

# Bite force in pre-orthodontic children with unilateral crossbite

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**SUMMARY** In the present study bite force was examined in pre-orthodontic children with unilateral posterior crossbite and compared with an age- and sex-matched control group. The sample comprised 52 children aged 7–13 years, 26 pre-orthodontic children with unilateral posterior crossbite (crossbite group), and 26 children with neutral occlusion (control group). Unilateral bite force was measured at the first molar by means of a pressure transducer. Furthermore, symptoms and signs of temporomandibular disorders (TMD) and number of teeth in contact in the intercuspal position (ICP) were recorded.

In both groups, the maximum bite force increased significantly with age and with increasing stages of dental eruption, but the bite force in both sexes did not differ significantly. There were no significant differences in bite force between sides, but this was significantly smaller in the crossbite group than in the controls ( $P < 0.001$ ). Regression analysis showed that stage of dental eruption ( $P < 0.001$ ), number of teeth in occlusal contact ( $P < 0.01$ ), and unilateral crossbite ( $P < 0.001$ ) were the only variables significantly correlated with bite force. The number of teeth in contact was significantly smaller in the crossbite group than in the controls ( $P < 0.05$ ) and the frequency of muscle tenderness was significantly higher in the crossbite group than in the controls ( $P < 0.05$ ). These results suggest that differences in the muscle function associated with unilateral crossbite lead to a significantly smaller bite force in the crossbite group compared with controls and this difference did not diminish with age and development. These findings indicate that early treatment of unilateral posterior crossbite is advisable to optimize conditions for function.

## Introduction

Posterior crossbite occurs in 8–17 per cent of the population, most frequently unilaterally (Helm, 1968, 1970; Foster and Hamilton, 1969; Kutin and Hawes, 1969; Day and Foster, 1971; Ingervall *et al.*, 1972; Thilander and Myrberg, 1973; Ravn, 1975; Kisling and Krebs, 1976; Kerosuo *et al.*, 1991).

In unilateral posterior crossbite the morphological relationship between the upper and lower dentition is altered, and the malocclusion is associated with asymmetrical muscular function. Previous studies have found increased activity in

the temporalis and masseter muscles on the crossbite side compared with the non-crossbite side and controls during resting posture, and a lower activity level on the crossbite side compared with the non-crossbite side and controls during maximal intercuspal bite and chewing (Troelstrup and Møller, 1970; Ingervall and Thilander, 1975; Michler *et al.*, 1987; Ferrario *et al.*, 1999). This asymmetrical function reflects different development of the elevator muscles on each side of the jaws. Thus, Kiliaridis *et al.* (2000) found that the thickness of the masseter muscle on the crossbite side was thinner than on the non-crossbite side.

The size of the masseter muscles is one of the main factors that influence the magnitude of bite

†Deceased

force (Van Spronsen *et al.*, 1989; Bakke *et al.*, 1993; Raadsheer *et al.*, 1999; Stephan *et al.*, 2000). Other factors, which influence muscle activity and the magnitude of bite force, are dental occlusion, in terms of occlusal support, and functional pain. Previous studies have found that subjects with temporomandibular disorders (TMD) generally have a lower maximum bite force than healthy subjects (Helkimo *et al.*, 1975; Bakke *et al.*, 1989; Sato *et al.*, 1999). Sato *et al.* (1999) also found that the occlusal support and contact area were smaller in subjects with TMD than in healthy subjects. Moreover, some studies have shown that unilateral posterior crossbite has been statistically associated with symptoms and signs of TMD, such as pain, headache, and muscle tenderness (Egermark-Eriksson *et al.*, 1983, 1990; Brandt, 1985; Riolo *et al.*, 1987; Kritsineli and Shim, 1992; Sonnesen *et al.*, 1998), which may relate to activity of masticatory muscle performance.

The above-mentioned studies showed associations between crossbite and parameters related to the muscles of mastication, i.e. asymmetrical muscle function, size of the masseter muscle and TMD on one side, and factors influencing the magnitude of the bite force, e.g. size of the masseter muscle, occlusal support, and TMD on the other. Since the same factors that influence bite force are associated with crossbite, there may be an association between unilateral posterior crossbite and bite force, but only one investigation in pre-orthodontic children has been performed (Sonnesen *et al.*, 1998). Those authors found a reduced bite force in children with unilateral crossbite. However, it was uncertain whether this association was an effect of age. The same

investigation also showed a high frequency of TMD symptoms and signs in children with crossbite.

