Original Article

Functional Unilateral Posterior Crossbite Effects on Mastication Movements Using Axiography

Marco Antonio Canada Salioni[a]; Silmara Elena Papa Pellizoni[a]; Antonio Sérgio Guimarães[b]; Yara Juliano[c]; Luís Garcia Alonso[d]

Abstract: This prospective study investigated the influence of functional unilateral posterior crossbite on mastication movements. The study group included 16 patients (nine girls and seven boys) with functional unilateral posterior crossbite involving three or more posterior teeth. A control group comprised 15 individuals (nine girls and six boys) with normal occlusion and the mean age of both groups was 9.17 years. The mandibular masticatory movements were registered, using computer axiography, for 30 seconds during chewing to determine the preference side of chewing. The patterns of the first, third, and fifth chewing cycles were compared with the preference side to establish whether they would predict the chewing preference side. The extent of the maximal lateral and vertical displacements of the mandible during chewing were compared between study and control groups. This study found that overall the left side was the preferred mastication side in 43.7% of individuals in the study and 46.7% in the control group. There was no relationship between the side of the crossbite and the masticatory preference side (Mc Nemar test, $P = .5$). No correlation was present between the patterns of chewing movements in the first, third, or fifth cycles. Both study and control groups showed similar maximal lateral and vertical mandible displacement. (*Angle Orthod* 2005;75:362–367.)

Key Words: Crossbite; Temporomandibular joint; Mastication; Malocclusion; Jaw relation record

INTRODUCTION

Posterior crossbite is a common malocclusion with a prevalence of 7.7%[1] to 17%.[2] Some studies have shown that functional unilateral posterior crossbite (FUPXB) has been associated statistically with asymmetrical function of the masticatory muscles,[3] signs and symptoms of temporomandibular disorders (TMD), such as pain, headache, and muscle tenderness,[4–7] which may relate to activity of masticatory muscle performance.[8,9]

[a] Graduate student, Department of Morphology, Universidade Federal de São Paulo-Escola Paulista de Medicina, São Paulo, Brazil.

[b] Graduate student, Department of Morphology, Universidade Federal de São Paulo-Escola Paulista de Medicina, São Paulo, Brazil.

[c] Auxiliary Professor, Department of Morphology, Universidade Federal de São Paulo-Escola Paulista de Medicina, São Paulo, Brazil.

[d] Associate Professor, Department of Preventative Medicine, Universidade Federal de São Paulo-Escola Paulista de Medicina, São Paulo, Brazil.

[e] Associate Professor, Department of Morphology, Universidade Federal de São Paulo-Escola Paulista de Medicina, São Paulo, Brazil.

Corresponding author: Marco Antonio Canada Salioni, DDS, MSc, Departamento de Morfologia, Universidade Federal de São Paulo-Escola Paulista de Medicina, Rua Angelo Ongaro 152, Sumaré, São Paulo 13171-690, Brazil
(e-mail: msalioni@uol.com.br)

Accepted: November 2004. Submitted: August 2004.

Previous investigators have demonstrated that there is an individual chewing pattern for mandibular movements in adults.[10,11] Throckmorton et al[12] described chewing as an event determined at two levels, an individual central chewing pattern generator and peripheral events inducing chewing adaptations.

The individual central chewing pattern starts to be established with tooth eruption and is well established in a child with a complete deciduous dentition.[11,13,14] The central pattern generator appears to establish the chewing cycle shape by controlling the sequence of muscle contractions in the opening and closing movements of mandible. Once the central chewing cycle pattern has been established, it appears to be relatively resistant to change.[12] Occlusal interferences occurring during bone development may lead to mandibular displacement and can induce a compensatory asymmetric mandibular growth.[14]

In early life, there is a much greater potential for adaptive changes to determine the central pattern of chewing. Corrections made in adults do not show consistent changes in the overall mastication cycle shape[12] impairing the total effectiveness of an occlusal correction. Therefore, several studies suggest that FUPXB should be corrected as early as possible to promote bilateral condylar symmetry and enhance normal growth and development.[15]

This study was aimed at detecting whether there is any difference in the cycle of masticatory movements; chewing preference side; and relationship between pattern of the first, third, and fifth chewing movements and the preferred chewing side or maximal lateral and vertical displacements of the mandible between children with and without a FUPXB.

