Assessment of Head Tilt in Young Children with Unilateral Posterior Crossbite by Video Recording

Débora Bevilaqua-Grossi* / Thaís Cristina Chaves** / Margarete Lovato*** / Anamaria Siriani de Oliveira**** / Simone Cecílio Hallak Regalo*****

14 children with unilateral posterior crossbites (PCB) participated in this study and 14 children with Angle's class I occlusion. Body posture analysis was made by a video recording technique. The results showed greater tilt in the angles of head tilt in PCB children when compared to neutral occlusion children. We also observed that head tilt followed the side of crossbite. Such results suggest that unilateral PCB could be related to the development of head tilt on the same side of the crossbite.

Keywords: *Unilateral crossbite, children, occlusion, head tilt, facial asymmetry*

J Clin Pediatr Dent 32(2): 159–164, 2007

INTRODUCTION

Posterior crossbite (PCB) is one of the factors leading to asymmetrical masticatory muscle function[28] and can be defined as a malocclusion in the canine, premolar, and molar regions, characterized by the buccal cusps of the maxillary teeth occluding lingually to the buccal cusps of the corresponding mandibular teeth.[22] It is a transverse discrepancy in arch relationship in which the palatal cusps of one or more of the upper posterior teeth do not occlude in the central fossa of the opposing lower teeth.[19] A PCB normally occurs in one to 16 percent of the population, most frequently unilaterally.[10, 19, 23, 24]

* Débora Bevilaqua-Grossi P.T., Ph.D, Associate Professor, Department of Biomechanics, Medicine and Rehabilitation of the Locomotor Apparatus, Ribeirão Preto School of Medicine, University of São Paulo - USP

** Thaís Cristina Chaves P.T., MS in Medical Sciences, Orthopedics, Traumatology and Rehabilitation Program, Department of Biomechanics, Medicine and Rehabilitation of the Locomotor Apparatus, Ribeirão Preto School of Medicine, University of São Paulo – USP

*** Margarete Lovato P.T., MS in Physical Therapy from Centro Universitário do Triângulo Mineiro – UNIT

**** Anamaria Siriani de Oliveira P.T., Ph.D, Professor, Department of Biomechanics, Medicine and Rehabilitation of the Locomotor Apparatus, Ribeirão Preto School of Medicine, University of São Paulo - USP

***** Simone Cecílio Hallak Regalo D.D.S., Ph.D, Professor, Department Morphology, Stomatology and Physiology, Faculty of Dentistry of Ribeirão Preto, University of São Paulo - USP

Send all correspondence to: Dr Bevilaqua Grossi, Departamento de Biomecânica, Medicina e Reabilitação do Aparelho Locomotor, Faculdade de Medicina de Ribeirão Preto - Universidade de São Paulo - USP, Campus Universitário, CEP: 14048-900 Ribeirão Preto (SP) Brazil

Phone/fax: +55 16 3602 44 13 / +55 16 3633 03 36

e-mail: deborabg@fmrp.usp.br

A number of parameters can be associated with PCB etiology, and the most frequent cause of a unilateral PCB is a reduction in the width of the maxillary dental arch. It could be related to finger or dummy sucking habits[16] or nasal obstruction.[17] Malandris and Mahoney[19] reported that, in the primary dentition, a unilateral PCB commonly arises as a result of either genetic and environmental influences or both.

The development of malocclusion could be closely related to a muscular/postural imbalance and facial asymmetries (mandibular midline deviation). Previous electromyographic studies have found an asymmetrical masticatory muscle electrical activity pattern in unilateral PCB patients.[1, 2, 6, 13, 36]

Facial asymmetry is a relative distortion of multiple anatomical parts, such as the eyes, nose, lips and mandible.[37] The occlusal interferences caused by a unilateral PCB could guide the mandible to an acquired maximal closure asymmetry which would, in turn, create a transverse component of asymmetry.[9] However, Nerder *et al*.[23] found a mandibular midline deviation in children with unilateral PCB which was characterized by a frontal plane asymmetry.