The aims of the present study were, therefore:

1. To compare the maximum molar bite force in a group of pre-orthodontic children with crossbite (crossbite group) with an age-, stage of dental eruption-, and sex-matched control group with neutral or minor malocclusions who did not require orthodontic treatment.
2. To compare the occurrence of symptoms and signs of TMD and teeth in contact in the crossbite group with the findings in the control group.
3. To analyse associations between bite force, and the occurrence of the symptoms and signs of TMD, occlusal support, and crossbite in the whole group (crossbite and control group).

## Subjects

The sample comprised 52 Caucasian children, 26 pre-orthodontic children with crossbite (crossbite group) and 26 with neutral occlusion or minor malocclusion (control group) (Table 1). None of the children in the crossbite or control groups had craniofacial anomalies, systemic muscle, or joint disorders.

The crossbite group consisted of 13 girls and 13 boys aged 7–13 years (mean 9.35), admitted for orthodontic treatment at four Municipal Dental Health Services in Copenhagen and 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,

**Table 1** Distribution by sex, age, and stage of dental eruption in the crossbite group ( $n = 26$ ), which was identical to the matched control group ( $n = 26$ ).

Sex	Age in years							Stage of eruption (DS)				Total
	7	8	9	10	11	12	13	DS1	DS2	DS3	DS4	
Girls	3	4	5	0	1	0	0	6	7	0	0	13
Boys	2	2	2	1	1	0	5	3	4	3	3	13
Total	5	6	7	1	2	0	5	9	11	3	3	26

1995) by the orthodontic specialist in charge at the clinic concerned. In all children, the unilateral crossbite was accompanied by deviation of the lower dental arch midline to the crossbite side.

The control group consisted of 13 girls and 13 boys with a neutral occlusion or minor malocclusion who did not require orthodontic treatment according to the above-mentioned criteria for selection. All school children in Denmark are regularly seen by a dentist in the Municipal Dental Health Service. The control group was selected from children undergoing ordinary dental checks in the Municipal Dental Health Service in Copenhagen. The children were matched to the crossbite group with regard to age, gender, and stage of dental eruption (Table 1).

The study was approved by the Scientific-Ethical Committee for Copenhagen and Frederiksberg (Ref. no. KF 13-002/99).

## Methods

The study was based on the results from a clinical examination and a questionnaire. The crossbite was diagnosed by the orthodontist in charge at the clinic concerned, and the occlusion in the control group by one author (LS) and confirmed by the orthodontist. The same author, prior to orthodontic treatment, undertook the patient interview and the examination.

### *Registration of occlusion*

The occlusion and the stages of dental eruption were diagnosed according to Björk *et al.* (1964). Unilateral crossbite was recorded for the canine, premolar, and molar section, if the buccal cusp of the upper tooth occluded lingual to the buccal cusp of the corresponding lower tooth. The registration was made if at least one tooth was deviating and needed orthodontic treatment according to the above-mentioned criteria.

The stages of eruption were classified as:

- DS1 incisors erupting (early mixed dentition);
- DS2 incisors fully erupted (intermediate mixed dentition);
- DS3 canines or premolars erupting (late mixed dentition);

DS4 canines and premolars fully erupted (adolescent dentition).

### *Questionnaire and examination*

The questionnaire comprised a standardized interview of the child (Sonnesen *et al.*, 1998, 2001), consisting of questions related to functional disorders (difficulties in jaw opening and chewing and joint sounds) and pain (facial pain and headache) related to the masticatory system.

The standardized clinical examination (Sonnesen *et al.*, 1998, 2001) comprised registration of mandibular mobility and an evaluation of the temporomandibular joints (TMJs) with regard to clicking or grating sounds. Mobility was measured in whole millimetres between left central incisors on maximal opening, taking due account of the overbite. Joint sounds were classified as either clicking or grating sounds directly audible, audible by auscultation with a stethoscope, or noticeable as irregularities when palpated. Muscle tenderness was assessed for the anterior temporal and superficial masseter. Tenderness in these muscles was assessed on each side by unilateral palpation with firm pressure exerted by one or two fingers, and by a gradation of the response. Only tenderness that triggered reflex blinking or flinching (distinct/marked tenderness) was recorded (e.g. Bakke and Michler, 1991).

The 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.*, 1990a).

