Evaluation of Changes in Muscle Thickness, Bite Force and Facial Asymmetry during Early Treatment of Functional Posterior Crossbite

Paula Midori Castelo * / Maria Beatriz Duarte Gavião ** / Luciano José Pereira ***/
Leonardo Rigoldi Bonjardim ****

Objective: *To determine morphological and functional effects on masticatory system of early treatment of functional posterior crossbite in young children.* ***Study design:*** *23 children were divided into two groups: deciduous (DecG, n=11) and early mixed dentition (MixG, n=12), which received slow maxillary expansion. Maximal bite force, ultrasonographic masticatory muscle thickness and facial asymmetry were evaluated in three stages: before the start of treatment (s1), after three months of retention (s2), and after three months of observation (s3). The results were analyzed by Mann-Whitney U-test, correlation test, repeated measures ANOVA and backward stepwise multiple regression.* ***Results.*** *Bite force and temporalis thickness increased from s1 to s2 and s3 in both groups ($p<0.05$). Body mass index (BMI) increased significantly from s1 to s3 only in the MixG, but the masseter thickness did not differ among the stages. The correlation between the angle of the eye and the angle of the mouth in relation to the mid-sagital plane increased from s1 to s3. Masticatory muscle thickness contributed significantly to bite force magnitude in all stages, whereas age and BMI showed no significant contribution to its variation.* ***Conclusion:*** *Bite force and temporalis muscle thickness increased significantly in children after early treatment of functional crossbite.*
Keywords: *Ultrasonography; Bite Force; Face; Malocclusion*
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INTRODUCTION

The treatment of posterior crossbite in young children has been advocated for better long-term stability, reduction in overall treatment complexity and time, better functional and/or esthetic end results, and elimination of the lateral forced bite.[1,2] Past studies have reported that the persistency of this malocclusion is associated with decrease in bite force magnitude,[3-5] asymmetrical masticatory muscle activity[2] and growth of the muscles and hard tissues,[5-7] and an abnormal chewing pattern.[8-10] Moreover, the adult masticatory pattern is well established by the time a child develops complete deciduous dentition;[11,12] therefore, studies have suggested that patients with discrepancies in occlusion and asymmetric mandibular movements require earlier intervention.[7]

A crossbite is characterized by a reduction in width of the maxillary dental arch. This reduction is induced by non-nutritive sucking habits, obstruction of the upper airways, dietary consistency, and/or hereditary factors.[1,13,14] Early treatment is defined as intervention in the primary or early mixed dentition stage, i.e., before the age of 10 years.[15] Many studies about the characteristics of crossbite have been published, but there are few longitudinal studies about the form and function of the masticatory system in young children with such malocclusions. Thus, the aim of this study was to investigate intra-individually the changes in bite force, masticatory muscle thickness, and facial asymmetry after correction of crossbite.

MATERIAL AND METHODS

The sample comprised healthy children of both genders, with initial ages ranging from 5 to 6 years, some of whom were to start treatment at the Department of Pediatric

* Paula Midori Castelo, DDS, PhD, Department of Biological Sciences, Federal University of São Paulo (UNIFESP), Diadema, Brazil.
** Maria Beatriz Duarte Gavião, DDS, PhD, Department of Pediatric Dentistry, Piracicaba Dental School, State University of Campinas, Piracicaba, Brazil.
*** Luciano José Pereira, DDS, PhD, Department of Physiology, Federal University of Lavras, Lavras, Brazil.
**** Leonardo Rigoldi Bonjardim, DDS, PhD, Department of Physiology, Dental School of the Federal University of Sergipe, Sergipe, Brazil.

Send all correspondence to: Profa. Dra. Paula Midori Castelo - Departamento de Ciências Bilológicas - Universidade Federal de São Paulo (UNIFESP - Campus Diadema), Rua Prof. Artur Riedel, 275 - Diadema, SP, Brazil, zip code: 09972-270

