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Masticatory muscle thickness, bite force, and occlusal contacts in young children with unilateral posterior crossbite

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SUMMARY Few investigations have evaluated the characteristics of functional and structural malocclusion in young children. Thus, the aim of this study was to assess the ultrasonographic thickness of the masseter and anterior portion of the temporalis muscles, the maximum bite force, and the number of occlusal contacts in children with normal occlusion and unilateral crossbite, in the primary and early mixed dentition. Forty-nine children (26 males and 23 females) was divided into four groups: primary-normal occlusion (PNO), mean (PNO) age 58.67 months; primary-crossbite (PCB), mean age 60.50 months; mixed-normal occlusion (MNO), mean age 72.85 months; and mixed-crossbite (MCB), mean age 71.91 months. Thickness was evaluated with the muscles at rest and during maximal clenching, and comparison was made between the right and left side (normal occlusion), and between the normal and crossbite side (crossbite). The results were analysed using Pearson's correlation, paired and unpaired *t*-test, and Mann–Whitney ranked sum test.

The anterior temporalis thickness at rest was statistically thicker for the crossbite side than the normal side in the MCB group ($P = 0.0106$). A statistical difference in bite force and the number of occlusal contacts was observed between the MNO and MCB groups, with greater values for the MNO subjects ($P < 0.05$). Masseter muscle thickness showed a positive correlation with bite force, but the anterior temporalis thickness in the PCB and MCB groups was not related to bite force. Masticatory muscle thickness and bite force did not present a significant correlation with occlusal contacts, weight, or height. It was concluded that functional and anatomical variables differ in the early mixed dentition in the presence of a malocclusion and early diagnosis and treatment planning should be considered.

Introduction

A posterior crossbite is one of the most prevalent malocclusions in the early dentition stage and is reported to occur with a prevalence of between 8 and 22 per cent, depending on the population sampled (Foster and Hamilton, 1969; Egermark-Eriksson *et al.*, 1990; da Silva Filho *et al.*, 2003; Keski-Nisula *et al.*, 2003). This malocclusion has been associated with asymmetrical growth of the hard tissues and muscular function, as a difference between the activity of the temporalis and masseter muscles on the crossbite and non-crossbite sides, and a significantly smaller bite force in crossbite subjects in the mixed dentition (Troelstrup and Møller, 1970; Ingervall and Thilander, 1975; Pinto *et al.*, 2001; Sonnesen *et al.*, 2001). Malocclusion and asymmetrical function reflect asymmetric development of these muscles (van Keulen *et al.*, 2004) and appropriate treatment seems to normalize muscle function (Tsarapatsani *et al.*, 1999; Yawaka *et al.*, 2003). In addition, occlusal contacts promote mandibular stability at maximal intercuspation (Rodrigues *et al.*, 2003), and have an influence on chewing function (Owens *et al.*, 2002) and on masticatory muscle activity (Ferrario *et al.*, 2002).

Ultrasound scanning (US) enables dynamic visualization of the muscles of the head and neck (Emshoff *et al.*, 1999; Kiliaridis *et al.*, 2003), and it is an accurate and rapid method for measuring the thickness of superficial muscles, such as the masseter and temporalis, without known adverse effects (Emshoff *et al.*, 2002). Computerized tomography (CT; van Spronsen *et al.*, 1989; Katsumata *et al.*, 2004) and magnetic resonance imaging (MRI; van Spronsen *et al.*, 1989; Raadsheer *et al.*, 1994; Zanoteli *et al.*, 2002) are common diagnostic methods for the evaluation of cross-sectional areas and masticatory muscle volume. However, CT shows cumulative biological effects, and MRI poses a problem in terms of clinical availability and cost.

Bite force has an influence on muscle efficiency and development of masticatory function (Ingervall and Helkimo, 1978; Braun *et al.*, 1995). The size of the masticatory muscles, dental occlusion, facial morphology, and functional pain are the main factors that influence the magnitude of bite force (van Spronsen *et al.*, 1989; Ingervall and Minder, 1997; Raadsheer *et al.*, 1999; Sonnesen *et al.*, 2001). Furthermore, bite force increases with teeth in occlusal contact, with the increasing number of erupted teeth, and with the stages of dental eruption (Sonnesen *et al.*, 2001; Sonnesen and Bakke, 2005).

After establishment of the primary occlusion, there is a period of relative stability with few changes occurring until the beginning of the mixed dentition (Tsujino and Machida, 1998), but increased asymmetry can occur in the mixed dentition period (Slaj *et al.*, 2003). After that period, dental arch forms and, consequently, the occlusion, begin to change systematically due to tooth movement and growth of the supporting bone (Ross-Powell and Harris, 2000), determining different characteristics between the primary and the early mixed dentition. It is known that the status of the primary occlusion has an influence on the development of the permanent dentition, both functionally and morphologically, as orthodontic treatment in the primary dentition serves as a basis for physiological development of the dentition and craniofacial growth (Mauck and Trankmann, 1998). Nevertheless, in subjects with malocclusions, decisions regarding timing, duration, and prognosis of treatment should be based on knowledge of the growth and function of the orofacial structures (Oueis *et al.*, 2002).

