European Journal of Orthodontics 26 (2004) 283–288

European Journal of Orthodontics vol. 26 no. 3

Unilateral posterior crossbite and chin deviation: is there a correlation?

Chris van Keulen*, Guy Martens** and Luc Dermaut*
Departments of *Orthodontics and **Medicine and Health Science, University of Gent, Belgium

SUMMARY A retrospective study evaluating the clinical discernment of chin deviations in general, and especially in relation to unilateral posterior crossbite (UPXB), was carried out to determine whether (1) there is a correlation between UPXB and clinically discernible chin deviation, (2) there are differences between the judgement of professional dental observers and laymen, (3) visual assessment of chin deviation compares well with computer-assisted assessment and (4) how large a chin deviation should be before it is noticed.

The experimental group consisted of 72 patients (30 males and 42 females, average age 14.5 years) with a UPXB. A control group of 72 subjects without a UPXB was matched for age and sex. In addition, one computer-designed face was added with chin deviations of 0, 2, 4, 6 and 8 mm to the left. The full-face slides of all subjects were shown twice, with an interval of 2 weeks, to an audience of seven orthodontists, ten dental students and five laymen judging by eye. A computer-assisted assessment was carried out by one observer, in order to create a standardized comparison to visual scoring.

Inter-observer examination of visual scoring showed moderate agreement (kappa = 0.48). When comparing the computer-assisted and visual scores, the intra-class correlation coefficient (ICC) was 0.87. There were no major differences between professional observers and laymen, although the latter gave significantly more responses in the direction opposite to the crossbite. In 70.3 per cent (on average) of the subjects with a crossbite, a deviation in the same direction as the crossbite was noticed visually. The majority of the observers observed a chin deviation of at least 4 mm.

Introduction

A posterior crossbite is a relatively common malocclusion, often present in the primary and mixed dentition stages. An incidence ranging between 7 and 23 per cent of the population has been found, most frequently unilaterally (Kutin and Hawes, 1969; Day and Foster, 1971; Infante, 1976; De Vis *et al.*, 1984; Schroder and Schroder, 1984; Thilander *et al.*, 1984). Leighton (1966) reported that unilateral posterior crossbites (UPXB) first appear between 19 months and 5 years of age.

Several authors have attempted to find a relationship between mandibular asymmetry and malocclusion in general (Lundström, 1961; Letzer and Kronman, 1967), as well as in relation to crossbite (Cheney, 1961; Chebib and Chamma, 1981; Mongini and Schmid, 1987; Santos Pinto *et al.*, 2001). Most of these studies mainly focused on radiographic evidence. A clinically discernible deviation of the chin due to a possible mandibular asymmetry in UXPB does not appear to have been investigated.

Previous investigations have found increased activity in the temporalis and masseter muscles on the crossbite side compared with the non-crossbite side during resting as well as during chewing (Troelstrup and Møller, 1970; Ingervall and Thilander, 1975; Michler *et al.*, 1987; Ferrario *et al.*, 1999; Sonnesen *et al.*, 2001). This asymmetrical function reflects asymmetrical development of these muscles. Moreover, Kiliardis *et al.* (2000) found that the thickness of the masseter muscle on the crossbite side was thinner than on the non-crossbite side.

Separate studies by Ben-Bassat *et al.* (1993) and Brin *et al.* (1996) indicated that orthodontic correction of a UPXB with slow palatal expansion did not eliminate reverse sequencing in the chewing cycle. Throckmorton *et al.* (2001) also found that treatment did not alter the patients' abnormal cycle shape and speculated that the original skeletal asymmetry may have contributed to the unresolved reverse sequencing.

Santos Pinto *et al.* (2001) found radiographically that the mandible was significantly longer on the non-crossbite side than on the crossbite side. This was especially so for the ramus.