It is known that a masticatory stimuli is important in defining mandibular development. If a child has an asymmetrical muscle function, stimuli for facial development and posture should also be asymmetric,[33] which could, in turn, lead to body posture asymmetries.

Some studies have found associations between body posture and malocclusion.[7, 11, 12, 18, 20, 26, 29, 35, 40] In a review, Huggare[11] reported greater prevalence of a unilateral PCB in scoliotic patients, suggesting a relationship between crossbite and body posture alterations on the frontal plane, whereas Solow and Sonnesen[35] did not find any association between PCB and posture of the head and neck on the sagittal plane. However, research on the relationship between unilateral PCB and body posture lack, especially regarding children.

Posture is often defined as the relative arrangement of

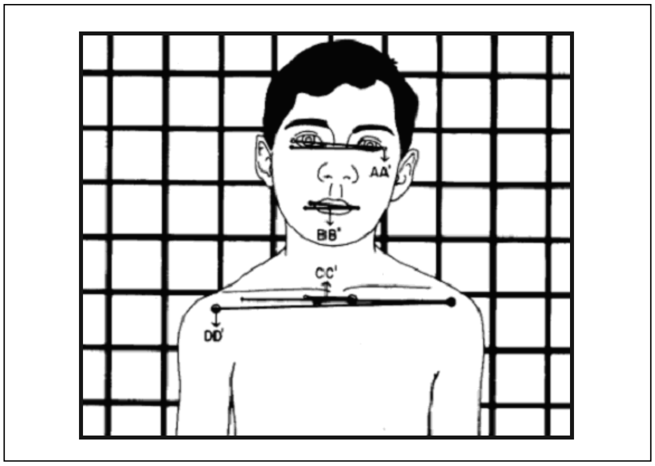

Figure 1. Picture of the face and upper thorax describing the measurement of angles AA' (lateral corner-of-the-eye angle), BB' (lateral corner-of-the-mouth angle), CC' (External clavicle joints angle) and DD´ (acromion clavicle joints angle).

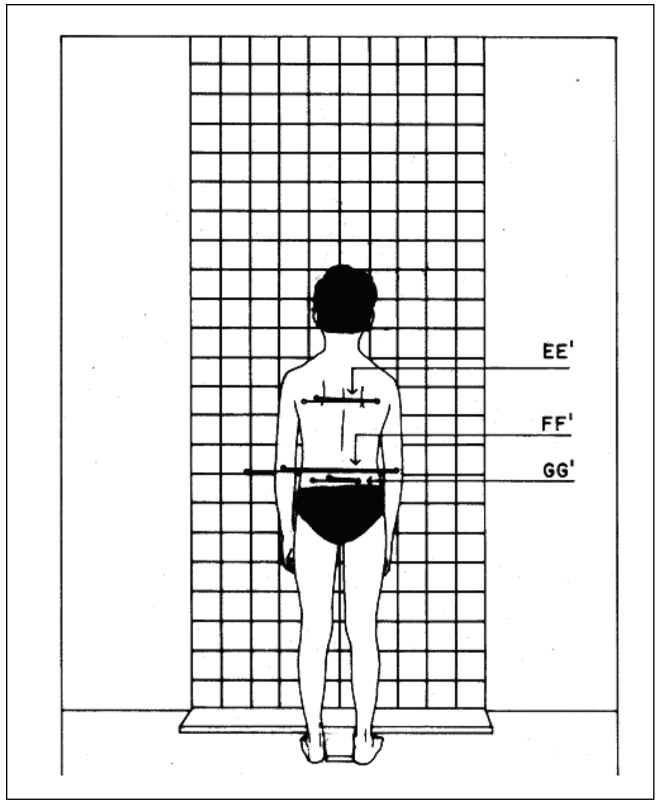

Figure 2. Picture of posterior body posture describing the measurement of angle EE' (Inferior angles of the scapula angle), FF' (Posterior central elbow joints angle) and GG' (Posterior superior iliac spine angle).

