2000) 563. — 5. ERHARDSON, S., A. SHEIKHOLESLAM, C. M. FORSBERG, P. LOCKOWANDT, Swed. Dent. J., 17 (1993) 23. — 6. PROMBONAS, A., D. VLISSIDIS, P. MOLYVDAS, J. Prosthet. Dent., 71 (1994) 139. — 7. WALTIMO, A., M. KÖNÖNEN. Scand. J. Dent. Res., 102 (1994) 372. — 8. SAIFUDDIN, M., K. MIYAMOTO, HM. UEDA, N SHIKATA, K TANNE, Oral Diseases, 7 (2001) 94. — 9. LAMEY, PJ., CA. BURNETT, L. FARTASH, TJ. CLIFFORD, JM. McGOVERN, Headache, 41 (2001) 49. — 10. YOUSSEF, RE., GS. TROCKMORTON, E. ELLIS 3rd, DP. SINN, J. Prosthet. Dent. 78 (1997) 179. — 11. GROZDEK, G.: Povezanost ličnosti i jakosti mišića u djevojčica viših razreda osnovne škole. In Croat. M.D. Thesis. (Faculty of Kineology, University of Zagreb, Zagreb, 1997). — 12. LINDERHOLM, H., A. WENNSTRÖM, Acta. Odontol. Scand., 28 (1970) 679. — 13. BRAUN, S., H. P. BANTLEON, W. P. HNAT, J. W. TREU-

DENTHALER, M. R. MARCOTTE, E. J. BAXTER, Angle. Orthodont., 65 (1995) 367. — 14. SHIAN, Y. Y., J-S. WANG, J. Craniomandibular Practice, 11 (1993) 48. — 15. WALTIMO, A., M. KÖNÖNEN, Scand. J. Dent. Res., 101 (1993) 171. — 16. KOMAR, D., Z. KELOVIĆ, A. ĆATOVIĆ, T. IVANIŠ, Acta. Stomatol. Croat., 26 (1992) 181. — 17. PAOLINI, D. A.: A study on the method of recording and the differences in maximal bite force between extremes of vertical facial types. Ph.D. Thesis. (School of Dental Medicine, University of Pittsburg, Pittsburg, 1970). — 18. KOMAR, D., J. KEROS, B. LAZIĆ, Z. AZINOVIĆ, K. JORGIĆ-SRĐAK, Acta. Stomatol. Croat., 32 (1998) 577. — 19. NISHIGAWA, K., E. BANDO, M. NAKANO, J. Oral. Rehabil., 28 (2001) 485. — 20. WALTIMO, A., M. NYSTRÖM, M. KÖNÖNEN, Scand. J. Dent. Res., 102 (1994) 92. — 21. KILIARDIS, S., H. KJELLBERG, B. WENNEBERG, C. ENGSTROM, Acta. Odontol. Scand., 51 (1993) 323. — 22. KIKUCHI, M., T. W. P. KORIOTH, A. G. HANNAM, J. Dent. Res., 76 (1997) 1316. — 23. ANDERSEN, K., E. PEDERSEN, A. KILDERGAARD, Messtech. Briefe., 26 (1990) 17. — 24. MARUNICK, M., B. E. MATHES, B. B. KLEIN, M. SEYEDSADR, J. Prosthet. Dent., 67 (1992) 835. — 25. WINDECKER, D., Messtech. Briefe., 7 (1991) 34. — 26. IVANIŠ T., J. ŽIVKO-BABIĆ, J. ŠTALEC, Acta. Stomatol. Croat., 22 (1988) 107. — 27. HIDAKA, O., M. IWASAKI, M. SAITO, T. MORIMOTO, J. Dent. Res., 78 (1999) 1336. — 28. JULIEN, K., P. BUSCHANG, G. THROCKMORTON, P. DECHOW, Arch. Oral. Biol., 41 (1996) 69. — 29. TAKAI, A., M. NAKANO, E. BANDO, E. HEWLETT, J. Prosthet. Dent., 73 (1995) 44. — 30. SHINOGAYA, T., A. SODEYAMA, M. MATSUMOTO, Eur. J. Prosth. & Rest. Dent., 7 (1999) 65. — 31. SHINOGAYA, T., M. BAKKE, CE. THOMSEN, A. VILMANN, M. MATSUMOTO, Eur. J. Prosthet. & Rest. Dent., 8 (2000) 11. — 32. TORTOPIDIS, D., M: LYONS, R. BAXENDALE, W. GILMOUR, J. Oral. Rehabil., 25 (1998) 681. — 33. SATO, M., T. AKUMURA, Nippon. Dent. Univ. Animal. Pub., 29 (1995) 87. — 34. MIYAURA, K., Y. MATSUKA, M. MORITA, A. YAMASHITA, T. WATANABE, J. Oral. Rehabil., 26 (1999) 223. — 35. GARNER, L. D., N. S. KOTWAL, J. Dent. Res., 52 (1973) 698. — 36. VOEIKER, N., M. SONNENBURG, Dtsch. Zahnärztl. Z., 39 (1984) 54. — 37. ŽIVKO, J.: Komparativna studija gnatodinamometrijskih metoda s posebnim obzirom na vlastitu konstrukciju. In Croat. MD Thesis. (School of Dental Medicine, University of Zagreb, Zagreb, 1980).

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ŽVAČNE SILE U OSOBA S POTPUNOM, PRIRODNOM DENTICIJOM

S A Ž E T A K

Žvačne sile su uvjet, izraz i mjerilo žvačne funkcije. Svrha rada bila je ispitati novo dizajniranim elektronskim gnatodinamometrom kolike su vrijednosti maksimalno izraženih žvačnih sila u osoba koje imaju sve zube, u kojim vremenima izražavaju 50% odnosno 75% sveukupne vrijednosti sila i kakav je oblik krivulje zagriza tijekom testiranja. U statističkoj obradi rezultata korištena je ANOVA analiza. Student T-testom uspoređene su vrijednosti žvačnih sila i mjernih mjesta. Dobiveni rezultati analizirani su s obzirom na spol i dob ispitanika. Analiza varijance potvrdila je nalaz da nema statistički značajne povezanosti između vrijednosti sila i dobi ispitanika, ali da postoji statistički značajna razlika u vrijednostima žvačnih sila između muškaraca i žena u prednjem segmentu, te između vrijednosti sila na prednjim i bočnim zubima. Statistički su značajne korelacije između vremena T_1 desno i T_1 lijevo, kao i između T_1 i T_2 sprijeda. Analizom krivulja zagriza može se zaključiti da muškarci »grizu« kraće od ženskih ispitanika s oštrijim pikom krivulje. Numeričke vrijednosti sila kao i krivulje zagriza mogu poslužiti kao jedan od dijagnostičkih čimbenika u praćenju ispitanika ili u izboru protetske terapije.