Phone: 55-11-4049-3300
Fax: 55-11-4049-6428

Email: pcastelo@yahoo.com

Dentistry, and from day care centers. They were selected after a detailed anamnesis and clinical examination[16] in order to assess the normality of oral tissues, morphological occlusion (terminal relationship of second deciduous molars, Angle's Class first molar, incisal and canine relationships, bucco-lingual relationship), absence of alterations in tooth dimensions, and the presence of functional posterior crossbite involving at least three teeth and functional shift of the mandibular midline. Children with bilateral/skeletal crossbite, dental caries, early tooth loss, persistent sucking habit, severe obstruction of upper airways, history of orthodontic treatment, anterior crossbite, and open/deep bite were excluded. The subjects and their parents consented to participate in the study (Ethics Committee protocols n. 147/01 and 148/02), and they were distributed into two groups: complete deciduous dentition (DecG, n=11) and early mixed dentition (MixG, n=12). The inclusion criterion for MixG was the eruption of the first molars and/or permanent incisors,[17] and the body mass index (BMI) was calculated as weight/height^2 (Kg/m^2). Forty subjects fulfilled the above criteria, and efforts were made to invite them to participate, but only 23 effectively participated in all stages of the study (14 girls and 9 boys).

The subjects were treated with removable maxillary expansion plates, made of acrylic resin and occlusal surface covering, clasps, and passive labial arch of 0.7 mm stainless steel wire. The expander screw was placed transversally to the palate, and the appliance was worn 24 hours a day, being removed only for eating or brushing the teeth. The children were seen twice a month to activate the screw, and the end of the expansion was established when the over-correction of the malocclusion and the absence of lateral deviations during opening and closing of the mouth were confirmed. The appliance was replaced at least two times for each child until the end of the correction, and treatment was followed by a retention period of three months[18] with a removable plate (Hawley retainer). The analyses were done in three stages: before the start of treatment (s1), when crossbite had improved and the retainer used for three months had been removed (s2), and after three months of observation without any appliance (s3). For ethical reasons, no attempts were made to set up crossbite groups without treatment.

Masseter and temporalis muscle thickness

The masseter and anterior portion of the temporalis muscle thicknesses were assessed by means of ultrasonography (Just Vision, Toshiba Co., Minato-ku, Tokio, Japan; 56 mm/10 MHz), with the muscle at rest (RE) and in maximal intercuspal position (maximal clenching, MI) of both sides of the dental arches (normal/crossbite side). The measurements were performed three times, while the child was seated upright, and head in natural position. The recording site was determined by palpation, following the orientations: masseter - level halfway between the zygomatic arch and gonial angle, close to the occlusal plane; anterior portion of the temporalis muscle - in front of the anterior border of the hairline; the measurements were done directly on the screen, and it corresponded to the most bulky part of the muscle image. The final value was obtained from the average of them (accuracy of 0.1 mm).

Bite force

Maximal bilateral bite force was measured in the deciduous molars region with a pressurized and flexible tube (10 mm diameter) connected to a sensor element (MPX5700 Motorola, Austin, TX, USA). Children were seated upright, with their heads in natural position, and they were asked to bite the tube as forcefully as possible. The procedure was made three times, with an interval of two minutes, and transferred to a computer in Basic language in pounds per square inch (PSI); later, they were converted into Newton (N), and the final value was determined as the average of the measurements.

Facial asymmetry

Standardized frontal photographs (10 x15 cm) were taken with the subjects standing up in front of a digital camera with automatic flash (Canon EOS DS6041, Canon Inc., Ohta-ku, Tokyo, Japan), teeth in maximal intercuspal position and the Frankfort plane approximately parallel to the floor. Five images were obtained of each subject, and the best one was printed. The planes and measurements[19-21] were hand traced on acetate paper as they are presented in Figure 1. The angle of the eye (AE) was determined between the mid-saggital plane (vertical line formed by soft tissue nasion and soft tissue subnasale) and interpupillary line; the angle of the mouth (AM) was determined between the mid-saggital plane and the commisure line.

Statistics

The analyses were performed using Sigma Stat (3.1 Sigma Stat Software Inc., Richmond, CA, USA), and each group was separately analyzed. Normality was assessed using the Shapiro-Wilk *W*-test and the difference in the total treatment time between the groups was assessed by Mann-Whitney U-test.

Muscle thickness did not differ significantly between the

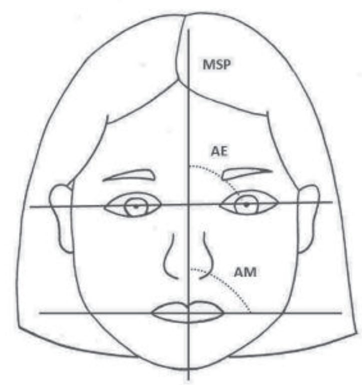

Figure 1. MSP: mid-sagittal plane; AE: angle of the eye; AM: angle of the mouth.

normal- and crossbite-side, thus it was considered as the mean of both. Differences in bite force, muscle thickness, and BMI among the stages were evaluated by means of One Way repeated measures analysis of variance (RM ANOVA) and Friedman repeated measures analysis of variance on ranks (FRM ANOVA), where appropriate. Pearson's correlation tests were used to determine the correlation between the AE and the AM. Backward stepwise regression determined the relationship between bite force as the dependent variable, and masticatory muscle thickness, age, and BMI as the independent variables between the stages s1 and s2, and the stages s2 and s3; a dummy variable (0 or 1) was used to capture the transition of the stages.