Considering the different functional and morphological characteristics in the primary and early mixed dentitions, and the controversies about when or even whether to treat an orthodontic problem in the primary dentition (Chate, 2000; Timms, 2000), the aim of this study was to investigate the morphological and functional aspects of unilateral posterior crossbite, evaluating the thickness of the masticatory muscles, maximal bite force, and occlusal contacts among children in the primary and early mixed dentition.

Materials and methods

The study comprised 49 children (26 males and 23 females) aged 3.5–7 years, who were to start dental treatment at the Department of Pediatric Dentistry, Dental School of Piracicaba, State University of Campinas. The children and their parents consented to participate in the study, and the research was approved by the Ethics Committee of that Dental School (protocol nos. 147/2001 and 148/2002).

Healthy subjects were selected after a complete anamnesis and clinical examination, verifying the presence of all teeth without anomalies and alterations of form, structure, or number, and the normality of the oral tissues. Morphological examination of the occlusion verified the relationship of the primary second molars; bucco-lingual relationship of the molars, canine, and incisors; antero-posterior relationship of the canines; overjet; overbite (Foster and Hamilton, 1969; Keski-Nisula *et al.*, 2003); and the stage of the dentition: primary or early mixed (Sonnesen *et al.*, 2001). Thus, the children were divided into four groups, according to the stage and type of occlusion: primary-normal occlusion (PNO; five girls and ten boys, mean age 58.67 months), primary-crossbite (PCB; four girls and six boys, mean age 60.50 months), mixed-normal occlusion (MNO; six girls and seven boys, mean age 72.85 months), and mixed-crossbite (MCB; eight girls and three boys, mean age 71.91 months). Children with dental caries and/or restorations that could compromise cervico-occlusal and mesio-distal tooth dimensions and systemic disturbances had been excluded, before selection. Those selected for the PNO and MNO groups did not present signs or symptoms of temporomandibular joint dysfunction or midline deviation. Only subjects with a functional posterior crossbite or a crossbite resulting from dental inclination were selected. Children with a bilateral skeletal crossbite were not considered.

For recordings of muscle thickness and occlusal contacts, the dental arches were divided into right and left (groups with normal occlusion) and normal and crossbite (groups with crossbite) sides. Body weight and height were determined and correlated with the thickness of the masticatory muscles and bite force.

Ultrasound imaging

The thickness of the masseter and anterior portion of the temporalis muscle were assessed bilaterally by US (Just Vision Toshiba™, Otawara, Japan; 56-mm/10-MHz linear transducer), and the image was measured directly on screen with an accuracy of 0.1 mm. For each side (left and right/normal and crossbite), US imaging was assessed with the subject seated in an upright position, with the head in natural posture, under two different conditions: with the muscles relaxed (resting) and during maximum clenching (maximum intercuspal position). The imaging and measurements were performed three times, with an interval of at least 2 minutes between measurements, using an airtight inert gel on the skin surface, and the thickness per side was calculated as the average of the three measurements. The locations for US imaging were determined by palpation, following the orientations: masseter—a level halfway between the zygomatic arch and gonial angle—and anterior portion of the temporalis muscle—in front of the anterior border of the hairline. During the recordings, the transducer was placed perpendicular to the direction of the muscle fibres.

Bite force measurements

Maximum bilateral bite force was determined with a pressure transducer which was constructed with a flexible tube connected to a sensor element (Motorola MPX5700, Austin, Texas, USA). A computer and software (QBASIC, MSDOS) were used for reading the pressure change in Basic language and data were transferred to Excel™ (Microsoft). The values were obtained in pounds per square inch and were later converted into Newtons, taking into account the area of the tube, since force is equal to pressure × area.

The recordings were undertaken three times, with an interval of at least 2 minutes between each and the tube was placed bilaterally on the primary molars. The subjects, seated in an upright position with the head in natural posture, were instructed to bite as forcefully as possible. The difference between the minimum and maximum values for each evaluation was calculated and bite force was determined as the average of the three measurements (with an accuracy of 0.1 N).

Occlusal contacts

After prophylaxis and drying of all teeth, occlusal contacts were assessed using articulating film (Accufilm II, Parkell™, Farmingdale, New York, USA), while the child being examined was seated in a dental chair in a semi-supine position. The films were placed on occlusal surfaces bilaterally and the child was asked to occlude at maximum intercuspation position (Rodrigues *et al.*, 2003). The occlusal contacts of the upper and lower primary molars were then transferred to an occlusalgraph.

Statistical analysis

Data were submitted to descriptive statistical analysis, and each stage of the dentition (primary/early mixed) was analysed separately. The thickness of the masseter and anterior temporalis muscle and the number of occlusal contacts were compared between sides (right and left/normal and crossbite) using a paired *t*-test. Differences in the thickness of the muscles between the groups with normal occlusion and crossbite were evaluated using analyses of variance (ANOVA).

Differences in the means of the bilateral bite forces and the total number of occlusal contacts (sum of the sides) between the groups with normal occlusion and crossbite were assessed by Mann–Whitney ranked sum test and unpaired *t*-test, respectively. Pearson's coefficient was used to determine correlations among the variables: thickness, bite force, weight, and height. The significance level was set at $P \leq 0.05$.

