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Molar bite force in relation to occlusion, craniofacial dimensions, and head posture in pre-orthodontic children

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SUMMARY The present study examined bite force in relation to occlusion, craniofacial dimensions, and head posture. The sample comprised 88 children (48 girls, 40 boys) aged 7–13 years, sequentially admitted for orthodontic treatment of malocclusions entailing health risks. Bite force was measured in the molar region by means of a pressure transducer. Angle classification, number of teeth and contact in the intercuspal position (ICP) were recorded and dental arch widths were measured on plaster casts. Craniofacial dimensions and head posture were recorded from lateral cephalometric radiographs taken with the subject standing with their head in a standardized posture (mirror position). Associations were assessed by Spearman correlations and multiple stepwise regression analyses.

The maximum bite force increased significantly with age in girls, with teeth in occlusal contact in boys, and with increasing number of erupted teeth in both genders. Bite force did not vary significantly between the Angle malocclusion types. Only in boys was there a clear correlation between bite force and craniofacial morphology: cranial base length (n–ba, n–ar), posterior face height (s–tgo, ar–tgo), vertical jaw relationship (NL–ML), mandibular inclination (NSL–ML), form (ML–RL) and length (pg–tgo), and inclination of the lower incisors (Ili–ML). Multiple regression analysis showed that the vertical jaw relationship ($P < 0.001$) and the number of teeth present ($P < 0.01$) were the most important factors for the magnitude of bite force in boys. In girls, the most important factor was the number of teeth present ($P < 0.001$). No correlations between bite force and head posture were found.

Introduction

Skeletal, craniofacial morphology, and craniocervical relationships are influenced by masticatory and respiratory functions (Solow, 1992; Kiliaridis, 1995). The jaw elevator muscles and bite force affect the transversal and vertical dimensions of the face, and correlations between masticatory muscle strength and craniofacial morphology are well documented in adults (Møller, 1966; Ringqvist, 1973; Ingervall and Helkimo, 1978; Proffit *et al.*, 1983; Weijs and Hillen, 1986; Bakke and Michler, 1991; Raadsheer *et al.*, 1999). Bite force in adults with a rectangular craniofacial morphology and skeletal deep bite is greater than in adults who have a long-face morphology and an open bite. In children, such correlations are less apparent. Proffit and Fields (1983) were not able to find any correlation between bite force and craniofacial morphology, and Ingervall and Minder (1997) found that only the gonial angle remained significant when tested for the effect of age and occlusal contact. However, Ingervall and Thilander (1974) previously found that children with high levels of muscle activity during maximal contraction were characterized by a rectangular facial shape. It has also been shown that children with low bite force have more tenderness of the jaw elevator muscles and more signs of temporomandibular disorders (TMD) in terms of Helkimo's Clinical Dysfunction Index (Sonnesen *et al.*, 2001). In addition, bite force and muscle function are positively correlated with occlusion in terms of posterior tooth contact (Bakke *et al.*, 1990; Julien *et al.*, 1996; Ingervall and Minder, 1997). The relationship between bite force and Angle's classification has not previously been investigated systematically, but the masticatory performance has been shown to be reduced in subjects with malocclusions, especially in those with Class II and III, compared with normal occlusions (English *et al.*, 2002).

The standardized posture of the head, defined as the position of the head relative to the cervical column, is more extended in children with asthma and nasal obstruction (Wenzel *et al.*, 1983). Findings in adult males also seem to reflect a compensatory physiological postural mechanism that serves to maintain airway adequacy (Solow *et al.*, 1996). In children, extreme extended head posture is associated with a vertical facial development of long-face morphology (Solow and Siersbæk-Nielsen, 1992), and a craniofacial morphology which is also correlated with low bite force. Furthermore, TMD are seen in connection with a marked forward inclination of the upper cervical spine and an extended head posture (Sonnesen *et al.*, 2001). Surprisingly, a direct relationship between bite force and head posture has been reported by Hellsing and Hagberg (1990) who, in adults, found a temporary increase in bite force during extension of the head as compared with the subject's natural head posture. In contrast. Kovero *et al.* (2002) found no correlations between bite force and spinal posture in young adults.

The present investigation focused on bite force in relation to (a) Angle's classification, (b) craniofacial dimensions, (c) occlusion, and (d) head posture. It was the aim of the study to analyse which parameters were most important for bite force when tested for the effect of age. Such an analysis has not been previously performed.

