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Maximum occlusal bite forces in Jordanian individuals with different dentofacial vertical skeletal patterns

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SUMMARY This study was carried out to record maximum occlusal bite force (MBF) in Jordanian students with three different facial types: short, average, and long, and to determine the effect of gender, type of functional occlusion, and the presence of premature contacts and parafunctional habits on MBF. Sixty dental students (30 males and 30 females) were divided into three equal groups based on the maxillomandibular planes angle (Max/Mand) and degree of anterior overlap: included short-faced students with a deep anterior overbite (Max/Mand $\leq$ 22 degrees), normal-faced students with a normal overbite that served as the controls (Max/Mand = 27 $\pm$ 5 degrees), and long-faced students with an anterior open bite (Max/Mand $\geq$ 32 degrees). Their age ranged between 20 and 23 years. MBF was measured using a hydraulic occlusal force gauge. Occlusal factors, including the type of functional occlusion, the presence of premature contacts, and parafunctional habits, were recorded. Differences between groups were assessed using a *t*-test and analysis of variance.

The average MBF in Jordanian adults was 573.42 $\pm$ 140.18 N. Those with a short face had the highest MBF (679.60 $\pm$ 117.46 N) while the long-face types had the lowest MBF (453.57 $\pm$ 98.30 N; $P < 0.001$). The average MBF was 599.02 $\pm$ 145.91 in males and 546.97 $\pm$ 131.18 in females ($P = 0.149$). No gender differences were observed. The average MBF was higher in patients with premature contacts than those without, while it did not differ in subjects with different types of functional occlusion or in the presence of parafunctional habits.

Introduction

It is generally accepted that there is a relationship between occlusal forces and facial morphology. Three basic types of facial morphology are said to exist: short, average, and long. Those with a long face have excessive vertical facial growth which is usually associated with an anterior open bite, increased sella–nasion (SN)/mandibular plane (MP) angle, increased gonial angle, and increased maxillary/mandibular planes angle (Fields *et al.*, 1984; Cangiaolosi, 1989). The short face types have reduced vertical growth that is usually accompanied by a deep anterior overbite, reduced facial heights, and reduced SN–MP angle (Opdebeeck and Bell, 1978). Between the two types lies the 'average' face (Edgerton, 1976). The relationship between bite force and craniofacial morphology has been investigated (Sassouni, 1969; Ringqvist, 1973; Ingervall and Helkimo, 1978; Proffit *et al.*, 1983). The mean bite force in the molar region was twice as great in the normal as in long-face subjects; short-face subjects generating even higher forces than normal face subjects (Proffit *et al.*, 1983).

A wide range of maximum bite force values is reported in different studies. This can be attributed to several factors that can be individual or technique related. Individual-related factors include physical characteristics and craniofacial morphology. Shiau and Wang (1993) reported that bite force increased with age, height, and weight. Nonetheless, Braun *et al.* (1995) found a low correlation between bite force and body variables. Gender differences in bite force have also been reported. It was found that the mean bite force values were significantly higher in males than in females (Helkimo *et al.*, 1977; Kiliaridis *et al.*, 1995; Waltimo and Kononen, 1995; Tuxen *et al.*, 1999; Kovero *et al.*, 2002). Corruccini *et al.* (1985) reported higher bite forces among rural youths with forceful harder chewing habits. On the other hand, technique-related factors include interocclusal separation, location of the measuring device on the dentition, and head posture at the time of measurement.

A number of different devices have been used to obtain direct measurement of bite force including the bite fork (Helkimo *et al.*, 1977; van Steenberghe and de Vries, 1978; Kiliaridis *et al.*, 1993), strain gauge transducers (Hellsing and Hagberg, 1990; Lindauer *et al.*, 1993; Braun *et al.*, 1996), foil transducers (Burke *et al.*, 1973; Proffit *et al.*, 1983), the pressurized rubber tube (Braun *et al.*, 1995), the gnathodynamometer (Ortug, 2002), the pressure-sensitive sheet (Hidaka *et al.*, 1999; Sondang *et al.*, 2003), and force-sensing resistors (Fernandes *et al.*, 2003).