Measurement errors

The reliability of muscle thickness, bite force, and facial measurements was determined on 15 randomly selected children not included in this study. Two repeated measurements (x_1, x_2), at interval of 15 days, were taking and the differences between both were calculated using the Dahlberg's formula: Method Error (ME) = $\sqrt{\Sigma(x_1 - x_2)^2/2n}$ (Table 1).

RESULTS

The total mean active treatment time (±SD) was 13.64 (5.07) and 16.25 (5.40) months, for the DecG and MixG, respectively, and they did not differ significantly (p>0.05). Only one child, from the DecG, presented relapse after s2.

Figures 2 and 3 show the variation in bite force among the stages; the average of its magnitude increased significantly from s1 to s2 and from s1 to s3 in both groups (p<0.05), but not from s2 to s3. The thickness of the temporalis at rest and in the maximal intercuspal position showed significant increase in s2 and s3 in comparison with s1 in both groups, whereas the masseter thickness showed no differences among the stages. BMI increased significantly from s1 to s3 only in the MixG. From analysis of photographs, it was observed that the correlation between the AE and the AM increased from s1 to s3 (Table 2). As regards the relative contribution of muscle thickness, age and BMI to the bite force between the stages s1 and s2, and s2 and s3, it was observed that muscle thickness contributed significantly to its magnitude in the transition of all stages in both groups, while age and BMI did not show significant influence (Table 3).

Table 1. Error of the method (ME) for masticatory muscle thickness (mm), bite force (N), and photographic measurements (°) assessed on repeated measurements of 15 subjects.

Variable	ME
Left masseter / resting	0.53
Left masseter / maximal intercuspal position	0.36
Left temporalis / resting	0.09
Left temporalis / maximal intercuspal position	0.15
Bite force	16.28
Angle of the eye (AE)	0.48
Angle of the mouth (AM)	0.35

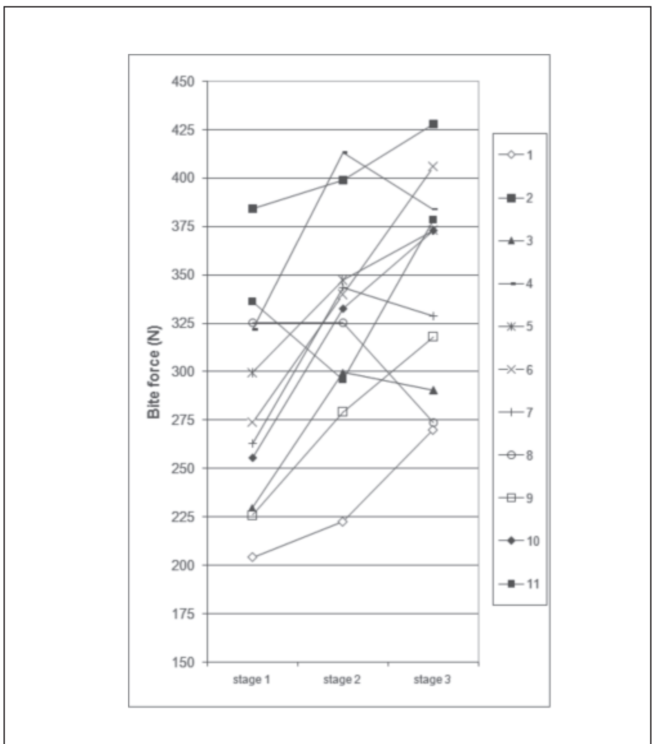

Figure 2. Bite force magnitude changes for each child of the DecG. Average (±SD): s1 = 283.57 N (54.87), s2 = 327.12 N (53.29), s3 = 347.64 N (54.20). There were significant differences of the averages between s1 and s2, and s1 and s3 (P<.05, RM ANOVA).