In order to assess the strength of the mandibular elevator muscles, the maximum unilateral bite force was measured in all subjects. The recordings were made at the first mandibular molars on each side by means of a pressure transducer (Flöystrand *et al.*, 1982) during 1–2 seconds maximal clenching, according to a standard procedure (Bakke *et al.*, 1989). 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. None of the children experienced any discomfort or pain during biting on the transducer, but subsequently some experienced fatigue or slight discomfort in the cheeks.

### *Reliability and calibration*

The reliability of the functional registration was determined by inter-observer examinations before, during, and after the data collection (Sonnesen *et al.*, 1998, 2001). Before the inter-observer examinations, LS was trained and calibrated with one of the other authors (MB), who is a specialist in stomatognathic physiology. All variables in the inter-observer examinations showed 'good' to 'perfect' agreement as assessed by the kappa coefficient (Cohen, 1960).

The reliability of the bite force measurements was determined by double recordings on 23 randomly selected children with an interval of 14 days (Sonnesen *et al.*, 2001). There was no significant difference between the two sets of measurements, and the method error (Dahlberg, 1940) of the individual double recordings with 2-week intervals was  $s(i) = 6$  per cent and the coefficient of reliability was 0.91 (Houston, 1983).

### *Statistical methods*

For the bite force in the two groups, effects of age, gender, stage of dental eruption, and number of teeth in contact were assessed by linear regression analyses. Differences in prevalence of symptoms and signs of TMD between the two groups were assessed by Fisher's exact test. Differences in the means of the bite force, number of erupted teeth, and number of teeth in contact, in, and between the two groups, were assessed by paired and unpaired *t*-tests. In the whole group, associations between bite force and the occurrence of each of the symptoms and signs of TMD, number of erupted teeth, and number of teeth in contact and crossbite were assessed by Spearman rank order correlation coefficients. A multiple linear regression analysis with stepwise backwards elimination was performed to determine the relationship between bite force as the dependent

variable and the variables that were significantly correlated with bite force as the independent variables. The normality of the distributions was assessed by the parameters of skewness and kurtosis, and by Shapiro–Wilks *W*-test. The results were considered to be significant at values below  $P < 0.05$ . The statistical analyses were performed using the SAS Statistical Programme Package (SAS Institute Inc., 1982, 1988).

## **Results**

### *Teeth in occlusal contact*

The children in the crossbite group had, on average, 23.8 (range 20.0–28.0) erupted primary and permanent teeth, with an average of 11.2 (range 4.0–16.0) teeth in contact. Fifteen children had unilateral crossbite on the right side and 11 on the left.

The children in the control group had, on average, 24.1 (range 20.0–28.0) erupted primary and permanent teeth, with an average of 13.1 (range 8.0–20.0) teeth in contact. The number of teeth in contact, i.e. the occlusal support, was significantly smaller in the crossbite group than in the control group ( $P < 0.05$ ).

### *Symptoms and signs of TMD*

The most prevalent symptom of TMD in the crossbite group (Table 2a) was recurrent headache at least once a week (15.4 per cent), while the most prevalent sign of TMD (Table 2b) was tenderness of the anterior temporal and superficial masseter muscles (15.4 per cent).

The most prevalent symptom of TMD in the control group (Table 2a) was weekly headache (7.7 per cent), while the only sign of TMD (Table 2b) was clicking of the joints (11.5 per cent).

Tenderness of the anterior temporal and superficial masseter muscles occurred significantly more frequently in the crossbite group than in the control group ( $P < 0.05$ ).

### *Bite force*

In both groups, the bite force increased significantly with age (Figure 1) and with

**Table 2a** Prevalence (per cent) of symptoms of TMD in the crossbite and control groups.

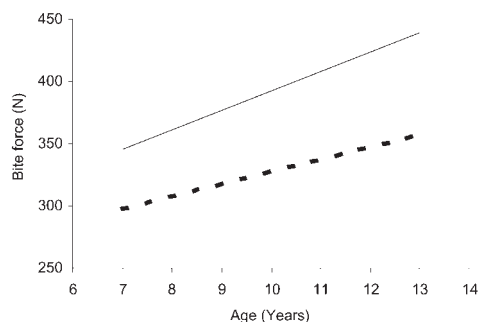
Variable	Crossbite group		Control group		<i>P</i>
	<i>n</i>	%	<i>n</i>	%	
Pain (weekly)					
Headache	4	15.4	2	7.7	NS
Facial pain	3	11.5	0	0.0	NS
Jaw mobility and chewing difficulty (weekly)					
Reported joint sounds	1	3.8	0	0.0	NS
Difficulty in opening	1	3.8	0	0.0	NS
Chewing difficulty	2	7.7	0	0.0	NS

NS: not significant (Fisher's exact test).