Lam *et al.* (1999) found, in children with a functional UPXB, symmetrical mandibles with a shift. Mongini and Schmid (1987) suggested that occlusal alterations, leading to mandibular displacement in the growth period, could result in compensatory asymmetrical growth. They found the condylar position normal in maximal occlusion. The fact that a functional shift is rarely detected in adults with a UPXB (O'Byrn *et al.*, 1995) may be an indication of mandibular and temporomandibular joint adaptive remodelling changes (Kantomaa, 1988; Pirttiniemi *et al.*, 1990).

Some clinicians prefer to carry out early treatment of crossbites in an attempt to correct abnormal closing patterns of the mandible so as not to disturb normal growth (Thilander *et al.*, 1984; Thilander, 1986; Heikinheimo and Salmi, 1987; Mongini and Schmid, 1987; Hannuksela *et al.*, 1988; Pirttiniemi *et al.*, 1990; Schmid *et al.*, 1991; Kurol and Bergland, 1992; Hesse *et al.*, 1997; Sonnesen *et al.*, 2001).

The aims of this investigation were to answer the questions as to whether a correlation exists between a discernible deviation of the chin in the resting position and the occurrence of a unilateral crossbite in general in a double-blind investigation, whether there would be differences in assessment of this asymmetry between laymen and professionals and how large a deviation of the chin has to be before it is visible with the eye compared with computer assessment.

Subjects and methods

A retrospective study was carried out to evaluate discernible mandibular asymmetry in two groups of natural faces as well as in computer-designed faces.

Composition of the groups

The sample (i.e. experimental and control) of natural faces comprised 144 pre-orthodontic Caucasian children. The experimental group consisted of 72 patients with unilateral crossbites in addition to fulfilling four other criteria. These were: more than one posterior tooth (starting from the canine) in full crossbite (i.e. the buccal cusp of the upper tooth occludes lingual to the buccal cusp of the corresponding lower tooth), all permanent teeth present and fully erupted (with the possible exception of the third molars), no craniofacial anomalies such as a cleft, and complete records (i.e. full-face photographs, casts). The average age of the group was 14.5 years (standard deviation = 3.7). Thirty patients were male and 42 were female.

A control group of 72 patients matched for age and gender was composed. All patients in the control group fulfilled the same criteria except that they did not have any tooth in crossbite.

The full-face photographs were taken with a Yashica Dental Eye III (100 mm f/4.0 macro lens 24 × 36 mm) on a 35 mm slide film positioned for 1:8 magnification. The patient was standing, with their head in the natural position, looking straight at the camera with the visual axis horizontal. The patients were asked not to close their teeth together, so that the natural mandibular position at rest was recorded, independent of the occlusion (excluding possible forced bites). Spectacles were removed. The photographs were taken on a dark blue background. To obtain standardization of the photographs for the study they were taken according to well-established rules. Small errors in standardization may result in small differences in magnification, but this would not affect the scoring of (a)symmetry. The possible occurrence of a crossbite was established on casts.

Composition of the computer-designed faces

A computer-designed perfectly symmetrical face was constructed by copying one side only of the face of a 13-year-old male patient to the contralateral side in reverse (Figure 1). Starting from a perfectly symmetrical face, the chin was warped to the left side over absolute distances of 2, 4, 6 and 8 mm parallel to the bi-pupilar line (WinMorph® v2.01, Satish Kumar Software, San Diego, CA, USA). A slide was made for each chin morphology (Figure 2).

Visual scoring

In total, 149 slides (i.e. 144 natural and one computer-designed face with five different induced chin asymmetries) were projected randomly to a selected audience sitting straight in front of a screen.

Figure 1 Example of a computer-designed face. A perfectly symmetrical face was constructed by copying one side of the face of a 13-year-old male patient to the contralateral side in reverse.