MATERIALS AND METHODS

This study was performed on 31 children ranging in age from six to 12.58 years (mean 9.17 years) assisted at the Head Institute of Federal University of São Paulo Paulista School of Medicine, from March 2003 to March 2004. None of the children had undergone orthodontic treatment previously nor showed any signs or symptoms of TMD by research diagnostic criteria. The study group comprised 16 patients (nine girls and seven boys) with FUPXB involving three or more posterior teeth. Among these patients, eight had right and the remaining eight had left crossbite. The control group included 15 individuals (nine girls and six boys) aged six to 12.75 years (mean 9.17 years) with normal occlusion. The participants' rights were protected, and informed consent and assent were obtained according to the University's Ethical Committee Board.

A complete clinical dental and functional examination of the mouth was carried out on the participants by a blind assessor. A closed-mouth, frontal view photograph of each individual was taken to determine the presence of any asymmetric features. Lateral photographs with teeth in occlusion, as well as models, were obtained to assess the posterior crossbites and the functional deviation between the midlines of the dental arches.

Equipment of measurement of mandibular movement

The jaw movements were captured using an ultrasonic measuring device, the Arcus Digma System®. (KaVo Elektrotechnisches Werk GmbG, Leutkirch, Germany) This system comprised a face bow, weighing approximately 22 g, attached to the mandibular dental arch through a dental clutch built of dental resin, which allowed the teeth normal occlusal contact and preserved normal mandibular function and movement of the lower lip and a reference piece adjusted to the subject's head, integrated with electronic equipment for recording movement.

Recording of jaw movement

Jaw movements were recorded with the subject seated in a relaxed position with natural head position. Only one series of mastication movements was recorded because no differences were recorded between the first and the second recordings made on the same individual.[16]

The mandibular masticatory movements were measured during the chewing of a one-cm^3 piece of carrot. The carrot piece was placed on the subject's tongue, and the child was asked to put their teeth in maximum intercuspation without biting the carrot piece and only then start chewing.[11] The mastication was performed and recorded for 30 seconds. Jaw movement recording in all children was performed by the same examiner (Figures 1 and 2).

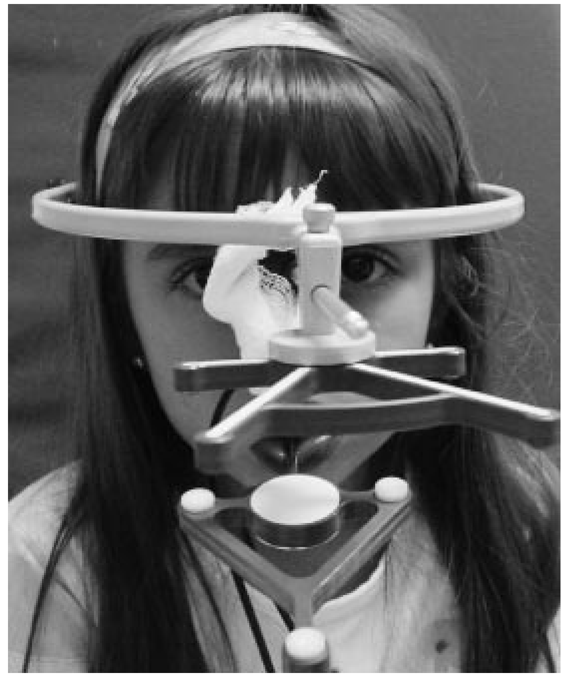

FIGURE 1. Axiography in a frontal view.

Jaw movement analysis

We used the classification proposed by Ahlgren[11] comprising seven different chewing patterns determined by the movements of the lower incisors relative to the frontal plane (Figure 3).

Statistical analyses

Student's *t*-test and Mc Nemar test were used to analyze the significant differences between the groups.