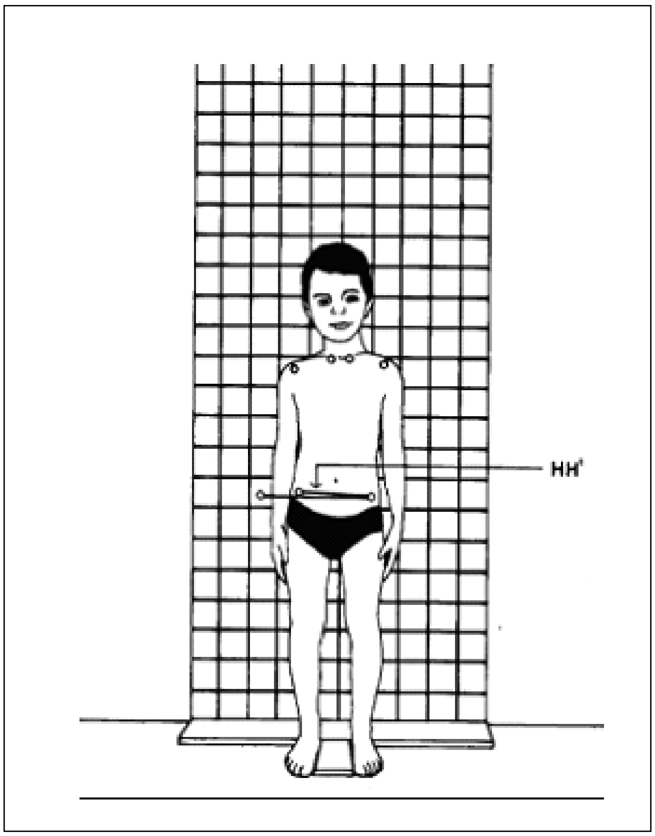

Figure 3. Picture of anterior body posture describing the measurement of angle HH´ (anterior superior iliac spine angle).

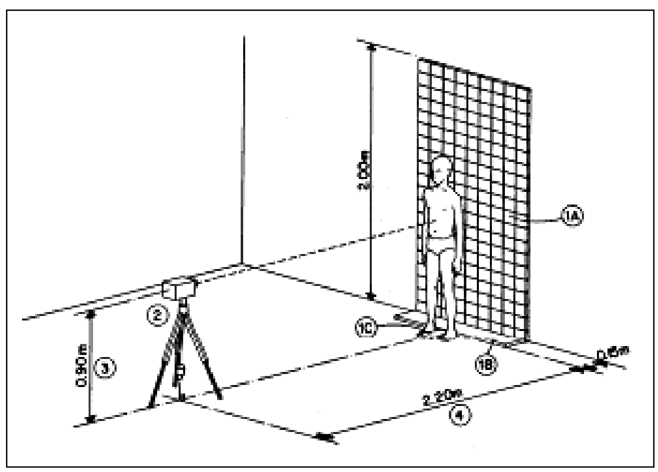

Figure 4. Video recording set-up.

body parts. Correct posture is the state of muscular and skeletal balance that protects the structures of the body against injury or progressive deformity.[15] Although there is wide agreement that good posture is important, it is surprisingly difficult to evaluate and to determine changes after postural retraining.[38] A large number of qualitative[27, 38] and quantitative[4, 5, 39] techniques have been proposed to assess body posture. The evaluation of static posture can be performed using photography[4, 14, 31, 39] and video recordings,[5] demonstrating acceptable levels of reliability.[4, 5, 14]

The aim of this study was to evaluate body posture asymmetries using a video-recording technique in children with unilateral PCB.

SUBJECTS AND METHODS

Twenty-eight children in the mixed dentition were randomly recruited from the Public Dental Clinic of a Private University (UNIT) to participate in this study.

They were then divided into two groups: The PCB Group comprised 14 unilateral PCB patients (eight boys and six girls), 11 with a right and three with a left posterior crossbite (6.6 ±1.8 years). The diagnosis of a unilateral PCB was performed by a dentist (SCHR) and the child must have more than one posterior tooth (starting from the canine tooth) in full crossbite, that is, the buccal cusp of the upper tooth occluding lingually to the buccal cusp of the lower tooth.[37]

The control group comprised 14 volunteers (7.5 ± 2.3 years) (five boys and nine girls) with a neutral occlusion (Angle Class I) without a unilateral PCB. The "ideal occlusion" was considered as class I, since it is the most common pattern of occlusion in the general population.[25]

The project was approved by the local Research Ethics Committee and the parents or persons responsible for the children signed a written informed consent to have the child participate in the study.