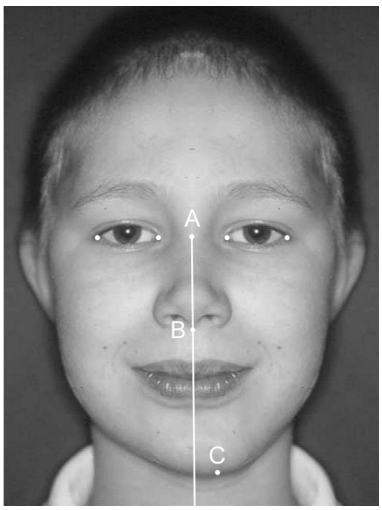

Figure 2 Example of a computer-designed face with chin deviations. Starting from a perfectly symmetrical face, the chin was warped 6 mm to the left. The computer-assisted way of scoring is also illustrated in this photograph. Point A was calculated as a mean of the co-ordinates of the inner and outer canthus of both eyes, and point B was defined as subnasale. The shortest distance between the estimated middle of the chin (point C) and the line through A and B was calculated.

All slides were shown twice with an interval of 2 weeks to seven orthodontists (two males, five females, average age 27.1 years), 10 dental students (five males, five females, average age 21.2 years) and five lay people (three males, two females, average age 32.2 years). The slides were numbered and marked 'L' for left and 'R' for right. Each slide was displayed for 15 seconds only and all observers were asked to write down their first impression of a possible chin deviation. Scoring was limited to three possibilities: chin deviation towards the left (score +1), towards the right (score –1) or no deviation (score 0).

Computer-assisted scoring

In addition to visual scoring of all faces, a computer-assisted assessment was made by one observer in order to create a standardized comparison of the visual scores. In order to do this, all slides were scanned and saved as jpeg files of approximately 3 MB each. The digitized images were analysed using an IBM® computer system.

To identify a chin point deviation, a reference system in the face had to be chosen (Figure 2). The X and Y co-ordinates of the inner and outer canthus of both eyes were determined and a median point 'A' was calculated. Soft tissue subnasale was defined as point B and the estimated chin point as C. The shortest distance from point C to a line through points A and B was calculated, enabling the amount of left and right deviation of the chin point to be identified. In contrast to the method used for visual scoring, in which only three scores were available, the computer-assisted scoring used quantitative values expressing the amount of chin point deviation. This procedure was carried out twice with an interval of 2 weeks by one observer.

The statistical analyses were performed using SPSS® software (SPSS® Inc, Chicago, IL, USA).

Results

Visual scoring

All variables in the inter-observer examinations showed moderate agreement as assessed by the kappa (κ) coefficient (Cohen, 1960) of 0.48. When comparing the first and second assessment of the visual scoring, the intra-observer reliability showed κ ranging between 0.40 and 0.57. The average values were 0.50 for the orthodontists, 0.47 for the dental students and 0.45 for the laymen.

Visual scoring of the computer-designed face

For the computer-designed face, with perfect symmetry, 17 per cent of the observers thought they saw a deviation of the chin to the right and 14 per cent to the left. The majority, 69 per cent, agreed that they saw a perfectly symmetrical face. When a chin deviation of 2 mm towards the left was shown, 50 per cent noted this deviation, whereas 50 per cent did not. None of the observers thought the deviation of the chin point was towards the contralateral side. Only a deviation of 6 mm was noted by all observers, whereas the majority, 89 per cent, noted a deviation of 4 mm in the correct direction. There were no significant differences between the groups of observers.

Visual scoring of the natural faces (crossbite patients and control group)

There were no significant differences in the assessment of chin deviation in the crossbite group between the differing levels of experience of the professional observers. Laymen gave significantly more answers in the direction opposite to the crossbite.

From the 72 subjects with a crossbite (34 to the right, 38 to the left), on average 52 chin deviations were noted by the observers: 26 to the left, 26 to the right. In 20 cases no deviation was noted. This finding is supported by a mean scoring value of –0.06 indicating that on average the chin points were situated in the middle of the face. The average answers are presented in Table 1.