**Table 2b** Prevalence (per cent) of signs of TMD in the crossbite and control groups.

Variable	Crossbite group		Control group		<i>P</i>
	<i>n</i>	%	<i>n</i>	%	
Joint sounds recorded by examiner (directly audible or through stethoscope)					
Clicking	3	11.5	3	11.5	NS
Crepitation	0	0.0	0	0.0	NS
Palpatory tenderness of muscles (unilateral or bilateral)					
Anterior temporal	4	15.4	0	0.0	*
Superficial masseter	4	15.4	0	0.0	*
Reduced jaw mobility					
Maximal opening capacity (< 30 mm)	0	0.0	0	0.0	NS

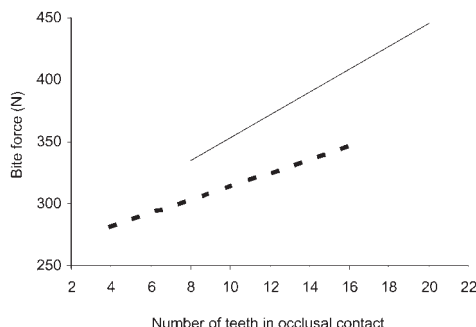
\* $P < 0.05$ ; NS: not significant (Fisher's exact test).



**Figure 1** Relationships between maximum molar bite force and age in children with and without crossbite. Solid line: regression line for controls  $y = 15.529x + 237.1$ ,  $P < 0.01$ . Dotted line: regression line for crossbite group  $y = 10.061x + 226.97$ ,  $P < 0.05$ .

increasing stage of dental eruption. However, only in the control group was bite force significantly and positively correlated with the increasing number of teeth present and number of teeth in occlusal contact (Figure 2). There was no significant difference in bite force between gender in the two groups, nor were there significant differences between sides, i.e. right and left, or crossbite and non-crossbite side (Table 3).

The level of maximum bite force in the crossbite group was significantly smaller than in the control group (Table 3, Figure 1). The different increase of bite force with age in the two groups (Figure 1) was not significant.



**Figure 2** Relationships between maximum molar bite force and teeth in occlusal contact in children with and without crossbite. Solid line: regression line for controls  $y = 9.27x + 260.65$ ,  $P < 0.05$ . Dotted line: regression line for crossbite group  $y = 5.42x + 260.38$ , NS.

In the whole group, correlation analysis showed that age, stage of dental eruption, and number of teeth with occlusal contact were significantly positively correlated with bite force, while unilateral crossbite was significantly negatively correlated. The significant Spearman correlation coefficients were moderate, numerical values ranging from 0.37 to 0.45 (Table 4). Regression analysis showed that stage of dental eruption ( $P < 0.001$ ), number of teeth in occlusal contact ( $P < 0.01$ ), and unilateral crossbite ( $P < 0.001$ ) were the only variables significantly correlated with bite force.

## Discussion

### Teeth in occlusal contact

In the control group the number of erupted teeth and teeth in contact corresponded to reference (normal) material based on Danish school children

of the same age (Bakke *et al.*, 1990a). The level of maximum bite force in the control group also corresponded to reference material (Bakke *et al.*, 1990a). Thus, the control group in the present study was considered to be representative for the population in general of the same age.

In the crossbite group, the number of erupted teeth corresponded to the control group. However, the occlusal support, i.e. the number of teeth in contact, was lower in the crossbite group than in the control group. This finding has not previously been reported.

### Symptoms and signs of TMD

The most prevalent symptom in both groups was weekly headache (15.5 and 7.7 per cent, respectively). Compared with studies of children that represent the population in general with a prevalence ranging from 4 to 14 per cent (Nilner and Lassing, 1981; Heikinheimo *et al.*, 1989; Bakke *et al.*, 1990b), the frequency of reported weekly headache in the present subjects studied was within normal range. Only tenderness of the anterior temporal and masseter muscles occurred significantly more frequently in the crossbite group than in the control group. This is in agreement with previous investigations where unilateral crossbite was found to be associated with pain, headache, and muscle tenderness (Egermark-Eriksson *et al.*, 1983, 1990; Brandt, 1985; Riolo *et al.*, 1987; Kritsineli and Shim, 1992; Sonnesen *et al.*, 1998).