Children with a history of head trauma, a bilateral posterior crossbite, those undergoing orthodontic or craniofacial orthopedic treatment or presenting craniofacial anomalies, such as a cleft, were excluded.

POSTURAL ASSESSMENT

Eight pairs of bilateral anatomical points (A - Lateral corner of the eyes, B- Lateral corner of the mouth, C - Sternum clavicle joints, D - A point 2cm in front of the acromion clavicle joints, E - Inferior angles of the scapula, F - Posterior central elbow joints, G - Posterior superior iliac spine, H - Anterior superior iliac spine) located by palpation, were used in this study[3, 39] (Figures 1, 2 and 3).

Twelve white adhesive markers (0.9 cm in diameter) were placed on points C-C', D-D', E-E', F-F', G-G' and H-H'. Points A, A', B and B' were not marked as they are easy to locate and visualize (Figures 1, 2 and 3).

Since the anatomical points were defined, the subjects were advised to stand 15 cm in front of a background screen with the feet 7.5 cm apart and the foot in abduction of 10 degrees.[15] They were also guided to stay in natural body posture, with the arms hanging on the side of the body, looking ahead, breathing normally and with the jaw and lips at rest.[3] The images (640 x 460 pixels) were taken by a Panasonic camcorder (Palmcorder VHSC, Wide X 14, Lens, Power Zoom, NV – RJ 27) fixed on a tripod (Tron - VPT30). A video data acquisition board was used to obtain and store the images taken from the camcorder (640 x 460 pixels), which was positioned according to figure 4. For better definition of images of the head and of the superior region of the thorax, the camcorder was positioned 1.35 m from the floor and 80 cm from the subject.

The recordings were made over short-time periods (5 seconds) to prevent body posture alterations and the effect of less collaboration from younger children, with a time interval of 10 seconds between each recording, and then digitized using video software. The images were transformed into photographic records therefore; the selected images were those with the best defined digital characteristics. Three pictures were taken for each subject for posture assessment: an anterior and a posterior image of the whole body and an anterior image of the superior region of the head and thorax.

IMAGE ANALYSIS

To obtain the angles an image analysis software (*ALC*imagem 2000, version 1.5) was used and lines were drawn from right to left, binding the anatomical points bilaterally, and the angle of each line to the horizontal plane was calculated in degrees. Consequently, asymmetries were quantified according to the tilt of the line going through the anatomical points bilaterally in relation to a line parallel to the horizontal plane. The angles described the tilt level of body segments to the right or the left. The following angles were measured: Head tilt 1 (A-A'), Head tilt 2 (B-B'), Sternum-clavicle tilt (C-C'), Shoulder tilt (D-D'), Inferior Scapula tilt (E-E'), Arms tilt (F-F'), Posterior pelvic tilt (G-G') and Anterior pelvic tilt (H-H') (Figures 1, 2 and 3).

A value of 180 degrees indicated whether both segments were aligned horizontally; a value lower than 180 degrees indicated a tilt to the left, and a value greater than 180 degrees a tilt to the right. For statistical purposes, each value obtained was subtracted from 180 degrees. As a result, values greater than zero degrees ($x > 0$ degrees) described a tilt to the right, and values lower than zero degrees ($x < 0$ degrees) a tilt to the left.

A total of eight angles were obtained. Each angle was obtained three times and the mean value was considered for statistical analysis. Reliability of angle measurements in the procedure has been previously reported.[14] The authors reported values of Intraclass Correlation Coefficient (ICC) for all the angles measured, which ranged from excellent to moderate (ICC values were respectively, 0.99 to 0.71 and 0.99 to 0.63). The standard error of the method ranged from 0.51 to 0.27 and from 0.63 to 0.33 for inter and intra reliability, respectively. The reproducibility of the method for obtaining the video images on two separate occasions was also verified. For the majority of the angles, the values were moderate (ICC values from 0.4 to 0.75), according to Fleiss' classification.[8]

The examiners who performed the video recordings (ML) and those who obtained the angles (TCC) were blinded for the group's characteristics (patients or control group).