On average, 76.1 per cent of all given answers reported the asymmetry as being to the right, in the same direction as the crossbites. When the crossbite was on the right side, an average of 96.8 per cent of all given answers were not in the opposite direction from the crossbite. This meant that a chin deviation to the right side or no chin deviation at all was noted by almost all observers. For the left side, on average 65.8 per cent of all given answers were in the same direction as the crossbites i.e. to the left (Table 1). Although differences in percentages between left and right chin deviations were observed, they were not statistically significant ($P > 0.05$).

Using Fisher's exact test, the standard deviations (SD) of left-sided crossbites (SD = 5.5 and 5.8) appeared to be significantly higher than the right-sided crossbites (SD = 2.8 and 2.4) except when the deviation of the chin was reputed to be to the right (SD = 3.0 versus 3.3) (see Table 1). The SDs of left and right side noted chin deviations were not significantly different. Where no chin deviation was noted there appeared to be significantly more crossbites on the left side compared with the right side.

There were no significant differences in the non-crossbite subjects between the groups of observers. Of the 72 cases without a crossbite (control group), on average 40 chin deviations were noted: 14 to the left, 26 to the right. In 32 cases no deviation was observed. The average answers are also shown in Table 1. As in the crossbite group, the SDs of left and right side noted chin deviations were not significantly different. There were significantly more chin deviations noted to the right than to the left side.

For the control group less chin deviations were seen, due to less deviations being noted towards the left side.

Table 1 Agreement between observed chin deviations and registered crossbites.

	Chin deviation seen towards the right	No chin deviation noted	Chin deviation seen towards the left
Crossbite on the right side (n = 34)			
Average	25.9	7.0	1.1
SD	3.0	2.8	2.4
%	76.1	20.7	3.3
Crossbite on the left side (n = 38)			
Average	1.4	11.6	25.0
SD	3.3	5.5	5.8
%	3.7	30.5	65.8
No crossbite (n = 72)			
Average	25.9	31.6	14.4
SD	6.9	8.9	7.0
%	36.0	43.9	20.0

SD, standard deviation.

The number of cases where no chin deviation was seen was significantly larger in the control group compared with the crossbite group.

Computer-assisted scoring

Of the 72 subjects with a crossbite, on average all chin deviations were noted by the observer using computer-assisted scoring: 37 deviations to the left and 35 to the right. When the crossbite was on the left side, in 36 cases a chin deviation was found in the same direction and in two cases in the opposite direction. When the crossbite was on the right side, in 33 cases a chin deviation was found in the same direction and in one case in the opposite direction.

Of 72 cases without a crossbite, on average 72 chin deviations were noted: 28 to the left and 44 to the right. There was no significant difference between the first and second computer-assisted scoring. Spearman's rho showed a correlation coefficient of 0.97 between the first and second computer-assisted scoring.

Comparison of visual and computer-assisted scoring

The individual intra-class correlation coefficient (ICC) between the computer-assisted scoring and the average answers of the visual scoring per patient ranged between 0.65 and 0.77. For the senior orthodontists the ICC was 0.82, for the junior orthodontists 0.86, for the dental students 0.91 and 0.79 for the laymen. The ICC of all investigators together was 0.87. The average of the answers of the visual scores for all observers plotted against the z-score of the computer-assisted scores is shown in Figure 3.

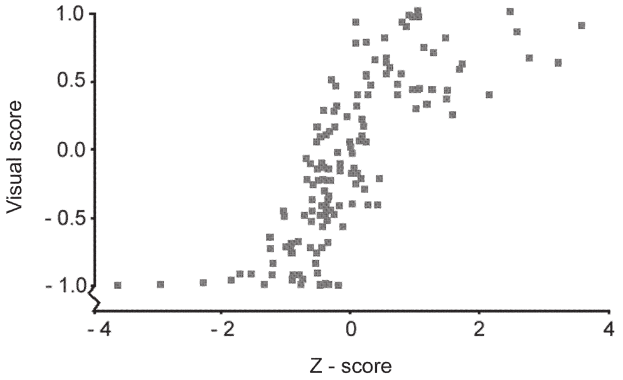

Figure 3 A scattergram illustrating the correlation between visual and computer-assisted scoring. The average of the answers of the visual scores for all observers on the vertical axis is plotted against the z-scores of the computer-assisted scores on the horizontal axis.