RESULTS

In the study group, the crossbites were equally distributed between the left and right sides. Among those with left crossbite, the preference was also equally distributed with left, right, and no preference of 37.5%, 37.5%, and 25.0%, respectively. Comparatively, only a slight difference was observed with their right crossbite counterparts with left, right, and no preference side of 50.0%, 12.5%, and 37.5%, respectively. The overall preference among individuals with FUPXB was 43.8%, 31.2%, and 25.0% for the left, right, and no preference side, respectively, with a similar distribution in the control group of 46.7%, 33.3%, and 20.0% for the left, right, and no preference side, respec-

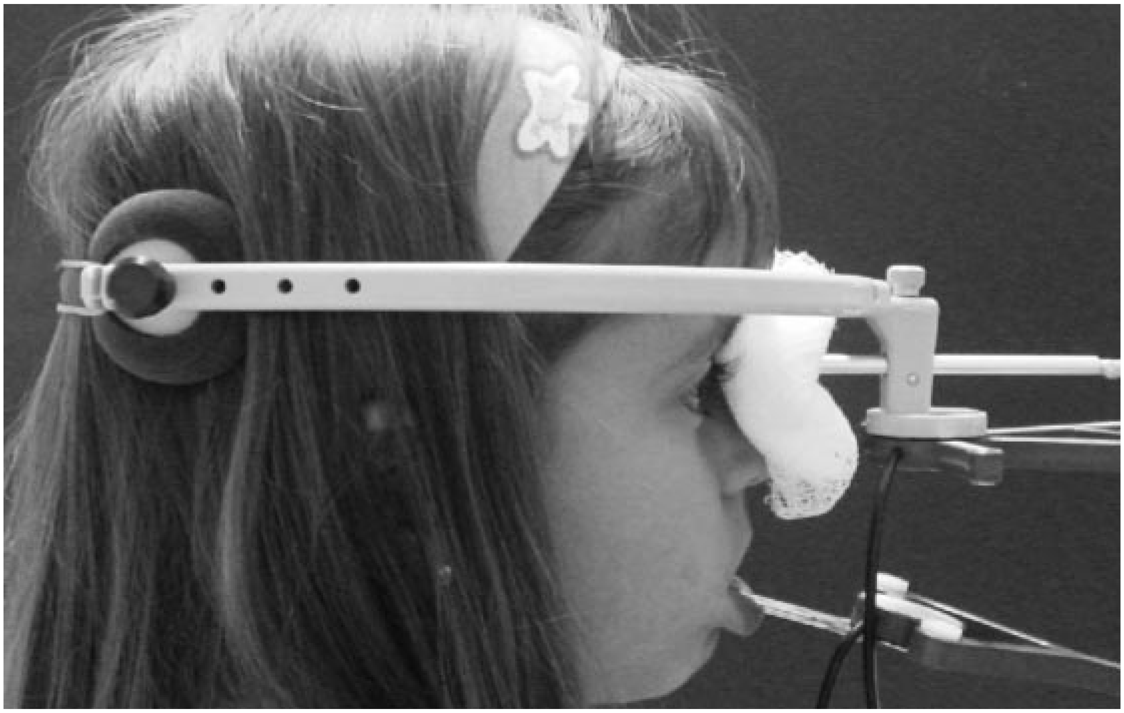

FIGURE 2. Axiography in a lateral view.

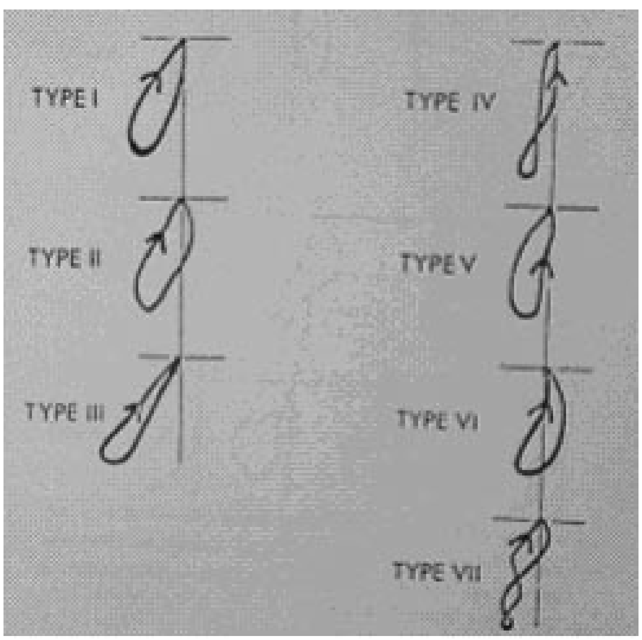

FIGURE 3. Mastication cycle types (from Ahlgren.[11])