STATISTICAL ANALYSIS

As the data showed normal distribution (Shapiro Wilk's test, $p<0.05$), parametric statistics were used. Student's t-test ($p<0.05$) was used to determine significant differences between mean angle values between the PCB and control groups and between the genders.

In order to assess significant differences between the three groups (right PCB patients, left PCB patients and controls) regarding the mean values of the angles, one-way ANOVA ($p<0.05$) was used. Age effect was tested using MANOVA ($p<0.05$).

Table 1. Comparisons of mean angle values (degrees) and standard deviations between PCB and control groups.

Angles	Mean (degrees)	
	PCB group (n = 14)	Control Group (n = 14)
AA´	3.65 ± 2.65*	1.55 ± 1.21
BB´	3.38 ± 2.84*	1.37 ± 1.23
CC´	1.88 ± 1.66	1.68 ± 1.58
DD´	1.71 ± 1.13	1.30 ± 1.13
EE´	3.58 ± 2.51	2.61 ± 2.81
FF´	2.32 ± 1.79	2.31 ± 2.08
GG´	2.34 ± 2.73	1.95 ± 1.48
HH´	1.61 ± 1.15	2.29 ± 1.38

* $p < 0.05$

Table 2. Comparisons of mean angle values (degrees) and standard deviations between the three groups: right PCB patients, Left PCB patients and neutral occlusion volunteers.

Angles	Mean (degrees)		
	Right PCB (n = 11)	Left PCB (n = 3)	Neutral occlusion (n = 14)
AA´	4.18 ± 2.56*	2.35 ± 2.30	1.55 ± 1.21
BB´	2.10 ± 1.04	3.84 ± 3.33	1.37 ± 1.23
CC´	1.52 ± 3.04	2.27 ± 1.47	1.68 ± 1.58
DD´	1.87 ± 1.11	0.51 ± 0.48	1.30 ± 1.13
EE´	4.04 ± 2.90	2.26 ± 0.39	2.61 ± 2.81
FF´	3.65 ± 3.14	3.23 ± 1.71	2.31 ± 2.08
GG´	1.80 ± 1.13	1.91 ± 1.37	1.95 ± 1.48
HH´	1.96 ± 1.74	1.41 ± 1.50	2.29 ± 1.38

Significant difference between right PCB and neutral occlusion groups ($p < 0.05$, ANOVA). PCB: posterior crossbite

RESULTS

Student's t-test did not show statistical differences for the angles considered between the groups formed according to gender (AA': p = 0.17, BB': p = 0.11, CC': p = 0.44, DD': p = 0.29, EE': p = 0.33, FF': p = 0.25, GG': p = 0.77, HH': p = 0.21), and for those formed according to age, no statistical difference was found by MANOVA ($p < 0.05$) (AA': p = 0.19, BB': p = 0.98, CC': p = 0.50, DD': p = 0.17, EE': p = 0.81, FF': p = 0.93, GG': p = 0.99, HH': p = 0.60).

It was shown that angles AA´ (head tilt angle 1) and BB´ (head tilt angle 2) showed significantly increased values ($x > 0$ degrees) for the PCB group (n=14) in relation to the control group (n=14), demonstrating a greater lateral tilt of the corner-of-the-eye and corner-of-the-mouth planes for the PCB group (Table 1). Considering all the volunteers with PCB (G1) (n=14), head tilt, shown by angles AA' and BB', followed the crossbite side in 64% (n=9), and it was observed on the opposite direction for 36% (n=5).

In Table 2, the means and standard deviations (SD) for the three groups with right PCB (n=11), left PCB (n=3) and control group (n=14) are reported. It was observed that only right PCB patients exhibited a significantly increased AA' angle (head tilt angle 1) in relation to the control group. Considering the head tilt side and its relation to the crossbite side, it was observed that, for 54% (n=6) of the patients with right PCB, head tilt followed the crossbite side and, for 45% (n=5), it was in the opposite direction. For all patients with left PCB, head tilt followed the same side as that of the crossbite (n=3).