Discussion

The aim of the present study was to evaluate visually facial (a)symmetry in crossbite patients. Both the visual as well as the computer-assisted scoring method were not designed to detect absolute deviations. As the focus of this study was on clinical discernment, the use of facial photographs was considered to be sufficient.

When using computer-assisted scoring, an attempt was made to make a more accurate assessment using a minimum of mathematical formulae (after having defined the location of reference points and the middle of the chin). Even here emphasis was placed on the clinically discernible deviation. The computer-assisted scoring was developed as a reference. It was only used as a comparison with the visual scores in order to inform, in a more objective way, the differences in scoring between the groups of observers.

Facial asymmetry is a relative distortion of multiple anatomical parts, such as the eyes, nose, lips and mandible. Because all structures in the face can be involved in asymmetry, a combined reference system was chosen, including both the eyes and the nose, for the computer-assisted scoring.

The facial photographs were taken in the relaxed position, without the teeth in occlusion, despite the fact that crossbite is a malocclusion. By doing so, chin deviations due to forced bites were excluded.

It is not surprising that the consistency of the first and second computer-assisted scores (intra-observer reliability) was more accurate (Spearman's rho = 0.97) than that for the first and second visual scores. To test the consistency of the visual scores, a Spearman correlation could not be used, as only three scores per face were available. Therefore, κ was used to test this consistency. The consistency in visual scoring by the same observer was moderate (κ ranging between 0.40 and 0.57). For inter-observer reliability, again moderate agreement was found (average κ of 0.48). This finding proves that visual scoring of chin point deviations is not easily undertaken. Differences in scoring between the orthodontic and dentally trained personnel and the laymen were moderate. This difference in observation can perhaps be explained by the fact that dentists in general are probably better trained to focus on facial and dental (a)symmetry than laymen. In addition, the limited number of observers in each subgroup should be taken into consideration while interpreting this moderate difference.

A so-called symmetrical face consists of a multitude of minor asymmetrical components. This has been demonstrated in different studies mostly based on radiographic (Hewitt, 1975; Shah and Joshi, 1978; Melnik, 1992) and anthropometric assessment (Farkas and Cheung, 1981). Clearly there is a threshold beyond which asymmetry becomes a clinically discernible problem for the orthodontist (Edler *et al.*, 2001). This threshold is individual, but the computer-designed face provides a better indication. The majority of observers were able to identify a chin deviation of 4 mm or larger. It is interesting that with the slightest deviation of the chin, i.e. 2 mm, no observer reported a deviation in the contralateral direction. It again appears there are no major differences in this part of the study between the observers, although the answers of the laymen were slightly poorer.

In the subjects with crossbites, equal numbers of right- and left-sided crossbites were found. No predominance of right-sided crossbites was found. This is in contrast to Santos Pinto *et al.* (2001) who, in a small sample, reported a predominance (10 right, five left).

In the control group, more right-sided chin deviations were found (36 versus 20 per cent). Chebib and Chamma (1981) also found a larger left side of the face resulting in more right-sided chin deviations. In their study, the maxillary dento-alveolar mid-sagittal structures and the chin point (menton) displayed the largest deviations. This is in contrast with the right-side dominance in the general population resulting in left-sided chin deviations (Vig and Hewitt, 1975; Shah and Joshi, 1978; Farkas and Cheung, 1981). The larger standard deviation for crossbites on the left side (5.5 and 5.8 versus 3.3 and 3.0) may also indicate more disagreement in scoring. Thus, it may be more difficult to determine a deviation of the chin towards the left side. Another explanation could be that there were more chin deviations to the right in the control group. The computer-assisted scoring of the control group also showed more deviations to the right.