TABLE 1. Frequences of Mastication Preference Side

	Mastication Preference Side	
	Crossbite (%)	Normal (%)
Left	7 (43.8)	7 (46.7)
Right	4 (25.0)	5 (33.3)
No preference	5 (31.2)	3 (20.0)

tively (Table 1). There was no relationship between the side of the crossbite and the masticatory preference side (Mc Nemar test, $P = .5$) (Table 2).

The observation regarding the first, third, and fifth cycles as predictor of the chewing preference side showed that the mastication side in the first cycle coincided with the preference chewing side, as determined by the mastication movements during 30 seconds, in 91% of the cases against

TABLE 2. Data Crossbite Side, Mastication Preference Side, Cycle Side, and Cycle Type in Study Group[a]

Patient No.	Sex	XB	MPS	Cycle Side First	Third	Fifth	Cycle Type First	Third	Fifth
1	F	L	L	L	L	R	II	II	I
2	F	L	L	L	L	L	IV	IV	II
3	F	L	L	L	L	L	V	VI	V
4	F	R	L	R	R	R	IV	II	V
5	F	R	L	L	L	L	V	II	II
6	F	R	L	L	L	L	I	III	I
7	M	R	L	L	L	L	IV	II	IV
8	M	L	NP	L	L	L	V	IV	I
9	F	L	NP	L	R	L	I	V	II
10	F	R	NP	L	L	L	VII	VII	V
11	M	R	NP	L	L	R	I	III	VII
12	M	R	NP	R	L	L	IV	III	III
13	M	L	R	R	L	R	VII	V	I
14	F	L	R	R	L	L	V	IV	I
15	M	L	R	L	R	R	II	IV	VI
16	M	R	R	R	R	R	V	III	I

[a] F indicates female; M, male; XB, crossbite side; L, left; R, right; MPS, mastication preference side; NP, no preference.

TABLE 3. Data Mastication Preference Side, Cycle Side, and Cycle Type in Control Group[a]

Patient No.	Sex	MPS	Cycle Side			Cycle Type		
			First	Third	Fifth	First	Third	Fifth
1	F	L	L	L	L	I	II	IV
2	M	L	L	L	L	I	I	I
3	F	L	R	L	L	VII	II	I
4	F	L	L	L	L	II	II	II
5	F	L	L	L	L	IV	IV	IV
6	M	L	L	L	L	I	III	V
7	F	L	L	R	L	IV	II	IV
8	F	NP	L	L	L	III	IV	V
9	M	NP	L	R	R	II	IV	IV
10	M	NP	L	R	R	VII	I	VII
11	M	R	R	R	R	II	I	I
12	M	R	R	R	R	I	I	I
13	F	R	R	R	R	V	I	V
14	F	R	L	L	R	V	V	II
15	M	R	R	R	R	V	IV	IV

[a] F indicates female; M, male; XB, crossbite side; L, left; R, right; MPS, mastication preference side; NP, no preference.

TABLE 4. Comparison Between Opening and Jaw Lateral Displacement

	Opening (mm)		Lateral Displacement (mm)	
	Mean	Maximum	Mean	Maximum
Normal	19.20	23.00	5.53	5.93
Crossbite	18.43	28.00	6.31	5.62

73% for the third and fifth cycles (Table 2). On the other hand, in the control group, the chewing side in the fifth cycle coincided with the preference side in 100% of the cases against 83% for the first and third cycles (Table 3).

In the crossbite group, the chewing patterns observed in the first, third, and fifth chewing cycles showed patterns V, IV, and I,[11] respectively, as the most frequent. In the control group, the chewing patterns observed in the first, third, and fifth chewing cycles showed patterns I and IV, respectively, as the most frequent independent occurrences in each cycle.