DISCUSSION

The results showed an increase in head tilt for unilateral PCB children when compared to children with neutral occlusion and that such increased head tilt was only significant in right PCB patients (4.18 degrees) when compared to left PCB (2.35 degrees) patients and volunteers with neutral occlusion (1.55 degrees). Therefore, such results suggest that patients with posterior right PCB exhibited pronounced head tilt, but no relationship could be observed between the PCB side and the head tilt side, since 54% of right PCB patients exhibited head tilt to the right (in the same direction as that of crossbite), and 45% (n=5) presented it to the left (in the opposite direction to that of crossbite). The same tendency, of greater head tilt, was not shown by left PCB patients, which could be explained by the small sample of left PCB patients (n=3) examined in this study. Consequently, our results could not be extrapolated for both types of unilateral PCB. On the other hand, considering all the unilateral PCB patients (right and left crossbite), it was observed that, for 64% of the patients, head tilt followed the side of the crossbite, which could suggest that regardless of the crossbite side, head tilt seems to follow the crossbite side in patients with unilateral PCB.

The results also suggest that body posture alterations in volunteers with unilateral PCB could be observed, particularly in the cranial region (or more commonly observed in the upper body segment) and on the frontal plane (lateral inclination of upper body segments). Michelotti *et al*[21] confirmed our findings. They suggested that alterations in body posture could be associated with occlusion alterations and reported that such alterations were more directly related to the craniocervical region and to the spine as a whole.

Huggare[11] carried out one of the few clinical studies which reported the correlation between frontal plane postural alterations and a unilateral PCB. That author also observed increased head tilt, orbital plane tilt, mandibular and maxillary plane tilt as well as unilateral PCB in patients with scoliosis treated with a boston brace. In a review, Huggare[11] suggested a possible association between unilateral PCB and head tilt as found in this study.

A possible explanation for head posture alterations on the frontal plane, identified in children with unilateral PCB was reported by Zuñiga *et al,*[40] who demonstrated that a shift in mandible positioning (neuromuscular guidance of the mandible) influences the electrical activity of the sternocleidomastoid and trapezius muscles (upper fibers). If we take into account that those muscles are responsible for the stability of the head and for movements such as tilt and rotation of the head, we could suppose that head tilt may be caused by the change in dental contact that is typical in unilateral PCB, resulting in the unilateral imbalance of the sternocleidomastoid and trapezius muscles, probably a shortening of the neck muscles ipsilaterally to the crossbite side and leading to head tilt to the crossbite side.

Another important aspect is that, for 64% of the volunteers with a unilateral PCB, the tilt of the head followed the crossbite side, suggesting the existence of a correlation between crossbite side and postural asymmetry of the head. Shimazaki *et al*[34] demonstrated, by biomechanical models, that tilt of the occlusal plane may only promote differences in cervical spine stress distribution, leading to a cervical spine tilt and, consequently, a head tilt to the same side of the crossbite, when not followed by compensatory asymmetries in the activity of masticatory muscles.

In the literature there are reports on the association between asymmetries or imbalances in the activity of masticatory muscles in unilateral PCB volunteers by the use of surface electromyography,[1, 6, 13, 36] and those asymmetrical muscle activity patterns could be related to the development of common facial asymmetries, but can also be a consequence of anatomical and functional dental asymmetries, such as those found in children with unilateral PCB.

Thus, the tilt verified for lateral corner-of-the-eye and mouth planes in this study could represent a head tilt on the frontal plane or could indicate the presence of facial asymmetry (mandibular midline deviation, for example) in children with unilateral PCB. Pirttiniemi *et al* [29] suggested that facial asymmetries should be greater for patients with transversal malocclusion (such as unilateral PCB). Some authors stated that unilateral PCB children showed deviation of the midline towards the crossbite.[22,36] Such deviation is defined by the lateral shifting of the mandible due the asymmetrical occlusion or by neuromuscular guidance of the mandible[23] shown in unilateral PCB patients, and that can justify the asymmetry to the same crossbite side of the mouth angle observed in this study. On the other hand, it is important to consider the fact that the angle of inclination of the eyes' corner (Head tilt 2) also showed to be significantly increased in the group with unilateral PCB, which may suggest that the alterations in these angles more directly translate alterations in head positioning and not necessarily facial asymmetries (mandibular midline deviation).