Subjects

The sample comprised 88 children (48 girls, 40 boys) aged 7–13 years (Table 1), sequentially admitted for orthodontic treatment at three municipal dental health services in North Zealand, Denmark. The children were selected by the Danish procedure for screening the child population for malocclusions entailing health risks (Danish Ministry of Health, 1990; Solow, 1995) by the orthodontic specialist in charge of the clinic concerned. Most of the children were Caucasian. There were no gender differences in the distribution of the stage of dental eruption and age (Sonnesen *et al.*, 1998). None of the children had craniofacial anomalies, obstruction of the upper airway or systemic muscle or joint disorders and only 7 per cent of the children were evaluated as having a need for referral for TMD treatment (Sonnesen *et al.*, 1998). The sample was obtained from that reported by Sonnesen (1997) and Sonnesen *et al.* (1998) after exclusion of subjects with insufficient quality of cephalometric radiographs, and children who did not have their bite force recorded, either because of large restorations or due to their anxiety about the procedure. The study was approved by the Scientific–Ethical Committee for Copenhagen and Frederiksberg (ref. no. 03-010/93).

Methods

The study was based on three types of examination: recordings of the maximum unilateral bite force, cephalometric analysis including head posture based on profile radiographs, and assessment of occlusion in the children and on casts of the dental arches.

Table 1 Distribution of sequentially admitted pre-orthodontic children by gender and age.

	Age in years							
	7	8	9	10	11	12	13	Total
Girls	4	10	6	6	9	5	8	48
Boys	4	3	8	4	3	5	13	40
Total	8	13	14	10	12	10	21	88

Molar bite force

In order to assess the strength of the mandibular elevator muscles, the maximum unilateral bite force was measured at the first mandibular molars on each side by means of a miniature pressure transducer (Flöystrand *et al.*, 1982) during 1–2 seconds of maximum clenching. The peak value of the bite force was measured four times on each side and repeated in reverse order after a 2–3 minute interval. Bite force was determined as the average of the 16 measurements (Bakke *et al.*, 1989; Sonnesen *et al.*, 1998).

Cephalometry

Profile radiographs were taken with the teeth in occlusion and in the natural head posture (mirror position) as described by Siersbæk-Nielsen and Solow (1982). The radiographs were taken in a Dana Cephalix cephalostat with a film-to-focus distance of 180 cm and a film-to-median plane distance of 10 cm. No correction was made for the constant linear enlargement of 5.6 per cent. An aluminium wedge placed between the cassette and the patient's face and a movable grid were used to increase the sharpness of the image. The reference points were marked and digitized directly on the radiographs (Figure 1) and 42 variables describing craniofacial morphology and head posture were calculated (Table 2).

Occlusion

Occlusal support in terms of the number of teeth in contact in the intercuspal position (ICP) was assessed from the ability to hold a plastic strip, 0.05 mm thick and 6 mm wide (Hawe Transparent Strips no. 690, straight), between the teeth against a strong pull when the child's teeth were firmly closed (Bakke *et al.*, 1990). The method error (Dahlberg, 1940) with repeated measurements with 1 week intervals has previously been reported to be 10 per cent of the mean value (Bakke and Michler, 1991).

Angle classification and dental arch widths were assessed on plaster casts of the upper and lower dental arches (Table 3). The measuring points for arch widths were defined as the mesial contact points of the first molars on the right and left sides (Solow, 1966). The distance between the two points was measured using digital sliding callipers. If the tooth was rotated or damaged on the mesial surface, the corresponding point on the distal surface of the second premolar or the second primary molar was used.