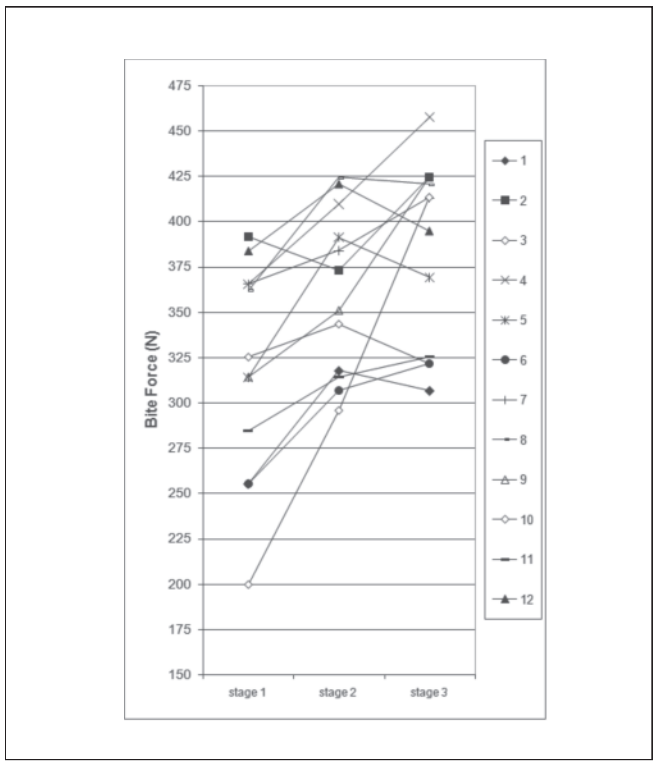

Figure 3. Bite force magnitude changes for each child of the MixG. Average (±SD): s1 = 318.20 N (59.64), s2 = 361.07 N (45.88), s3 = 382.79 N (51.54). There were significant differences of the averages between s1 and s2, and s1 and s3 (P<.05, RM ANOVA).

Table 2. Average (±SD) for age (months), BMI (Kg/m^2), and masticatory muscle thicknesses (mm), and the correlation's coefficients (r) between the angle of the eye and the angle of the mouth for both groups in each stage of the treatment.

Group	DecG			MixG		
Stage	s1	s2	s3	s1	s2	s3
Age	60.45 (4.46)	80.36 (9.87)	83.36 (9.87)	72.33 (7.41)	96.83 (10.88)	99.92 (11.03)
BMI	15.69 (1.18)	15.73 (1.24)	16.36 (1.59)	16.05^A (2.65)	16.80 (2.71)	17.24^B(2.93)
mRE	9.42 (0.84)	9.58 (1.08)	9.51 (1.00)	9.84 (1.08)	10.34 (1.28)	10.30 (1.38)
mMI	10.73 (1.11)	10.86 (1.22)	10.88 (1.01)	11.46 (1.18)	11.77 (1.31)	11.68 (1.51)
tRE	2.72^A (0.18)	2.95^B (0.18)	3.02^{BC} (0.25)	2.74^A (0.23)	3.15^B (0.30)	3.05^{BC} (0.28)
tMI	3.34^A (0.22)	3.66^B (0.35)	3.76^{BC} (0.40)	3.45^A (0.36)	3.88^B (0.37)	3.82^{BC} (0.38)
r	0.18	-0.06	0.22	0.18	0.81*	0.50

DecG, deciduous dentition group; MixG, mixed dentition group; BMI, body mass index; m, masseter muscle; t, temporalis muscle; RE, resting; MI, maximal intercuspation.
Different capital letters in the same line mean statistical difference between findings for each group (A#B, A#BC, and B=BC; p<0.05, RM ANOVA).
* p<0.001

Table 3. Results of the backward stepwise regression used to test the significance of independent variables on bite force magnitude between the stages s1 to s2 and s2 to s3 for both groups. Only significant independent variables are presented.

Group	Stage of the treatment	Independent variables	Significance of the model		
			R^2	*p*_ value	Power
DecG	s1 to s2	mMI, tRE	0.73	<0.001	1.00
	s2 to s3	mRE, tMI	0.62	<0.001	1.00
MixG	s1 to s2	mRE	0.34	0.014	0.86
	s2 to s3	mRE, tMI	0.45	0.041	0.96

DecG, deciduous dentition group; MixG, mixed dentition group; m, masseter muscle; t, temporalis muscle; RE, rest; MI, maximal intercuspal position.
A *dummy* variable was used to capture the transition of the stages.