Measurement errors

The errors of measurement (S_e) for the thickness of the masticatory muscles (only the left side was chosen to serve as an example), bite force, and the number of occlusal contacts were assessed on repeated measurements on two separate occasions (m1, m2) of 15 randomly selected subjects (n), using Dahlberg's formula: $S_e = \sqrt{\sum (m1-m2)^2/2n}$ (Dahlberg, 1940). The results are shown in Table 1.

Table 1 Error of the method (S_e) for ultrasonography of the masseter and anterior portion of the temporalis muscle thickness (mm), bite force (N), and occlusal contacts assessed on repeated measurements of 15 subjects.

Muscle thickness	S_e	%
Left masseter/resting	0.53	5.78
Left masseter/maximal intercuspal position	0.36	3.18
Left temporalis/resting	0.09	3.63
Left temporalis/maximal intercuspal position	0.15	4.38
Bite force	16.28	6.55
Occlusal contacts—right side	3.41	14.67
Occlusal contacts—left side	3.64	13.75

% = (S_e/mean) × 100.

Results

Table 2 shows the averages and standard deviations of muscle thickness for all groups. ANOVA did not show significant statistical differences between the PNO and PCB groups, or between the MNO and MCB groups. On comparing the left and right sides in normal occlusion, there were no significant statistical differences for the thickness of the masseter and anterior temporalis muscles, during rest or in maximum intercuspation. However, in the MCB group, the anterior temporalis muscle at rest was statistically thicker on the normal side than on the crossbite side.

The magnitude of maximum bite force for the MCB group was significantly lower than for the MNO group. This difference was not present between the groups in the primary dentition (Table 3). For the number of occlusal contacts, the comparison between the sides did not show a statistical difference in all groups, but the sum of dental occlusal contacts was significantly smaller in the MCB group than in the MNO group (Table 3).

The thickness of the masseter muscle was positively correlated with bite force in all groups, and some correlation coefficients were statistically significant (Table 4). However, the anterior temporalis muscle was found only to relate positively with bite force in the groups with normal occlusion. The correlation coefficients of the variables: muscle thickness, bite force, weight, and height are shown in Table 5. The results showed weak correlation between the body variables and muscle thickness and body variables and bite force in all groups.

Discussion

US is a reliable and safe method to investigate superficial muscles *in vivo*, as shown in previous child studies (Raadsheer *et al.*, 1996; Rasheed *et al.*, 1996; Kiliaridis *et al.*, 2003). Raadsheer *et al.* (1994), who compared masseter muscle thickness measured by US and MRI, found no difference in thickness between the left and right muscles, but a high correlation between the two techniques. Thus, US can be considered to be an accurate and reproducible method for measuring masseter thickness *in vivo*. It allows for large-scale longitudinal studies of changes in jaw muscle thickness during growth in relation to the change in the biomechanical properties of the masticatory muscles.

The method error values were low, and similar to those found by Raadsheer *et al.* (1996, 1999, 2004). The error for relaxed masseter muscle thickness was higher than that for the contracted state and for the anterior temporalis muscle (Table 1). The lower reproducibility for the relaxed than for the contracted thickness was considered to be the result of

Table 2 Average (mm) and standard deviation for ultrasonographic thickness of the masseter and anterior portion of the temporalis muscle during maximum intercuspation (MI) and at rest (RE) in the primary-normal occlusion (PNO), primary-crossbite (PCB), mixed-normal occlusion (MNO), and mixed-crossbite (MCB) groups.

Group	Masseter				Temporalis			
	Left side/normal side		Right side/crossbite side		Left side/ normal side		Right side/crossbite side	
	RE	MI	RE	MI	RE	MI	RE	MI
PNO	9.36 ± 1.06	10.92 ± 1.06	9.38 ± 0.77	11.15 ± 0.95	2.59 ± 0.14	3.52 ± 0.26	2.54 ± 0.18	3.42 ± 0.30
PCB	9.78 ± 0.94	11.43 ± 1.40	9.76 ± 0.79	11.25 ± 1.13	2.59 ± 0.19	3.24 ± 0.23	2.65 ± 0.21	3.38 ± 0.26
MNO	10.54 ± 0.98	12.16 ± 1.29	10.37 ± 0.97	12.17 ± 1.21	2.76 ± 0.26	3.52 ± 0.33	2.72 ± 0.23	3.49 ± 0.30
MCB	10.13 ± 1.16	11.88 ± 1.33	9.88 ± 1.25	11.67 ± 1.35	2.63[a] ± 0.21	3.44 ± 0.39	2.68[b] ± 0.18	3.46 ± 0.31

[a ≠ b] ($P = 0.0106$, paired *t*-test).

Table 3 Average and standard deviation for the number of occlusal contacts and maximum bite force (N) in the primary-normal occlusion (PNO), primary-crossbite (PCB), mixed–normal occlusion (MNO), and mixed-crossbite (MCB) groups.