The aims of the present study were to

1. Measure the maximum bite force among Jordanian subjects using a hydraulic pressure–force gauge.

Table 1 Mean and standard deviations (SD) of age in the three groups.

	Number		Age		
	Female	Male	Males, mean ± SD	Females, mean ± SD	Total, mean ± SD
Short face	10	10	21.90 ± 0.88	21.70 ± 0.68	21.80 ± 0.77
Average face	10	10	21.55 ± 0.69	21.56 ± 0.88	21.55 ± 0.75
Long face	10	10	22.10 ± 0.57	21.55 ± 1.04	21.81 ± 0.87

2. Compare bite force between different vertical facial patterns.
3. Study the effects of gender, weight, height, type of functional occlusion, and the presence of parafunctional habits and premature contacts on occlusal bite force.

Subjects and methods

Ethical permission was obtained from Institutional Review Board at the Jordan University of Science and Technology. The objectives and methodology were explained to all participants and written consent was obtained.

Five hundred dental students at the Jordan University of Science and Technology were screened and 60 subjects (30 males and 30 females) were included in this study fulfilling the following criteria: a Class I skeletal pattern, no previous orthodontic treatment, no missing posterior teeth other than third molars, no large carious cavities or restorations in the permanent first molars, and no posterior crossbite.

The subjects were divided into three equal groups based on the maxillomandibular plane angle (Max/Mand) and degree of anterior overlap: included short-faced students with deep anterior overbite (Max/Mand ≤ 22 degrees), normal-faced students with a normal overbite that served as the controls (Max/Mand = 27 ± 5 degrees), and long-faced students with an anterior open bite (Max/Mand ≥ 32 degrees).

For each subject age, gender, weight in kilograms, height in metres, and body mass index (BMI; weight/height^2) were recorded. Their ages ranged between 20 and 23 years, with a mean of 21.80 ± 0.77, 21.55 ± 0.75, and 21.81 ± 0.87 years in the short-, average-, and long-face groups, respectively. Gender and age distribution are shown in Table 1.

The clinical examination and maximum bite force registration were carried out by two postgraduate students (IAZ and MER). The examination included assessment of dynamic occlusion and determination of the presence of parafunctional habits and premature contacts. Dynamic occlusion was classified into canine guidance or group function occlusion. A canine-guided occlusion was defined as canine-only contact on the working side on lateral mandibular movements and group function occlusion as posterior tooth contact on the working side on lateral mandibular movements.

Figure 1 Hydraulic pressure occlusal force gauge.

Bite force was measured bilaterally in the first molar region using a portable occlusal force gauge (GM10, Nagano Keiki, Tokyo, Japan; Figure 1), that consisted of a hydraulic pressure gauge and a biting element made of a vinyl material encased in a polyethylene tube. Bite force was displayed digitally in Newtons. The accuracy of this occlusal force gauge has previously been confirmed (Sakaguchi *et al.*, 1996). Before the recording, the subject was seated upright and without head support with the Frankfort plane nearly parallel to the floor. Each subject was instructed to bite as hard as possible on the gauge without moving the head. Bite force was measured alternately on the right and left sides with a 15 second resting time between each bite. Three readings were obtained on each side. From these six recordings, two values were used in the analysis; the maximum bite force (MBF), which is the maximum measurement achieved on each side, and the average MBF from both sides.

For allocation to the groups, lateral cephalograms were taken for each participant in centric using an Orthoslice 1000 C (Trophy, Marne La Vallee, France) cephalostat at 64 kV, 16 mA, and 0.64 seconds exposure. The cephalograms were traced manually by one author (ESJAA) and 13 hard tissue cephalometric points were registered yielding four angular and two linear measurements (Figure 2).