### Bite force

In agreement with previous studies in young children, there was no difference in bite force

**Table 3** Maximum molar bite force in the crossbite and control groups.

Bite force (N)	Crossbite			Control			
	Crossbite side	Non-crossbite side	Average	Right	Left	Average	<i>P</i>
Mean	321.7	320.3	321.0	386.2	378.3	382.2	***
SD	53.2	73.1	54.6	62.9	70.6	63.9	

\*\*\* $P < 0.001$  (unpaired *t*-test; crossbite versus control).



**Table 4** Significant correlations between bite force and age, stage of dental eruption (DS), number of teeth in contact, and crossbite in the whole group ( $n = 52$ ).

	Age	DS	Number of teeth in contact	Crossbite
Bite force	0.37**	0.41**	0.43**	-0.45***

\*\* $P < 0.01$ , \*\*\* $P < 0.001$  (Spearman correlation).

between genders (Lindquist and Ringquist, 1973; Helle *et al.*, 1983; Kiliaridis *et al.*, 1993) or sides (Lindquist and Ringquist, 1973; Helle *et al.*, 1983; Bakke *et al.*, 1989; Shiau and Wang, 1993; Ingervall and Minder, 1997). In agreement with earlier studies, the bite force in the present investigation increased with age and increasing stage of dental eruption (Helle *et al.*, 1983; Bakke *et al.*, 1990a; Kiliaridis *et al.*, 1993; Shiau and Wang, 1993; Ingervall and Minder, 1997). The level of maximum bite force in the crossbite group was significantly smaller than in the controls. Furthermore, the difference in the increase of bite force in the two groups did not diminish with age and development. It has previously been shown that early treatment of unilateral posterior crossbite leads to a symmetrical muscle function in treated subjects (Tsarapatsani *et al.*, 1999). Therefore, the present findings support the view that early treatment is advisable to optimize conditions for function and development.

In the crossbite group there was no significant difference between maximum molar bite force at the crossbite and the non-crossbite side. This is surprising, since Kiliaridis *et al.* (2000) found that the masseter muscle on the crossbite side was thinner than on the non-crossbite side. Since one of the factors that determines maximum bite force is the size of the masseter muscle (Van Spronsen *et al.*, 1989; Bakke *et al.*, 1993; Raadsheer *et al.*, 1999; Stephan *et al.*, 2000), it would have been expected that the bite force on the non-crossbite side would be greater than on the crossbite side. On the other hand, mandibular elevation is a bilateral action. An example is seen in patients with complete

unilateral paralysis of the jaw elevator muscles, where it is still possible to obtain low levels of molar bite force on the side with complete paralysis (166 N versus 238 N, unreported data). Therefore, the magnitude of bite force on the right and left side is not independent. This is probably the main reason why it is not possible to detect any differences between crossbite and non-crossbite sides.

Previous research has found that the magnitude of bite force is also strongly associated with occlusal support (Helkimo *et al.*, 1977; Bakke *et al.*, 1990a; Ingervall and Minder, 1997). Similarly, regression analysis in the present study showed that the magnitude of the maximum bite force was significantly related to the stage of dental eruption, the number of teeth in occlusion, and unilateral posterior crossbite. The number of teeth in contact was also significantly smaller in the crossbite group. Only one study has found a relationship between bite force and unilateral posterior crossbite in children (Sonnesen *et al.*, 1998), but is was uncertain whether this relationship was due to the effect of age. However, the results of the present investigation have now confirmed the relationship between low bite force and unilateral posterior crossbite. An explanation for this relationship could be that subjects with unilateral crossbite have altered muscle activity and asymmetrical muscle function compared with subjects with neutral occlusion and more tooth contacts (Troelstrup and Møller, 1970; Ingervall and Thilander, 1975; Michler *et al.*, 1987; Bakke *et al.*, 1990a; Ingervall and Minder, 1997; Ferrario *et al.*, 1999).

## Conclusions

The present study suggests that differences in muscle function associated with the unilateral crossbite lead to a significantly smaller bite force compared with bite-force values in the control group, and this difference did not diminish with age and development. These findings indicate that early treatment of functional unilateral posterior crossbite is advisable to optimize conditions for function and development.

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