Normal occlusion					Crossbite				
Group	Left side	Right side	Total contacts	Bite force (N)	Group	Crossbite side	Normal side	Total contacts	Bite force (N)
PNO	11.27 ± 4.46	10.33 ± 4.15	21.60 ± 7.23	180.54 ± 41.28	PCB	10.00 ± 4.35	8.50 ± 3.75	18.50 ± 6.54	180.19 ± 48.68
MNO	15.15 ± 7.49	13.69 ± 5.30	28.85[a] ± 11.26	254.25[c] ± 28.92	MCB	10.09 ± 3.83	10.64 ± 4.48	20.73[b] ± 7.25	194.50[d] ± 45.54

[a ≠ b] ($P \leq 0.05$, unpaired *t*-test); [c ≠ d] ($P = 0.0018$, Mann–Whitney ranked sum test).

the muscle being more susceptible to the pressure of the transducer (Kiliaridis *et al.*, 2003), mainly for the masseter muscle because the transducer is held against the cheek (Emshoff *et al.*, 2002). Thus, some procedures were carried out during the examination, with the aim of avoiding errors (Kiliaridis and Kalebo, 1991; Kiliaridis *et al.*, 2003). The transducer was placed directly over the muscle region, with gel applied to both surfaces to reduce tissue compression, and orientated perpendicular to the ramus, since scanning the muscle obliquely would increase its thickness. Furthermore, the high ultrasonic frequency of the probe produces clearer images (Kubota *et al.*, 1998).

The masseter muscle thickness ranged from 9.36 to 10.54 mm in the relaxed position, and from 10.92 to 12.17 mm in maximum intercuspation. For the anterior portion of the temporalis muscle, the values ranged from 2.54 to 2.76 and 3.24 to 3.52 mm, respectively. Rasheed *et al.* (1996) reported similar results and they also included children in their study, while in adults, Raadsheer *et al.* (1999) found higher values for the temporalis muscle thickness at rest (mean 14.35 mm). The discrepancies among the values in different studies may be due to differences between the samples, the location of the measuring points, and the use of different imaging techniques (Benington *et al.*, 1999).

The groups with a normal occlusion did not show significant difference in masseter and temporalis muscle thickness between the right and left sides (Table 2), which is in agreement with the findings of Raadsheer *et al.* (1996). On comparing the normal and crossbite sides, the MCB group showed a statistically significant difference for the anterior portion of the temporalis muscle at rest, i.e. a thicker anterior temporalis muscle on the crossbite side (Table 2). Troelstrup and Møller (1970), in a study of children with posterior crossbite, reported higher activity of the posterior temporalis at rest on the crossbite side. In subjects with a unilateral posterior crossbite, the condyles on the crossbite side are positioned in a more superior and posterior position in the glenoid fossae than on the normal side (Myers *et al.*, 1980). Since function influences the dimensions of the muscles (Raadsheer *et al.*, 1996; Tuxen *et al.*, 1999), the postural asymmetry that exists in the presence of a malocclusion (Ingervall and Thilander, 1975) may contribute to differences in muscle thickness. Thus, subjects with other types of malocclusion, such as an open or deep bite in the mixed dentition, show a significantly thicker anterior temporalis muscle than those with normal occlusion (Rasheed *et al.*, 1996). There was no statistical difference in masseter muscle thickness between the crossbite and normal side in the PCB and MCB groups. Nevertheless, Kiliaridis *et al.* (2000) observed that among children with a unilateral crossbite, the masseter muscle was significantly thinner on the crossbite side, and after treatment of the malocclusion, the difference was not statistically significant. Their sample,

Table 4 Correlation coefficients (*r*) of masseter and anterior portion of the temporalis muscle thickness with bite force during rest (RE) and at maximal intercuspation (MI) in the primary-normal occlusion (PNO), primary-crossbite (PCB), mixed-normal occlusion (MNO), and mixed-crossbite (MCB) groups.

	Masseter				Temporalis			
	Left side/normal side		Right side/crossbite side		Left side/normal side		Right side/crossbite side	
	RE	MI	RE	MI	RE	MI	RE	MI
PNO	0.35	0.23	0.58*	0.60*	0.21	0.63*	0.33	0.62*
PCB	0.40	0.73*	0.60	0.60	−0.70*	−0.17	−0.74*	0.05
MNO	0.59*	0.71*	0.54	0.51	0.32	0.05	0.14	0.10
MCB	0.33	0.14	0.26	0.30	−0.47	−0.34	−0.46	−0.43

*$P \leq 0.05$ (Pearson's correlation).

Table 5 Correlation coefficients (*r*) of masseter and anterior portion of the temporalis muscle thickness and bite force with weight (W) and height (H) during rest (RE) and at maximal intercuspation (MI) in the primary-normal occlusion (PNO), primary-crossbite (PCB), mixed-normal occlusion (MNO), and mixed-crossbite (MCB) groups.

		Bite force	Masseter				Temporalis			
			Left side/normal side		Right side/crossbite side		Left side/normal side		Right side/crossbite side	
			RE	MI	RE	MI	RE	MI	RE	MI
PNO	W	0.09	0.22	0.22	0.31	0.20	0.31	0.41	−0.05	0.25
	H	0.33	0.06	0.14	0.26	0.27	0.14	0.54*	0.05	0.26
PCB	W	0.37	0.49	0.38	0.56	0.43	0.02	0.08	0.00	0.21
	H	0.44	0.77*	0.61	0.75*	0.64*	−0.15	0.27	0.07	0.40
MNO	W	0.42	0.01	0.18	0.15	0.11	−0.10	−0.17	−0.28	−0.18
	H	0.34	−0.05	0.06	0.05	0.02	−0.29	−0.31	−0.34	−0.49
MCB	W	0.30	0.33	0.34	0.35	0.33	0.46	0.43	0.45	0.31
	H	0.08	0.16	0.24	0.26	0.26	0.53	0.40	0.48	0.24

*$P \leq 0.05$ (Pearson's correlation).

however, included children older than those in the present study.