Method error

The reliability of the measurements was assessed by the sine integrator re-examining and re-measuring records of 10 subjects after an interval of 1 week. Kappa statistics were used to evaluate the reliability of the categorical data

(Cohen, 1960). The results of the kappa values were above 80 per cent for both intra- and interexaminer reliability which indicate a substantial agreement between readings (Landis and Koch, 1977). Method errors for numerical variables were examined using the formula of Dahlberg (1940) and coefficients of Houston (1983). The error ranged between 0.1 and 0.2 and the coefficient of reliability was above 90 per cent for all the measurements, indicating good agreement.

Statistical analysis

Data analysis was carried out using the Statistical Package for Social Science version 10 (SPSS Inc.®, Chicago, Illinois, USA). Descriptive data were tabulated. Pearson's correlation test was used to correlate different variables with MBF. Analysis of variance was used to determine whether significant differences existed between the groups. A least significant differences test and a multiple comparison test were applied to identify which of the groups were different.

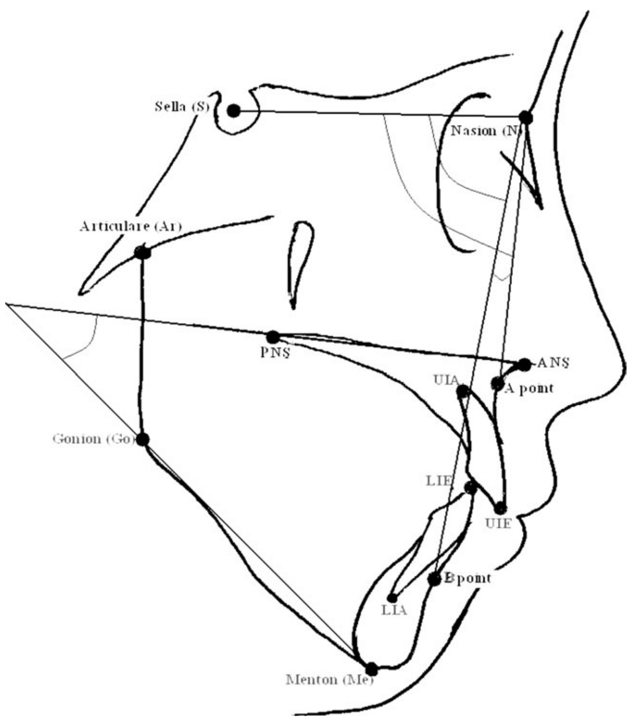

Figure 2 Points, lines, and measurements used in the cephalometric analysis. SNA: angle between sella–nasion–point A; SNB: angle between sella–nasion–point B; ANB: angle between point A–nasion–point B; Maxillomandibular planes angle (MM angle): angle between the maxillary and mandibular planes; overbite (OB) The vertical distance between the incisal edges of the upper and lower incisors; overjet (OJ) The horizontal distance between the incisal edges of the upper and lower incisors.

Results

Physical characteristics

The mean weight, height, and BMI for subjects in each group are shown in Table 2. The weight of the subjects ranged between 45 and 108 kg, with a mean of 67.05 ± 14.40, 65.50 ± 13.65, and 66.14 ± 14.82 kg in the short-, average-, and long-face groups, respectively. Height ranged between 1.50 and 1.80 m with a mean of 1.68 ± 0.06, 1.66 ± 0.06, and 1.67 ± 0.08 in the short-, average-, and long-face groups, respectively. BMI ranged between 19 and 27 with a mean of 22.96 ± 2.59, 22.86 ± 2.54, and 22.30 ± 2.60 in the short-, average-, and long-face groups, respectively.

Cephalometric measurements

The means, standard deviations, and differences between the means and *P* values for cephalometric measurements in the three groups are shown in Table 3. The Max/Mand averaged 19.05 ± 2.01, 26.95 ± 1.67, and 33.40 ± 1.14 degrees and overbite 5.68 ± 0.75, 2.55 ± 0.51, and −2.35 ± 1.80 mm in the short-, average- and long-face types, respectively. The three groups differed significantly in their vertical cephalometric measurements ($P < 0.001$).