DISCUSSION

Three therapeutic modalities are mentioned in the literature for managing posterior crossbite in young children: discontinuance of sucking habit, selective grinding of tooth interferences, and expansion of a constricted arch.[1,15] Despite the limitations of this type of treatment, such as broken appliances and lack of cooperation, the slow expansion plate has shown to be the most popular and successful form of maxillary expansion in the early stages,[1] with a success rate close to 100%,[18,22] and mean treatment time ranging from 11 to 20 months.[22] The mechanical movements are a result of forces applied on the teeth and transmitted to the bones, with the aim of changing the direction of growth[14] and eliminating structural asymmetries.[23] It has also been shown that maxillary expansion and elimination of mandibular lateral shift lead to improvement of unbalanced muscle activity, elimination of the asymmetric position of the condyles on glenoid fossa,[2,9,10] and an increase in bite force.[24] Moreover, increase in widths of the maxilla and nasal cavity, and improvements in anatomy and nasal respiration could also be seen.[25]

Bite force may decrease with pain, malocclusion, dental caries, and hyperdivergence, so that assessment of its magnitude has been shown to be relevant for diagnosis and treatment planning.[26-30] On comparing subjects with normal occlusion, previous studies showed that in children with crossbite, bite force did not increase from the deciduous to the mixed dentition stage.[3-5,31] In this study, the improvement of crossbite led to an increase in bite force in both groups. However, some subjects showed a decrease in bite force after the retention period (s3), which may be explained by fact that this period is characterized by transient changes, such reduced occlusal support on the crossbite-side, pain adaptation, and differences in muscle length resulting from wearing the appliance,[25,32] until occlusal support could be acquired with chewing function.

As regards the body variables contribution, past studies showed that weight explained only 6 and 16 per cent of the bite force variance among children and adults, respectively,[31,33] since weight may be related to adipose tissue, and not necessarily to muscle strength. However, Linderholm *et al*[34] observed that young subjects who have a stronger body musculature presented a stronger bite force. The study conducted by Sonnesen and Bakke[24] observed no significant differences in bite force in relation to age and gender in children, although the contribution of body variables have not been evaluated. In the present study, BMI and age did not contribute to bite force variance in all stages, in spite of the increase in BMI observed from the s1 to s3 in the MixG.

The decrease in masticatory strength as a consequence of the increased consumption of processed food (soft diet) may also be responsible for the underdeveloped muscles and jaws and inadequate wear of deciduous teeth, resulting in dental interferences and forced guidance of the mandible into an incorrect position.[13] A different level of temporalis bilateral activity was observed in the presence of transverse malocclusion, possibly due to a functional adaptation of the temporalis to avoid cuspal interferences.[35] Moreover, ultrasonographic muscle thickness was shown to be positively correlated with muscle function in young subjects,[36] and the temporalis muscle showed morphological development during the treatment of crossbite in both groups studied. Therefore, the new occlusion should be compatible with the dynamics of the muscular and occlusal forces, and training of chewing after treatment may contribute to masticatory performance and occlusal balance, preventing relapse.

Skeletal asymmetry of the mandibular ramus and condyles related to an asymmetrical posture were seen among young subjects with crossbite.[9,37] Nowadays, the importance of face analysis has increased, and past studies observed that occlusal cant asymmetries, defined as a divergence of the occlusal plane from the horizontal axis, and orbit or globe asymmetries, may also be related to posterior crossbite, but they are not always easily detected because posture can compensate these imbalances.[38,39] Pompei *et al*[21] observed that children with normal occlusion presented stronger correlation between the interpupillary and commissure planes in relation to the midline of the face than those with crossbite. In this study, the correlation between the angle of the eye and the angle of the mouth increased from the s1 to s3, but without statistical significance. However, perfect bilateral body symmetry is largely a theoretical concept, and all subjects, including those who are perceived as normal, have some degree of craniofacial asymmetry.[39]

Although the number of subjects was small due to the longitudinal character of the study, the results found and the power of the tests performed were considered adequate and would enable determination of the sample size calculation for further studies. Moreover, the findings suggest that good treatment results can be achieved with early intervention, with a favorable cost-benefits ratio, in agreement with previous studies.[1,10]

CONCLUSIONS

The results found in the studied sample showed that early treatment of posterior crossbite provided morphological and functional development of some masticatory system aspects.

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