According to Planas (1997), the crossbite side presents a greater number of occlusal contacts in function, being the preferred chewing side. Nevertheless, in the present investigation, in subjects with a unilateral crossbite, these characteristics were not observed, contrary to Troelstrup and Møller (1970), Ingervall and Thilander (1975), Tsarapatsani *et al.* (1999), and Sonnesen *et al.* (2001).

The literature on occlusal forces presents a range of results, possibly, because of the many factors that could interfere in the recording of bite force, such as muscle thickness, facial morphology, age, gender, and condition of the dentition and temporomandibular joints (Ingervall and Minder, 1997; Raadsheer *et al.*, 1999; Sonnesen *et al.*, 2001; Fernandes *et al.*, 2003; Yawaka *et al.*, 2003; Sonnesen and Bakke, 2005); moreover, a transducer placed in a more posterior position, yields a large bite force in adults (Braun *et al.*, 1996), as well as in children (Karibe *et al.*, 2003). The transducer used in this study was constructed of a flexible material with a diameter of 10 mm, which gave a sensitive response to deformation, an important characteristic for a bite force recording system (Braun *et al.*, 1995; Rentes *et al.*, 2002; Fernandes *et al.*, 2003). Furthermore, multiple recordings are more reliable than a single recording, and children must be trained before evaluation. The method error found in this study (Table 1) was considered acceptable, when compared with those of Raadsheer *et al.* (1999) and Sonnesen and Bakke (2005).

The level of maximum bite force in the MCB group was significantly lower than in the MNO group, but this difference was not observed between the groups in the primary dentition (Table 3). Rentes *et al.* (2002) and Yawaka *et al.* (2003) also found no significant difference in bite force between preschool children with and without a malocclusion, while Sonnesen *et al.* (2001) found a significantly smaller bite force in children with a unilateral crossbite in the mixed dentition that did not diminish with age and development. Their results also showed that there was no difference between the crossbite and the non-crossbite sides, indicating that the magnitude of bite force between the sides is not independent. Maximum bite force has been related to muscle efficiency and development of the masticatory complex. Therefore, a decrease in its magnitude may be reflected in growth and developmental alterations and a reduced masticatory performance (Braun *et al.*, 1995; García-Morales *et al.*, 2003).

A connection between form and function of the muscle was shown by Bakke *et al.* (1992), who used US to demonstrate the relationship between the measurements of masseter thickness and bite force in adults. The thickness of the masticatory muscles in young children with normal occlusion in the present study was positively related to the magnitude of bite force. For those with a crossbite, only the masseter muscle presented this relationship (Table 4). It is possible that there is an asymmetry in the activity of anterior temporalis muscle in the presence of a crossbite, as reported by Troelstrup and Møller (1970) and Ingervall and Thilander (1975). Previous studies have also shown that the dimensions of the muscle may indicate the amount of force that it is capable of producing (van Spronsen *et al.*, 1989; Raadsheer *et al.*, 1999). Tuxen *et al.* (1999) observed that the cross-sectional area of the masseter muscle fibres correlated positively with maximal bite force in adults. No studies in young children were found in the literature.

Gender differences among the variables were not evaluated, since it has been reported that differences in body variables become significant at puberty (Kiliaridis *et al.*, 1993; Raadsheer *et al.*, 1996; Sonnesen *et al.*, 2001), and the correlation between weight/height and bite force in young children is weak (Kiliaridis *et al.*, 1993; Rentes *et al.*, 2002; García-Morales *et al.*, 2003). Among older children and adults, there could be a difference in muscle strength between males and females, with males exhibiting higher values (Braun *et al.*, 1995; Ingervall and Minder, 1997; Raadsheer *et al.*, 1999). Raadsheer *et al.* (1999) found that the variation in bite force magnitude is mainly dependent on the variation in size of the masseter muscle and craniofacial morphology. Earlier studies have shown an increase in bite force with age and increasing stage of dental eruption (Ingervall and Minder, 1997; Sonnesen *et al.*, 2001; Sonnesen and Bakke, 2005). In the present study, the sample was distributed according to the stage of the dentition and the type of occlusion, aiming to reduce influencing factors. The findings demonstrated that the muscle thickness and the magnitude of bite force did not correlate with weight and height (Table 5). Therefore, other factors might influence the variables studied, such as the presence of malocclusion and the morphological characteristics of the dental arches.