Maximal occlusal bite force

The means, standard deviations, and differences between the means of bite force measurements in the three groups are shown in Table 4. The average MBF ranged between 290 and 965 N. On the right side, MBF was 669.90 ± 133.58, 590.55 ± 119.72, and 470.24 ± 115.04 N for the short-, average-, and long-face groups, respectively. Statistically significant differences were detected between the short and average faces ($P < 0.05$), normal and long faces ($P < 0.01$), and short and long faces ($P < 0.001$). On the left side, average MBF was 689.30 ± 105.56, 595.60 ± 106.28, and 436.90 ± 108.06 N for the short-, average-, and long-face groups, respectively.

Table 2 Means and standard deviations (SD) of the physical characteristics in the three groups.

	Short face, mean ± SD			Average face, mean ± SD			Long face, mean ± SD		
	Females	Males	All	Females	Males	All	Females	Males	All
Weight (kg)	55.40 ± 3.17	78.70 ± 11.24	67.05 ± 14.40	52.44 ± 2.35	76.18 ± 8.44	65.50 ±13.66	54.18 ± 3.49	79.30 ± 10.35	66.14 ± 14.82
Height (m)	1.61 ± 0.05	1.72 ± 0.03	1.68 ± 0.06	1.61 ± 0.03	1.71 ± 0.04	1.66 ± 0.06	1.63 ± 0.08	1.72 ± 0.04	1.67 ± 0.08
Body mass index	20.89 ± 1.12	25.04 ± 1.83	22.96 ± 2.59	20.34 ± 0.71	21.97 ± 2.61	22.86 ± 2.54	20.48 ± 1.59	24.30 ± 1.92	22.30 ± 2.60

Statistically significant differences were observed between the short and average faces ($P < 0.01$), normal and long faces ($P < 0.001$), and short and long faces ($P < 0.001$). The average MBF was 679.60 ± 117.46, 593.08 ± 99.69, and 453.57 ± 98.30 N in the short-, average-, and long-face groups, respectively. Statistically significant differences were found between the short and average faces ($P < 0.05$), normal and long faces ($P < 0.001$), and short and long faces ($P < 0.001$). The total group average MBF was 575.15 ± 146.71, 571.69 ± 148.86, and 573.42 ± 140.18 N for the right side, the left side, and the overall sample, respectively.

Effect of weight, height, and BMI on biting force

A positive correlation was found between average MBF and weight ($R^2 = 0.138$), height ($R^2 = 0.022$), and BMI ($R^2 = 0.275$). However, the only statistically significant correlation was between average MBF and BMI ($P = 0.032$).

Effect of gender on biting force

The average MBF was 599.02 ± 145.91 in males and 546.97 ± 131.18 in females ($P = 0.149$; Table 5). The MBF in males averaged 712.45 ± 114.20, 622.41 ± 88.19, and

Table 3 Means, standard deviations (SD), *F* values, differences between the means and significance for cephalometric measurements in the three groups using analysis of variance (ANOVA) and least significant differences (LSD) tests.

Cephalometric measurement	Short face (group 1), mean ± SD	Average face (group 2), mean ± SD	Long face (group 3), mean ± SD	ANOVA *F* value	Group 1 and 2		Group 1 and 3		Group 2 and 3	
					Mean difference	LSD	Mean difference	LSD	Mean difference	LSD
SNA (°)	82.37 ± 4.77	81.55 ± 3.14	82.30 ± 4.59	1.192	0.82	NS	0.07	NS	0.75	NS
SNB (°)	79.79 ± 3.58	79.05 ± 4.85	79.75 ± 5.20	1.201	0.74	NS	0.04	NS	0.70	NS
ANB (°)	2.58 ± 0.51	2.50 ± 1.36	2.55 ± 1.05	0.12	0.08	NS	0.03	NS	0.05	NS
MM angle (°)	19.05 ± 2.01	26.95 ± 1.67	33.40 ± 1.14	373.38***	7.90	***	14.35	***	6.45	***
Overbite (mm)	5.68 ± 0.75	2.55 ± 0.51	−2.35 ± 1.80	606.99***	3.13	***	8.03	***	4.90	***
Overjet (mm)	2.53 ± 0.51	2.40 ± 0.50	2.70 ± 0.47	1.85	0.13	NS	0.17	NS	0.30	NS

NS, not significant, ***$P < 0.001$.