Reliability

The reliability of the bite force measurements was determined on 23 randomly selected children not included in the study. These children underwent bite force measurements at intervals of 14 days, using the

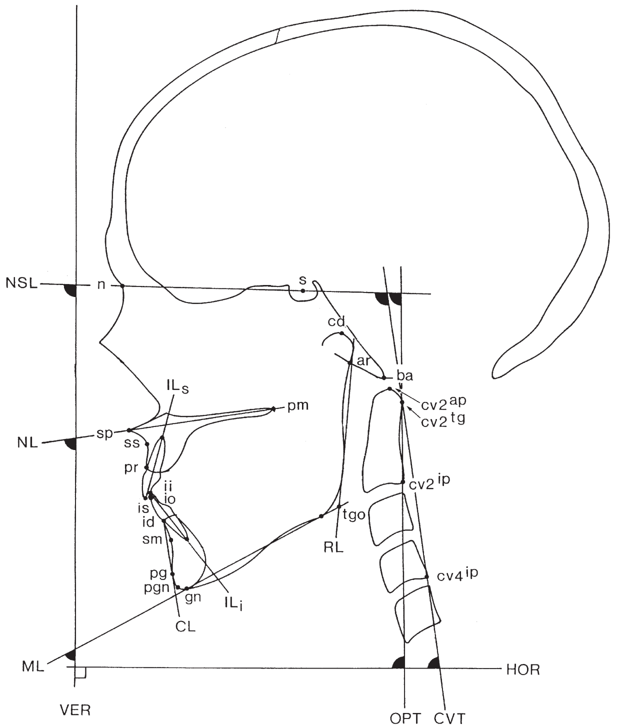

Figure 1 Reference points and lines according to Solow and Tallgren (1976). io, perpendicular projection of incision inferius (ii) on a line through incision superius (is) and the distobuccal cusp of the upper first molar.

same method as in the present investigation (Sonnesen *et al.*, 1998). There was no significant difference between the two sets of measurements, and the method error (Dahlberg, 1940) of the individual measurements was $s(i) = 6$ per cent.

The reliability of the cephalometric measurements was assessed by re-measurement of 26 lateral radiographs (Sonnesen *et al.*, 2001). There were no significant differences between the two sets of recordings. The method errors ranged from 0.21 to 0.83 degrees or millimetres (Dahlberg, 1940) and the reliability coefficients from 0.97 to 1.00 (Houston, 1983).

The reliability of the dental arch width measurements was determined on 30 randomly selected sets, not included in the study, measured twice with an interval of 1 week (Sonnesen *et al.*, 2001). The analysis showed no significant differences between the two sets of recordings. The method errors were 0.13 and 0.17 mm (Dahlberg, 1940), and the reliability coefficients 1.00 and 0.99 (Houston, 1983).

Statistical methods

The statistical analyses were performed using the SAS Statistical Package (SAS Institute Inc., 1982, 1988). The normality of the distributions was assessed by the parameters of skewness and kurtosis and by Shapiro–Wilks W-test. The results from the tests were considered to be significant at P-values below 0.05.

Table 2 Craniofacial morphology and head posture in 88 7–13-year-old pre-orthodontic children.

Variable	Mean	Standard deviation
Linear morphological variables (mm)		
n–s	69.20	2.83
n–ba	102.46	5.05
n–ar	91.93	4.52
n–sp	48.99	3.50
n–gn	109.99	6.88
s–ba	42.96	3.90
s–ar	33.35	3.14
s–pm	45.24	2.99
s–tgo	72.74	6.27
sp–gn	63.13	5.03
ar–tgo	42.94	4.36
sp–pm	51.78	3.05
ss–pm	47.26	2.70
pgn–cd	107.15	6.56
pg–tgo	72.72	4.92
Overjet (is–io)	5.75	2.60
Overbite (ii–io)	2.87	2.33
Width 6+6	42.04	3.01
Width 6–6	39.65	2.37
Angular morphological variables (degrees)		
n–s–ba	130.76	4.57
n–s–ar	123.66	4.56
s–n–sp	86.45	3.38
s–n–ss	80.95	3.27
s–n–sm	77.09	2.75
s–n–pg	77.72	3.04
ss–n–sm	3.86	2.15
ss–n–pg	3.22	2.69
NSL/NL	6.81	2.60
NSL/ML	32.16	5.66
NL/ML	25.34	5.48
ML/RL	124.78	6.74
ILs/NL	108.86	8.47
ILi/ML	95.48	6.77
pr–n–ss	2.00	1.13
CL/ML	72.24	4.52
Angular postural variables (degrees)		
NSL/VER	96.04	5.90
NL/VER	89.22	5.75
NSL/OPT	94.90	7.35
NSL/CVT	99.06	7.93
NL/OPT	88.09	7.37
NL/CVT	92.24	7.87
OPT/HOR	91.13	7.34
CVT/HOR	86.98	7.17
OPT/CVT	4.15	2.67

Table 3 Distribution of sequentially admitted pre-orthodontic children by Angle classification and age.