Regarding mouth opening

Regarding mouth opening, this study found that both study and control groups presented similar maximum measurements of mouth opening range of 28 and 23 mm during mastication (Student's t-test, $P = .28$) and similar average values of 18.43 and 19.20 mm (Student's t-test, $P = .51$). There was no difference between males and females in mouth opening in the study group ($P = 2.30$) or in the control group ($P = 1.74$). A similar behavior was also observed for lateral jaw displacement with average values of 6.31 and 5.62 mm for left and right excursions, respectively, in the study group, whereas the corresponding averages in the control group were 5.53 and 5.93 mm (Table 4). The amplitude of jaw movements decreased as the size of the bolus was reduced.

Preferential limb use

The side of preferential limb had also been analyzed, and the side of mastication preference did not present correlation with the side of preferential limb use of the patient. Therefore, of 31 patients analyzed, only one is left-handed, and she presented a preferred chewing on the left side.

DISCUSSION

Jaw displacement during mastication and its characteristic cyclic pattern has been of interest for many years. The masticatory pattern is established early in childhood and it is of interest to determine the time as exactly as possible.[3] Saitoh et al[14] found that the chewing pattern is well established in the child with a complete deciduous dentition, which occurs at the age of three years.[17–19]

FUPXB develops during eruption of the primary dentition influenced by occlusal interferences and establishes a chewing pattern at the level of the central nervous system.[12] Ahlgren[11] showed that children with normal occlusion develop a simple and more regular chewing pattern (types I, II, or III). They had a semicircular chewing with small variations in the masticatory pattern when a series of consecutive cycles was studied. In contrast, children with malocclusion showed more complex mandibular excursion and greater variations.

Our study did not find evidence of any prevalent pattern either in the control or study group. We found that 30% of the participants in the crossbite group presented with patterns I, II, and III, whereas 70% moved their mandibles in patterns IV, V, VI, and VII, which is in agreement with findings of Ahlgren[11]. At least one of these cycles (V) was clearly described by Ahlgren as a reverse cycle, which agrees with the reports of Lewis et al[20] regarding chewing patterns in participants with malocclusion. However, this study did not confirm the same predicting power of the fifth chewing cycle for the chewing pattern in participants with normal occlusion. In this study, 40% showed patterns I, II, and III (normal) and the remaining 60% exhibited patterns IV to VII, indicating no single prevalent pattern in the cycle under consideration.

Wickwire et al[21] determined that type V was characteristic of children with a deciduous dentition and this may explain the high incidence of such pattern in this study because the participant age ranged from six to 12 years, when a mixed dentition is normally found. Many others factors such as personality, temperament, social environment, and food selection are probably more decisive than the occlusion for the formation of the individual chewing pattern. We used only carrot for chewing because chewing of hard (carrot) vs soft (cheese) food in the child subject did not appear to make a large difference in the chewing pattern.[21]

Another chewing characteristic, the side of mastication preference, was investigated by Delport et al,[22] who established that chewing preference was associated with the chewing movements of the first cycle.

This study confirmed the finding of Delport et al[22] only in the case of individuals with crossbite when their lateral preference was associated with their lateral chewing movement in the first chewing cycle, 91% of coincidence against 73% in the third and fifth cycles. In the individuals with normal occlusion comprising this study's control group, the predicting cycle of lateral chewing preference was the fifth, 100% coincidence against 83% in the first and third cycles.

Varela et al[23] investigated an alternative method to determine the side of mastication preference. Instead of choosing a single key cycle, they studied the first, third, fifth, and seventh and found that if the biting movement of the mandible in three of these cycles coincided on the same side, this was the side of chewing preference.

This study confirmed the findings of previous authors, but it had a stricter determination because the three cycles we focused on had to show coincidence regarding the chewing side. In this study, among patients with crossbites, one patient exerted biting movements three consecutive times on the side opposite the side of preference, a fact that deserves further consideration.

Hoogmartens and Caubergh[24] found that during the first cycle 45% of the participants studied had a lateral chewing preference. Among these, 32% preferred the right side whereas only 13% preferred the left. Pond et al[25] studied 99 individuals by visual inspection and determined that 77.8% exhibited a preferred side of mastication, 39.4% chewed preferentially on the left side, whereas the other 38.4% preferred the right side. The remaining 22.2% of the study sample chewed alternatively on the left and right sides. Ahlgren[11] reported that 71% of the participants in his study showed a lateral preference.