Table 4 Means, standard deviations (SD), *F* values, differences between the means and significance for maximum bite force (MBF) on right and left sides in the three groups.

	Short face (group 1), mean ± SD	Average face (group 2), mean ± SD	Long face (group 3), mean ± SD	*F* values	Total	Differences in mean, groups 1 and 2	Differences in mean, groups 1 and 3	Differences mean, groups 2 and 3
Right MBF	669.90 ± 133.58	590.55 ± 119.72	470.24 ± 115.04	13.753	575.15 ± 146.71	79.35*	199.66***	120.31**
Left MBF	689.30 ± 105.56	595.60 ± 106.28	436.90 ± 108.06	29.427	571.69 ± 148.86	93.70**	252.40***	158.70***
Average MBF	679.60 ± 117.46	593.08 ± 99.69	453.57 ± 98.30	24.077	573.42 ± 140.18	86.53*	226.03***	139.50***

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

Table 5 Means, standard deviations (SD), and differences between means and significance in the subjects according to gender, type of dynamic occlusion, and presence of parafunctional habits and of premature contact.

Variables		Number	Bite force, means ± SD	Mean difference
Gender	Females	30	546.97 ± 131.18	52.05
	Males	30	599.02 ± 145.91	
Type of dynamic occlusion	Canine guidance	24	645.48 ± 116.52	122.10**
	Group function	36	523.38 ± 134.51	
Presence of parafunctional habits	Yes	15	563.97 ± 162.8	12.53
	No	45	576.50 ± 142.23	
Presence of premature contact	Yes	9	677.72 ± 166.49	122.36*
	No	51	555.37 ± 128.53	

*$P < 0.05$, **$P < 0.01$.

459.85 ± 113.15 in the short-, average-, and long-face groups, respectively, and females 646.75 ± 116.99, 557.22 ± 106.09, and 447.86 ± 87.91, respectively. No gender differences were found among the three groups studied.

Effect of the type of dynamic occlusion on biting force

In the short-face group, 13 subjects had a right-side canine guidance and 11 a left-side canine guidance, while in the average-face group, there were 10 subjects with right-side canine guidance and 10 with left-side canine guidance (Table 5). In the long-face group, there was only group function occlusion. The average MBF in subjects with canine guidance was 645.48 ± 116.52, while in patients with group function dynamic occlusion, it was 523.38 ± 134.51 ($P < 0.01$).

Effect of the presence of parafunctional habits on biting force

The majority of the subjects did not have any habits (Table 5). In the short-face group, six subjects had a parafunctional habit while in the average-face group there were five subjects. In long-face group, four subjects had a parafunctional habit. The average MBF in subjects with or without parafunctional habits was 563.97 ± 162.8 and 576.50 ± 142.23, respectively ($P = 0.764$).

Effect of premature contact on biting force

The majority of subjects had no premature contacts (Table 5). Five subjects had premature contacts in the short-face group, two in the average-face group, and two in the long-face group. No significant differences in the presence of premature contacts between the three groups were detected ($P = 0.271$). The average MBF in subjects with or without a premature contact was 677.72 ± 166.49 and 555.37 ± 128.53, respectively ($P < 0.05$).

Discussion

In this study, a hydraulic pressure gauge was used with a biting element encased in a plastic covering. This device has several advantages: it is easy to use, does not need any special mounting, has a small thickness of about 5.4 mm, does not interfere with the tongue, and can be easily disinfected by changing the disposable plastic coverings. However, it has a plastic covering that can still be considered hard to bite and this may be the main potential disadvantage. In this study, the only risk was tooth damage, and this was considerably reduced by excluding patients with large molar restorations. Bite force was measured at the first molar area unilaterally, which is more reproducible than bilateral measurements (Tortopidis *et al.*, 1998).