	Age in years							
	7	8	9	10	11	12	13	Total
Class I	3	3	4	4	4	4	5	27
Class II	5	9	10	6	8	6	16	60
Class III	0	1	0	0	0	0	0	1
Total	8	13	14	10	12	10	21	88

Table 4 Distribution of bite force by gender and age in 88 sequentially admitted pre-orthodontic children.

	Age in years							Bite force (Newton)
	7	8	9	10	11	12	13	Mean (SD)
Girls	276.8	368.2	296.4	302.7	366.9	392.6	425.8	355.3 (78.7)
Boys	368.1	366.9	327.4	343.4	376.9	415.4	387.9	370.4 (64.8)
Bite force (Newton)	322.5	367.9	314.1	319.0	369.4	404.0	402.4	362.2
Mean (SD)	(90.0)	(68.2)	(43.0)	(85.5)	(44.6)	(56.7)	(67.5)	(72.7)

SD, standard deviation

The maximum bite force for Angle Class I, II and III was compared by one-way ANOVA. Associations between maximum bite force and the variables describing craniofacial morphology, the number of erupted teeth, teeth in contact, age and head posture were assessed by Spearman rank order correlation coefficients. As the sample comprised boys and girls of different ages, each correlation significant at the $P < 0.05$ level was further tested for the possible effect of age by multiple linear regression analysis with stepwise backwards elimination. Furthermore, in order to test which parameters were most important for the magnitude of the bite force, a multiple linear regression analysis with stepwise backwards elimination was performed, with bite force as the dependent variable and the variables significantly correlated with bite force when tested for the effect of age as the independent variables.

Results

The children had, on average, 24.6 erupted primary and permanent teeth present with an average of 12.1 teeth in contact. The prevalence of malocclusion according to Angle's classification was 30.7 per cent Class I, 68.2 per cent Class II, and 1.1 per cent Class III (Table 3). The measurements of craniofacial morphology and head posture are presented in Table 2 and recordings of bite force in Table 4. Most of these variables were normally distributed, although a few showed a moderate deviation from normal distribution (overbite, NSL/CVT, NL/CVT).

The maximum bite force increased significantly with age in girls, with teeth in occlusal contact in boys, and with an increasing number of erupted teeth in both sexes. Bite force was lowest in subjects with an Angle Class III malocclusion, but this was not significant, as there was only one child with a Class III malocclusion [Angle Class I: 349.2 Newton (N) [standard deviation (SD) 87.6]; Class II: 369.3 N (SD 64.79); Class III: 288.3 N].

The results from the Spearman correlation analysis between bite force, age and craniofacial morphology, head posture, number of teeth present and in contact were generally moderate, the numerical values ranging from 0.33 to 0.55. There were no significant correlations between bite force and head posture. When the correlations were tested for the effect of age in boys, those that remained statistically significant were the number of teeth present, the number of teeth in contact, cranial base length (n–ba, n–ar), posterior face height (s–tgo, ar–tgo), vertical jaw relationship (NL–ML), mandibular inclination (NSL–ML), form (ML–RL) and length (pg–tgo), and inclination of the lower incisors (Ili–ML) (Table 5). Multiple regression analysis showed that the vertical jaw relationship ($P < 0.001$) and the number of erupted teeth ($P < 0.01$) were the most important factors for the magnitude of bite force in boys. When the correlations were tested for the effect of age in girls, the only one that remained statistically significant was the number of teeth present (Table 5). Multiple regression analysis showed that the number of erupted teeth ($P < 0.001$) was the most important factor for the magnitude of bite force in girls.

Discussion

With growth and development, the volume of mandibular elevator muscles and the resulting bite force increase with age and gender (Helle *et al.*, 1983; Bakke *et al.*, 1990; Kiliaridis *et al.*, 1993, 2003; Shiau and Wang, 1993;

Table 5 Significant correlations between bite force and craniofacial morphology, head posture, the number of teeth present and the number of teeth in contact when tested for the effect of age.