Compared with previous studies, 20% of the individuals in our control group exerted a similar number of chewing movements on both sides, whereas 80% had a preferred side: 46.7% the left and 33.3% the right side. These figures were not much different in the crossbite group, where 31.2% of the individuals did not tend to chew on a particular side, 25.0% preferred the right side, and 43.8% the left. This study confirmed the finding of Martin et al[26] that the preference for a chewing side seems to vary in different studies and there was no relationship between the side of the crossbite and the masticatory preference side.

Regarding the range of mouth opening during mastication, this study found that both study and control groups presented similar maximum measurements of 28 and 23 mm, respectively. The average values were similar also at 18.4 and 19.2 mm. A similar behavior was also observed for jaw lateral displacement with average values of 6.3 and 5.6 mm for left and right excursions, respectively, in the study group, whereas the corresponding averages in the control group were 5.5 and 5.9 mm.

Opening of mouth

There was no statistically significant difference between the average maximal mouth opening between the crossbite and the control groups. On the whole, the average maximal opening was 18.8 mm, a result slightly greater than the 16.1 mm found by Wickwire et al[21] and very close to the 19.1 mm found by Ahlgren[11] for children nine to 14 years of age. The amplitude of jaw movements decreased as the size of the bolus was reduced.[21,27,28]

Lateral movements

Regarding lateral movements of the mandible during chewing, our findings did not show any remarkable difference when compared with the ones reported in the literature. The average maximal displacement to the left and right sides when considering all participants in this study were 5.9 and 5.8 mm, respectively. The average sideways excursion reported by Wickwire et al[21,28] and Ahlgren[11] were 4.8 and 5.3 mm, respectively. The use of carrot only (hard food) in the study of lateral chewing excursion would not produce biased result because lateral movements do not appear to be governed by the texture of the food but by the cuspal inclination.[28]

Preferential limb use

No correlation with the preferential limb use of the patient was found according to several authors.[29–31]

CONCLUSIONS

- The types of cycles varied between the patients and did not correlate with the side of the crossbite with respect to the side of masticatory preference.
- In both groups, the left side was the side of preference for mastication. The side of the crossbite did not correlate with the side of the first, third, and fifth cycles.
- Both sides did not have a difference in laterality nor did they have a difference in the maximum opening.
- The lateral movements were similar for the boys and girls.

REFERENCES

1. Kutin G, Hawes RR. Posterior cross-bites in the deciduous and mixed dentition. *Am J Orthod.* 1969;56(5):491–504.
2. Helm S. Prevalence of malocclusion in relation to development of the dentition. *Acta Odontol Scand.* 1970;28:suppl 58.
3. Ben-Bassat Y, Yaffe A, Brin I, Freeman J, Ehrlich Y. Functional and morphological-occlusal aspects in children treated for unilateral posterior cross-bite. *Eur J Orthod.* 1993;15:57–63.
4. Egemark-Eriksson I, Carlsson GE, Magnusson T, Thilander B. A longitudinal study of malocclusion in relation to signs and symp-