REFERENCES

1. Alarcón J., Martin C., Palma J. Effect of unilateral posterior crossbite on the electromyographic activity of human masticatory muscles. Am J Orthod and Dentofac Orthop, 118: 328–334, 2000.
2. Bevilaqua-Grossi D., Chaves T.C., Duarte-Lima K., Oliveira A.S. Atividade Eletromiográfica dos músculos Masseter e Temporal anterior de Crianças Com Mordida Cruzada Posterior Unilateral (MCPU). Revista Brasileira de Fisioterapia, 9: 257–236, 2005.
3. Bishara S., Cummins D., Jorgensen G., Jakobsen J. A computer assisted photogrammetric analysis of soft tissue changes after orthodontic treatment - part I: methodology and reliability. J Am Assoc Orthod, 107: 633–639, 1995.
4. Dunk N.M., Chung Y.Y., Compton D.S., Callaghan J.P. The reliability of quantifying upright standing postures as a baseline diagnostic clinical tool. J. Manipulative Physiological Therapy, 27: 91–96, 2004.
5. Ferrario V.F., Sforza C., Tartaglia G, Barbini E, Michielon G. New television technique for natural head and body posture analysis. Cranio, 13: 247–255, 1995.
6. Ferrario V.F., Sforza C., Serrao G. The influence of crossbite on the coordinated electromyographic activity of human masticatory muscles during mastication. J Oral Rehab, 26: 575–581, 1999.
7. Festa F., Dáttilio M., Vecchiet F. Effects of horizontal oscillation of the mandible on the spinal column of the rat *in vivo* using radiographic monitoring. Ortognatontia Italiana, 6: 539–550, 1997.
8. Fleiss J.L., Levin B., Paik M.C. Statistical methods for rates and proportions. Ed John Wiley & Sons. Inc. Hoboken, New Jersey, 1994
9. Gazzit-Rappaport T., Weinreb M., Gazit E. Quantitative evaluation of lip asymmetry in functional asymmetry. Eur J Orthod, 25: 443–450, 2003.
10. Henry R. Slow maxillary expansion: a review of quad-helix therapy during the transitional dentition. Journal of Dentistry for Children, 60: 408–413, 1993.
11. Huggare J. Postural disorders and dentofacial morphology. Acta Odont Scand, 56: 383–386, 1998.
12. Huggare J. and Raustia A. Head posture and cervicovertebral and craniofascial morphology in patients with craniomandibular dysfunction. J Craniomandibular Practice, 10, 173–177, 1992.
13. Ingerval B. and Thilander B. Activity of temporal and masseter muscles in children with a lateral forced bite. Angle Orthod, 45: 249–258, 1975.
14, Iunes D.H., Castro F.A., Salgado H.S., Moura I.C., Oliveira A.S., Bevilaqua-Grossi D. Confiabilidade intra e interexaminadores e repetibilidade da avaliação Postural pela Fotogrametria. Revista Brasileira de Fisioterapia, 9: 327–334, 2005.
15. Kendall F.P. and McCreary E.K., Provance P.G. Músculos, provas e funções. Ed Manole, São Paulo.
16. Kisling E. and Krebs G. Patterns of occlusion in 3 year-old danish children. Community dentistry and oral epidemiology, 4:152–159, 1976.
17. Linder-Aronson S. Adenoids. Acta Oto-Laryngologica Suppl. 265, 1970.
18. Makofsky H.W. The effect of head posture on muscle contact position: the sliding cranium theory. J Craniomandibular Practice, 7: 286–292, 1989.
19. Malandris M. and Mahoney E.K. Aetiology, diagnosis and treatment of posterior crossbites in the primary dentition. International J Clin Ped Dent, 14: 155–166, 2004.
20. Mannheimer J. and Rosenthal R. Acute and chronic postural abnormalities as related to craniofacial pain and temporomandibular disorders. Dental Clinics of North America, 35: 185–207, 1991.
21. Michelotti A., Manzo P., Farella M., Martina R. Oclusione e postura: quali la evidenze di correlazione? Minerva Estomatologica, 48: 525–534, 1999.
22. Moyers E.R. Ortodontia. Ed.Guanabara Koogan, São Paulo.
23. Nerder P., Bakke M., Solow B. The functional shift of the mandible in unilateral posterior crossbite and the adaptation of the temporomandibular joints: a pilot study. Eur J Orthod, 21: 155–166, 1999.
24. Ng'ang'a P., Ohito F., Ögaard B., Valdehaug J. The prevalence of malocclusion in 13- to 15-year old children in Nairobi, Kenya. Acta Odont Scand, 54: 126–130, 1996.
25. Okeson J.P. Dor orofacial, guia de avaliação diagnóstico e tratamento. Ed Quintessence, São Paulo, 2001.
26. Palazzi C., Miralles R., Soto M., Santander H., Zuniga C., Moya H. Body position effects activy of sternocleidomastoid and masseter muscles in patients with myogenic cranio-cervical-mandibular dysfunction. Journal of Craniomandibular Practice, 14: 200–209, 1996.
27. Penha P.J., João S.M., Casarotto R.A., Amino C.J., Penteado D.C. Postural assessment of girls between 7 and 10 years of age. Clinics, 60: 9–16, 2005.
28. Pinto A.S., Buschang P.H., Throckmorton G.S., Chen P. Morphological and positional asymmetries of young children with functional unilateral posterior crossbite. Am J Orthod Dentofac Orthop, 120: 513–20, 2001.
29. Pirttiniemi P., Kantomaa T., Lahtela P. Relationship between craniofacial and condyle path asymmetry in unilateral cross: bite patients. Eur J Orthod, 12: 408–413, 1990.
30. Pirttiniemi P., Lahtela P., Huggare J., Serlo W. Head posture and dentofacial asymmetries in surgically treated muscular torticollis patients. Acta Odontologica Scandinavica, 47: 93–197, 1989.
31. Raine S. and Twomey L.T. Head and shoulder posture variations in 160 asymptomatic women and men. Archives of Physical Medicine and Rehabilitation, 78: 1215–1223, 1997.