Variables	Boys	Girls
Number of teeth present	0.43**	0.48**
Number of teeth in contact	0.35*	ns
n–ba	0.39*	ns
n–ar	0.37*	ns
s–tgo	0.43**	ns
ar–tgo	0.39*	ns
pg–tgo	0.39*	ns
NSL/ML	–0.43**	ns
NL/ML	–0.54**	ns
ML/RL	–0.55**	ns
ILi/ML	0.33*	ns

*$P < 0.05$; **$P < 0.01$ (Spearman correlation); ns, not significant. Variables with no significant associations when tested for the effect of age in both genders have been deleted from the table.

Ingervall and Minder, 1997). In the present investigation, bite force also increased with age and development, as reported earlier, but only in girls, and in agreement with previous studies (Helkimo *et al.*, 1977; Bakke *et al.*, 1990; Ingervall and Minder, 1997), the magnitude of bite force was significantly associated with the number of erupted teeth and teeth in occlusal contact. There have been no previous reports of systematic results regarding bite force in different Angle Classes. In the present study, the lowest bite force was found in Angle Class III, although it was not significant, as only one subject had a Class III malocclusion.

In boys, but not in girls, there was a clear correlation between bite force and craniofacial morphology when tested for the effect of age with respect to cranial base length, posterior face height, vertical jaw relationship, mandibular inclination, form and length, and inclination of the lower incisors. Neither Proffit and Fields (1983) nor Ingervall and Minder (1997) found significant correlations between bite force and craniofacial morphology in children. However, in adults (Møller, 1966; Ringqvist, 1973; Ingervall and Helkimo, 1978; Proffit *et al.*, 1983; Weijs and Hillen, 1986; Bakke and Michler, 1991; Raadsheer *et al.*, 1999), a negative correlation was shown between bite force and vertical jaw relationship, mandibular inclination and form, and a positive correlation between bite force and posterior face height, which are all components in the rectangular craniofacial morphology. Furthermore, the findings by Ingervall and Thilander (1974) that high levels of maximal muscle activity in children were associated with a rectangular shape of the face were also in agreement with the present results in boys. One likely explanation for the difference in boys and girls could be the different growth intensity of the two genders in the present age group: the pre-puberal minimum occurs at an average age of 10.5 years and the puberal maximum at 12.5 years in girls, and at 11.5 and 14 years, respectively, in boys, with an individual variation of approximately 4 years (Björk, 1963; Björk and Helm, 1967). This indicates that the boys in the present study had a slower and more steady growth than the girls, possibly allowing for a greater influence on craniofacial morphology from masticatory and respiratory function.

As both bite force and head posture have been found to be related to craniofacial morphology in adults, some correlations might also exist between bite force and head posture in children. However, in the present study there was no direct or clear correlation between bite force and head posture. The only previous study that reported a direct relationship between bite force and head posture found a temporary increase in bite force during extension of the head as compared with the subject's natural head posture (Hellsing and Hagberg, 1990). This finding may just reflect a more comfortable biting position in relation to the design and height of the bite force transducer. In contrast, extremely extended head posture has also been associated with long-face morphology (Solow and Siersbæk-Nielsen, 1992), normally correlated with low bite force and a low level of maximal jaw elevator muscle activity (e.g. Møller, 1966; Proffit *et al.*, 1983). However, masticatory function, including bite force, has probably little influence on head posture in comparison with respiratory and swallowing functions. In adults there is a correlation during swallowing between the vertical dimension of the face, elevator activity, and the extent of tooth contact. As the swallowing activity is negatively correlated to the vertical dimension and positively correlated to tooth contact (Møller, 1966), less force is applied between the teeth in adults with long-face morphology. In addition, a long-term extension of the head in children with compromised upper airways, e.g. from enlarged tonsils or adenoid hypertrophy (Solow *et al.*, 1984; Behlfelt *et al.*, 1990; Solow, 1992), is correlated with a long-face morphology (Solow and Tallgren, 1976; Solow and Siersbæk-Nielsen, 1986, 1992) and may indirectly influence bite force over a long period of time if the obstruction of the upper airway is not removed.

Conclusions

In both genders, bite force was associated with dental development in terms of erupted teeth. Only in boys was there a clear correlation between bite force and craniofacial morphology. The vertical jaw relationship and the number of teeth present were the most important factors for the magnitude of bite force in boys. In girls, the most important factor was the number of teeth present, a gender difference which may be due to different growth intensity in the studied age group. Bite force did not vary with Angle classification, and no correlation between bite force and head posture was found.

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