The subjects in the MNO group showed a statistically significant increase in the number of occlusal contacts compared with the MCB group; the PNO group also presented a higher number of occlusal contacts in relation to the PCB group, but this was not significant (Table 3). Yawaka *et al.* (2003) also did not find any difference in the occlusal contact area between children with a normal occlusion and those with an anterior crossbite in the primary dentition. Sonnesen *et al.* (2001), however, at a later stage (mixed dentition), observed a statistical difference in the number of teeth in contact between the crossbite and the normal occlusion groups, i.e. the occlusal support was lower in the group with a posterior crossbite. Between adults with and without a malocclusion, areas of near occlusal contacts have been shown to be greater in subjects with a normal occlusion (Owens *et al.*, 2002). The number of completely erupted teeth was the same among the four groups studied, but in the mixed dentition, the presence of a malocclusion was shown to be a factor that influenced the number of occlusal contacts. The subjects in the MNO group showed the greatest number of occlusal contacts, which might be a result of the higher bite force that was also present in this group, physiological tooth wear with age, or the normal relationship of the dental arches.

It is difficult to record occlusal contacts, which is dependent on the child's co-operation, the physical state of the masticatory muscles, and the material used (Ingervall and Minder, 1997; Millstein and Maya, 2001). In this study, the children were trained before the examination to occlude in maximum intercuspation, and a thin articulating film was preferred instead of wax to avoid resistance and deviation of the mandible (Molligoda *et al.*, 1986; Millstein and Maya, 2001). Despite this, the assessment had inherent methodological limitations, with a measurement error of 13.75–14.67 per cent (Table 1); comparable data were not found in the literature. Therefore, it is advisable to regard these findings as preliminary.

In the present study, the subjects in the MNO and MCB groups presented differences in all variables studied, while those in the PNO and PCB groups did not show these asymmetries. This may be due to changes and functional adaptability that occur with age and development in the presence of malocclusion. In the primary dentition, a functional posterior crossbite is more frequent than a skeletal crossbite (da Silva Filho *et al.*, 2000, 2003) and, if not treated, leads to morphological alterations in the hard and soft tissues, including dental inclination, muscle thickness asymmetries, differences in the magnitude of bite force and dental support, changes in the masticatory cycle, and asymmetrical growth of the dental arches and temporomandibular joints (Tsarapatsani *et al.*, 1999; Pinto *et al.*, 2001; Sonnesen *et al.*, 2001; Throckmorton *et al.*, 2001).

Many authors support the importance of early treatment of malocclusions to recover normal growth and improve chewing efficiency, jaw movements, and activity of the circumoral muscles (de Boer and Steenks, 1997; Sonnesen *et al.*, 2001; da Silva Filho *et al.*, 2003; Yawaka *et al.*, 2003; van Keulen *et al.*, 2004). Tsarapatsani *et al.* (1999) observed that following treatment for a unilateral crossbite the children presented a symmetrical bite force and masticatory performance between the sides of the dental arches. Moreover, Kiliaridis *et al.* (2000) and Pinto *et al.* (2001) showed that treatment of this malocclusion leads to changes in growth and development of muscles and hard tissues, eliminating asymmetries. The correction of an anterior crossbite was also shown to improve bite force in preschool children (Yawaka *et al*., 2003). Malandris and Mahoney (2004), following a review of the literature, suggested that selective grinding of premature contacts of teeth is the only clinically proven treatment modality for posterior crossbite correction in the primary dentition, but is only indicated for mild forms of unilateral posterior crossbite associated with a functional shift.

Recognizing conditions which predispose young children to malocclusions is an important part of any comprehensive paediatric dental assessment, since the detection of these conditions in the primary dentition can allow either intervention or monitoring on an effective basis (Ngan and Fields, 1995). In this way, despite the reduced size of the sample, which could be considered as a limitation of the present study, if the components of the stomatognathic function are altered in the early stages, because of the presence of malocclusion, it is important to diagnose and treat this condition as soon as possible, in order to avoid further severe alterations.

Further studies are, however, needed to validate the findings of the present investigation, considering the effects of the appropriate interventions and also their implications in a larger sample.

Conclusions

The results found in the sample studied provided the following conclusions:

1. Masseter and anterior temporalis muscle thickness correlated with maximum bite force in the groups with normal occlusion.
2. Masticatory muscle thickness and bite force did not correlate significantly with the number of occlusal contacts, body weight, or height.
3. The early mixed dentition group with a posterior crossbite presented differences in functional and anatomical variables of the stomatognathic system, i.e. maximum bite force was significantly lower in the crossbite subgroup, who also exhibited significantly fewer occlusal contacts and a thicker anterior temporalis muscle on the crossbite side.

These findings suggest that early treatment of a posterior crossbite is advisable to ensure correct growth and development of the masticatory system.

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References

Bakke M, Tuxen A, Vilmann P, Jensen B R, Vilmann A, Toft M 1992 Ultrasound image of human masseter muscle related to bite force, electromyography, facial morphology, and occlusal factors. Scandinavian Journal of Dental Research 100: 164–171

Benington P C, Gardener J E, Hunt N P 1999 Masseter muscle volume measured using ultrasonography and its relationship with facial morphology. European Journal of Orthodontics 21: 659–670

Braun S, Bantleon H P, Hnat W P, Freudenthaler J W, Marcotte M R, Johnson B E 1995 A study of bite force, part 1: relationship to various physical characteristics. Angle Orthodontist 65: 367–372

Braun S, Hnat W P, Freudenthaler J W, Marcotte M R, Honigle K, Johnson B E 1996 A study of maximum bite force during growth and development. Angle Orthodontist 66: 261–264