toms of cranio mandibular disorders in children and adolescents. *Eur J Orthod.* 1990;12(4):399–407.
5. Brandt D. *Temporomandibular disorders and their association with morphological malocclusion in children.* Monograph 16, Craniofacial Growth Series, Ann Arbor, MI: Center for Human Growth and Development, The University of Michigan; 1984: 279–298.
6. Riolo MI, Brandt D, TenHave TR. Associations between occlusal characteristics and signs and symptoms of TMJ dysfunction in children and young adults. *Am J Orthod Dentofacial Orthop.* 1987;92:467–477.
7. Kritsineli M, Shim YS. Malocclusion body posture and temporomandibular disorders in children with primary and mixed dentitions. *Am J Orthod.* 1992;16:86–93.
8. Sonnesen L, Bakke M, Solow B. Malocclusion traits and symptoms and signs of temporomandibular disorders in children with severe malocclusion. *Eur J Orthod.* 1998;20:543–559.
9. Sonnesen L, Bakke M, Solow B. Bite force in pre-orthodontic children with unilateral crossbite. *Eur J Orthod.* 2001;23(6):741–749.
10. Beyron H. Occlusal relations and mastication in Australian Aborigines. *Acta Odontol Scand.* 1964;22:597–678.
11. Ahlgren J. Mechanism of mastication. A quantitative cinematographic and eletromyographic study of masticatory movements in children, with special reference to occlusion of the teeth. *Acta Odontol Scand.* 1966;24:1–109.
12. Throckmorton GS, Buschang PH, Hayasaki H, Pinto AS. Changes in the masticatory cycle following treatment of posterior unilateral crossbite in children. *Am J Orthod Dentofacial Orthop.* 2001; 120(5):521–529.
13. Wickwire NA, Gibbs CH, Jacobson P, Lundeen HC. Chewing patterns in normal children. *Angle Orthod.* 1981;51(1):48–60.
14. Saitoh I, Hayasaki H, Iwase Y, Nakata M. Improvement in jaw motion following treatment of unilateral crossbite in a child with primary dentition: a case report. *Cranio* 2002;20(2):129–134.
15. Thilander B, Rubio G, Pena L, Mayorga C. Prevalence of temporomandibular dysfunction and its association with malocclusion in children and adolescents: an epidemiologic study related to specified stages of dental development. *Angle Orthod.* 2002; 72(2):146–154.
16. Karlsson S, Carlsson GE. Recording of masticatory mandibular movement and velocity by an optoelectronic method. *Int J Prosthodont.* 1989;2(5):490–496.
17. Logan WMC, Kronfeld R. Development of human jaws and surroceding structures from birth to age of fifteen years. *J Am Dent Assoc.* 1933;20(3):374–427.
18. Lunc RC, Law DB. A review of the chronology of eruption of deciduous teeth. *J Am Dent Assoc.* 1974;29(4):872–879.
19. Ravn JJ. Occlusion in the primary dentition in 3-year-old children. *Scand J Dent Res.* 1975;83(3):123–130.
20. Lewis RP, Buschang PH, Throckmorton GS. Sex differences in mandibular movements during opening and closing. *Am J Orthod Dentofacial Orthop.* 2001;120(3):294–303.
21. Wickwire NA, Gibbs CH, Jacobson P, Lundeen HC. Chewing patterns in normal children. *Angle Orthod.* 1981;51(1):48–60.
22. Delport HP, De Laat A, Nus J, Hoogmartens MJ. Preference pattern of mastication during the first chewing cycle. Electromyography. *Clin Neurophysiol.* 1983;23(6):491–500.
23. Varela JM, Castro NB, Biedma BM, Da Silva Dominguez JL, Quintanilla JS, Munoz FM, Penin US, Bahillo JG. A comparison of the methods used to determine chewing preference. *J Oral Rehabil.* 2003;30(10):990–994.
24. Hoogmartens MJ, Caubergh MAA. Chewing side preference during the first cycle as a new type of lateral preference in man. Electromyography. *Clin Neurophysiol.* 1987;27(5):293–300.
25. Pond LH, Bargui N, Barnwell GM. Occlusion and chewing side preference. *J Prosthet Dent.* 1986;55(4):498–500.
26. Martin C, Alarcon JA, Palma JC. Kinesiographic study of the mandible in young patients with unilateral posterior crossbite. *Am J Orthod Dentofacial Orthop.* 2000;118(5):541–548.
27. Lucas PW, Ow RK, Ritchie GM, Chew CL, Keng SB. Relationship between jaw movements and food breakdown in human mastication. *J Dent Res.* 1986;65(3):400–404.
28. Gibbs CH, Wickwire NA, Jacobson AP, Lundeen HC, Mahan PE, Lupkiewicz SM. Comparison of typical chewing patterns in normal children and adults. *J Am Dent Assoc.* 1982;105:33–42.
29. Gisel EG. Development of oral side preference during chewing and its relation to hand preference in normal 2- to 8-year-old children. *Am J Occup Ther.* 1988;42(6):378–383.
30. Weiner R. Chew on this: is there a dominant side for chewing? *J Mass Dent Soc.* 2001;50(2):36–38.
31. Christensen LV, Radue JT. Lateral preference in mastication: a feasibility study. *J Oral Rehabil.* 1985;12(5):421–427.