32. Rocabado M. Cabeza y cuello - tratamiento articular. Ed. Intermédica, Buenos Aires, 1993.
33. Simões W. Insights on maxillary and mandibular growth for better practice. J Clin Ped Dent, 21: 1–8, 1996.
34. Shimazaki T., Motoyoshi M., Hosoi K., Namura S. The effect of occlusal alteration and masticatory imbalance on the cervical spine. Eur J Orthod, 25: 457–463, 2003.
35. Solow B. and Sonnesen L. Head posture and malocclusions. Eur J Orthod, 20: 685–693, 1998.
36. Troelstrup B. and Möller E. Electromyography of the temporalis and masseter muscles in children with unilateral cross-bite. Scand J Dent Res, 78: 425–430, 1970.
37. van Keulen C., Martens G., Dermaut L. Unilateral posterior crossbite and chin deviation: is there a correlation? Eur J Orthod, 26: 283–288, 2004.
38. Watson A.W. and Mac Donncha C. A reliable technique for the assessment of posture: assessment criteria for aspects of posture. Journal of Sports Medicine and Physical Fitness, 40: 260–270, 2000.
39. Zonnenberg A., Van-Maanen C., Oostendorp R., Elves J. Body posture photographs as a diagnostic aid for musculoskeletal disorders related to temporomandibular disorders (TMD). J Craniomandibular Practice, 14: 225–232, 1996.
40. Zuniga C., Miralles R., Mina B., Montt R., Moran N., Santande H., Moya H. Influence of variation in jaw posture on sternocleidomastoid and trapezius electromiographic activity. J Craniomandibular Practice, 13: 157–162, 1995.