Chate R 2000 Do we really want a quick fix? British Dental Journal 188: 177–186

Dahlberg G 1940 Statistical methods for medical and biological students. Interscience Publications, New York

da Silva Filho O G, Ferrari Jr F M, Aiello C A, Zopone N 2000 Correction of posterior crossbite in the primary dentition. Journal of Clinical Pediatric Dentistry 24: 165–180

da Silva Filho O G, Silva P R B, Rego M V N N, Capelozza Filho L 2003 Epidemiology of the posterior crossbite in the primary dentition. Jornal Brasileiro de Odontopediatria e Odontologia do Bebê 6: 61–68 (in Portuguese)

de Boer M, Steenks M H 1997 Functional unilateral posterior crossbite. Orthodontic and functional aspects. Journal of Oral Rehabilitation 24: 614–623

Egermark-Eriksson I, Carlsson G E, Magnusson T, Thilander B 1990 A longitudinal study on malocclusion in relation to signs and symptoms of cranio-mandibular disorders in children and adolescents. European Journal of Orthodontics 12: 399–407

Emshoff R, Bertram S, Strobl H 1999 Ultrasonographic cross-sectional characteristics of muscles of the head and neck. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics 87: 93–106

Emshoff R, Bertram S, Brandlmaier I, Scheiderbauer G, Rudisch A, Bodner G 2002 Ultrasonographic assessment of local cross-sectional dimensions of masseter muscle sites: a reproducible technique? Journal of Oral Rehabilitation 29: 1059–1062

Fernandes C P, Glantz P O, Svensson S A, Bergmark A 2003 A novel sensor for bite force determinations. Dental Materials 19: 118–126

Ferrario V F, Serrao G, Dellavia C, Caruso E, Sforza C 2002 Relationship between the number of occlusal contacts and masticatory muscle activity in healthy young adults. Cranio. The Journal of Craniomandibular Practice 20: 91–98

Foster T D, Hamilton M C 1969 Occlusion in the primary dentition. Study of children at 2 and one-half to 3 years of age. British Dental Journal 126: 76–79

García-Morales P, Buschang P H, Throckmorton G S, English J D 2003 Maximum bite force, muscle efficiency and mechanical advantage in children with vertical growth patterns. European Journal of Orthodontics 25: 265–272

Ingervall B, Helkimo E 1978 Masticatory muscle force and facial morphology in man. Archives of Oral Biology 23: 203–206

Ingervall B, Minder C 1997 Correlation between maximum bite force and facial morphology in children. Angle Orthodontist 67: 415–422

Ingervall B, Thilander B 1975 Activity of temporal and masseter muscles in children with a lateral forced bite. Angle Orthodontist 45: 249–258

Karibe H, Ogata K, Hasegawa Y, Ogihara K 2003 Relation between clenching strength and occlusal force distribution in primary dentition. Journal of Oral Rehabilitation 30: 307–311

Katsumata A, Fujishita M, Ariji Y, Ariji E, Langlais R P 2004 3D CT evaluation of masseter muscle morphology after setback osteotomy for mandibular prognathism. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics 98: 461–470

Keski-Nisula K, Lehto R, Lusa V, Keski-Nisula L, Varrela J 2003 Occurrence of malocclusion and need of orthodontic treatment in early mixed dentition. American Journal of Orthodontics and Dentofacial Orthopedics 124: 631–638

Kiliaridis S, Kalebo P 1991 Masseter muscle thickness measured by ultrasonography and its relation to facial morphology. Journal of Dental Research 70: 1262–1265

Kiliaridis S, Kjellberg H, Wenneberg B, Engström C 1993 The relationship between maximal bite force, bite force endurance, and facial morphology during growth. A cross-sectional study. Acta Odontologica Scandinavica 51: 323–331

Kiliaridis S, Katsaros C, Raadsheer M C, Mahboubi P H 2000 Bilateral masseter muscle thickness in growing individuals with unilateral crossbite. Journal of Dental Research 79: 497 (Abstract)

Kiliaridis S, Georgiakaki I, Katsaros C 2003 Masseter muscle thickness and maxillary dental arch width. European Journal of Orthodontics 25: 259–263

Kubota M *et al*. 1998 Maxillofacial morphology and masseter muscle thickness in adults. European Journal of Orthodontics 20: 535–542

Malandris M, Mahoney E K 2004 Aetiology, diagnosis and treatment of posterior cross-bites in the primary dentition. International Journal of Paediatric Dentistry 14: 155–166

Mauck C, Trankmann J 1998 Influence of orthodontic treatment in the primary dentition upon development of the dentition and craniofacial growth. Journal of Orofacial Orthopedics 59: 229–236

Millstein P, Maya A 2001 An evaluation of occlusal contact marking indicators. A descriptive quantitative method. Journal of the American Rental Association 132: 1280–1286.