The average MBF in Jordanian adults in this study was 549 N. In females, MBF was 481 N, while in males, it was 610 N. The average MBF was higher than that measured by Sasaki *et al.* (1989), Bakke *et al.* (1990), Tortopidis *et al.* (1998), Raadsheer *et al.* (1999), Miyaura *et al.* (1999), and Ferrario *et al.* (2004). On the other hand, it was lower than that reported by Braun *et al.* (1995), Kovero *et al.* (2002), Okiyama *et al.* (2003), and Sondang *et al.* (2003).

This wide range in bite force can be explained by different factors. Firstly, different devices with different biting elements have been used to measure MBF. In this study, a bite force gauge with a plastic-covered biting element was used that may allow individuals to bite harder than a hard thick metallic transducer used in other research (Sasaki *et al.*, 1989; Tortopidis *et al.*, 1998; Raadsheer *et al.*, 1999; Ferrario *et al.*, 2004). This may explain the lower biting force reported by those authors. On the other hand, using thin biting sheets (Prescale system; Okiyama *et al.*, 2003; Sondang *et al.*, 2003) or a pressurized rubber tube (Braun *et al.*, 1995) may allow harder biting and this also may explain the higher biting force reported by those authors. Another possible factor is the composition of the study sample. All mentioned studies were conducted on a mixed sample with randomly selected individuals with no concentration on the facial morphology, while in the present investigation, a specific number of each facial type was selected. This may lead to a higher or lower number of extreme facial types (short or long faces) in the present than in the other studies.

Furthermore, this is the only study carried out on a Jordanian population, while the others were conducted on different populations (Bakke *et al.*, 1990; Sondang *et al.*, 2003; Ferrario *et al.*, 2004). It is possible that different races have different biting forces, which might be attributed to different eating habits and different facial morphology. Other factors such as the thickness of the biting element and control of measurement procedures can also play a role in the magnitude of MBF found in different studies.

MBF in the present investigation differed significantly between the different vertical facial morphologies. In the short-face group, a mean MBF of 680 N was found compared with 453 N in the long-face group, while the average-face group had an intermediate MBF value of about 593 N. These results are in agreement with Proffit *et al.*, (1983) who reported a mean MBF of 356 N in normal faces compared with 155 N in long-face subjects. Ingervall and Helkimo (1978) and Kiliaridis *et al.* (1995) also reported that strong muscles produce more uniform facial morphology, while weaker muscles produce more diverse facial morphology.

Regardless of the difference in measured MBF compared with the previous studies (Ingervall and Helkimo, 1978; Proffit *et al.*, 1983; Kiliaridis *et al.* 1995), an association between facial morphology and MBF was found. Deeper analysis showed a more pronounced difference in MBF between the short- and long-face groups than between the short- and average-face groups.

A significant positive correlation was observed between MBF and BMI. This is in agreement with the findings of Sasaki *et al.* (1989) and Kiliaridis *et al.* (1993).

The mean MBF in individuals with a parafunctional habit was similar to that in individuals with no habit. Cosme *et al.* (2005) found the same in an investigation of 80 young adults. However, that study had some limitations since only a small number of individuals had parafunctional habits. Therefore, further studies may be needed to clarify the correlation between parafunctional habits and MBF.

The mean MBF in individuals with a premature contact was higher than that recorded for subjects without a premature contact. This finding is contrary to the results of Ingervall and Minder (1997) who reported that as the number of teeth in contact increase, greater force distribution will be allowed thus reducing localized pain perception and permitting harder biting.

Conclusions

1. The average MBF in the Jordanian adults in this study was 573 N. In females, it was 547 N and in males, 599 N.
2. MBF significantly differed between subjects with different vertical facial morphologies. The short face type had the highest MBF of 680 N, the long-face type the lowest MBF of 454 N, and the average face type an MBF of 593 N.
3. The average MBF was higher in patients with a premature contact while it did not differ in subjects with different types of functional occlusion or in the presence of parafunctional habits.
4. No gender differences in average MBF were observed.

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