Molligoda M A, Berry D C, Gooding P G 1986 Measuring diurnal variations in occlusal contact areas. Journal of Prosthetic Dentistry 56: 487–492

Myers D R, Barenie J T, Bell R A, Williamson E H 1980 Condylar position in children with functional posterior crossbites: before and after crossbite correction. Pediatric Dentistry 2: 190–194

Ngan P, Fields H 1995 Orthodontic diagnosis and treatment planning in the primary dentition. Journal of Dentistry for Children 62: 25–33

Oueis H, Ono Y, Takagi Y 2002 Prediction of mandibular growth in Japanese children age 4 to 9 years. Pediatric Dentistry 24: 264–268

Owens S, Buschang P H, Throckmorton G S, Palmer L, English J 2002 Masticatory performance and areas of occlusal contact and near contact in subjects with normal occlusion and malocclusion. American Journal of Orthodontics and Dentofacial Orthopedics 121: 602–609

Pinto A S, Buschang P H, Throckmorton G S, Chen P 2001 Morphological and positional asymmetries of young children with functional unilateral posterior crossbite. American Journal of Orthodontics and Dentofacial Orthopedics 120: 513–520

Planas P 1997 Reabilitação Neuroclusal, 2nd edn. Meds, Rio de Janeiro

Raadsheer M C, van Eijden T M, van Spronsen P H, van Ginkel F C, Kiliaridis S, Prahl-Andersen B 1994 A comparison of human masseter muscle thickness measured by ultrasonography and magnetic resonance imaging. Archives of Oral Biology 39: 1079–1084

Raadsheer M C, Kiliaridis S, van Eijden T M, van Ginkel F C, Prahl-Andersen B 1996 Masseter muscle thickness in growing individuals and its relation to facial morphology. Archives of Oral Biology 41: 323–332

Raadsheer M C, van Eijden T M, van Ginkel F C, Prahl-Andersen B 1999 Contribution of jaw muscle size and craniofacial morphology to human bite force magnitude. Journal of Dental Research 78: 31–42

Raadsheer M C, van Eijden T M G J, van Ginkel F C, Prahl-Andersen B 2004 Human jaw muscle strength and size in relation to limb muscle strength and size. European Journal of Oral Sciences 112: 98–405

Rasheed S A, Prabhu N T, Munshi A K 1996 Electromyographic and ultrasonographic observations of masseter and anterior temporalis muscles in children. Journal of Clinical Pediatric Dentistry 20: 127–132

Rentes A M, Gavião M B, Amaral J R 2002 Bite force determination in children with primary dentition. Journal of Oral Rehabilitation 29: 1174–1180

Rodrigues C H, Mori M, Rodrigues A A, Nascimento E J, Gonçalves F M, Santana K C 2003 Distribution of different types of occlusal contacts at maximal intercuspal position in deciduous dentition. Journal of Clinical Pediatric Dentistry 27: 339–346

Ross-Powell R E, Harris E F 2000 Growth of the anterior dental arch in black American children: a longitudinal study from 3 to 18 years of age. American Journal of Orthodontics and Dentofacial Orthopedics 118: 649–657

Slaj M, Jezina M A, Lauc T, Rajic-Mestrovic S, Miksic M 2003 Longitudinal dental arch changes in the mixed dentition. Angle Orthodontist 73: 509–514

Sonnesen L, Bakke M 2005 Molar bite force in relation to occlusion, craniofacial dimensions, and head posture in pre-orthodontic children. European Journal of Orthodontics 27: 58–63

Sonnesen L, Bakke M, Solow B 2001 Bite force in pre-orthodontic children with unilateral crossbite. European Journal of Orthodontics 23: 741–749

Throckmorton G S, Buschang P H, Hayasaki H, Pinto A S 2001 Changes in the masticatory cycle following treatment of posterior unilateral crossbite in children. American Journal of Orthodontics and Dentofacial Orthopedics 120: 521–529

Timms D 2000 Quick fix? British Dental Journal 189: 123–124 (Letter)

Troelstrup B, Møller E 1970 Electromyography of the temporalis and masseter muscles in children with unilateral cross-bite. Scandinavian Journal of Dental Research 78: 425–430

Tsarapatsani P, Tullberg M, Lindner A, Huggare J 1999 Long-term follow-up of early treatment of unilateral forced posterior cross-bite. Orofacial status. Acta Odontologica Scandinavica 57: 97–104

Tsujino K, Machida Y 1998 A longitudinal study of the growth and development of the dental arch width from childhood to adolescence in Japanese. Bulletin of Tokyo Dental College 39: 75–89

Tuxen A, Bakke M, Pinholt E M 1999 Comparative data from young men and women on masseter muscle fibres, function and facial morphology. Archives of Oral Biology 44: 509–518

van Keulen C, Martens G, Dermaut L 2004 Unilateral posterior crossbite and chin deviation: is there a correlation? European Journal of Orthodontics 26: 283–288

van Spronsen P H, Weijs W A, Valk J, Prahl-Andersen B, van Ginkel F C 1989 Comparison of jaw-muscle bite-force cross-sections obtained by means of magnetic resonance imaging and high-resolution CT scanning. Journal of Dental Research 68: 1765–1770

Yawaka Y, Hironaka S, Akiyama A, Matzuduka I, Takasaki C, Oguchi H 2003 Changes in occlusal contact area and average bite pressure during treatment of anterior crossbite in primary dentition. Journal of Clinical Pediatric Dentistry 28: 75–79

Zanoteli E, Yamashita H K, Suzuki H, Oliveira A S, Gabbai A A 2002 Temporomandibular joint and masticatory muscle involvement in myotonic dystrophy: a study by magnetic resonance imaging. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics 94: 262–271