The chance of observing a chin deviation in the same direction as the UPXB is high. On average, 76.1 per cent of all answers were in the same direction as the crossbites towards the right. For the left-sided crossbites this was 65.8 per cent. However, for a particular practitioner it might still be difficult to observe, as the average answers of all observers together were used in this investigation.

It does not appear that a correlation exists between a UXPB and chin deviation. During growth, modelling occurs related to functional forces (Enlow, 1979). Variations, such as asymmetries in the skeletal or muscular structures, might be an underlying cause for the occlusion established by nature. However, the reverse may be true. Occlusion may also influence skeletal and muscular development.

Conclusions

1. Consistency in visual scoring was moderate.
2. Computer scoring was more reproducible.
3. Computer and visual scoring (average values of the observers for each patient) correlated (ICC = 0.81).
4. In the computer-designed face, a chin deviation of at least 4 mm was observed by the majority of judges, while all of them noted a chin deviation of at least 6 mm.
5. There were no major differences in the assessment of chin point deviations between the orthodontists and dental students, but the laymen (limited sample) showed slightly poorer reproducible answers when compared with the dental students and orthodontists.
6. On average, in 96.4 per cent of the subjects with a crossbite, no chin deviation or deviation in the same direction as the crossbite was observed.
7. On average, in 70.3 per cent of the cases with a crossbite, a deviation in the same direction as the crossbite was observed.
8. The control group showed a significant trend for more chin deviations towards the right side.

Address for correspondence

Professor L. Dermaut
Department of Orthodontics
School of Dentistry (P-8)
University of Gent
De Pintelaan 185
9000 Gent
Belgium

Acknowledgement

The authors would like to thank Geert Dermout for his assistance with the layout of the illustrations.

References

Ben-Bassat Y, Yaffe A, Brin I, Freeman J, Ehrlich Y 1993 Functional and morphological-occlusal aspects in children treated for unilateral posterior crossbite. European Journal of Orthodontics 15: 57–63

Brin I, Ben-Bassat Y, Blustein Y, Ehrlich J, Hochmann N, Marmary Y 1996 Skeletal and functional effects of treatment for unilateral posterior crossbite. American Journal of Orthodontics and Dentofacial Orthopedics 109: 173–179

Chebib F S, Chamma A M 1981 Indices of craniofacial asymmetry. Angle Orthodontist 51: 214–226

Cheney E A 1961 Dentofacial asymmetries and their clinical significance. American Journal of Orthodontics 47: 814–829

Cohen J 1960 A coefficient of agreement for nominal scales. Educational and Psychological Measurement 20: 37–46

Day A J, Foster T D 1971 An investigation into the prevalence of molar crossbite and some associated aetiological conditions. Dental Practice 21: 402–410

De Vis H, De Boever J A, Van Cauwenberghe P 1984 Epidemiologic survey of functional conditions of the masticatory system in Belgian children aged 3–6 years. Community Dentistry and Oral Epidemiology 12: 203–207

Edler R, Wertheim D, Greenhill D 2001 Clinical and computerized assessment of mandibular asymmetry. European Journal of Orthodontics 23: 485–494

Enlow D H 1979 The condyle and facial growth. In: Sarnat B G, Laskin D M (eds) The temporomandibular joint, 3rd edn. Thomas, Springfield, IL, pp. 70–84

Farkas L G, Cheung G 1981 Facial asymmetry in healthy North American Caucasians. An anthropometrical study. Angle Orthodontist 51: 70–77

Ferrario V, Sforza C, Serrao G 1999 The influence of crossbite on the coordinated electromyographic activity of human masticatory muscles during mastication. Journal of Oral Rehabilitation 26: 575–581

Hannukelsa A, Laurin A, Lehmus V, Kouri R 1988 Treatment of crossbite in early mixed dentition. Proceedings of the Finnish Dental Society 84: 175–182

Heikinheimo K, Salmi K 1987 Need for orthodontic intervention in five-year-old Finnish children. Proceedings of the Finnish Dental Society 83: 165–169

Hesse K L, Årtun J, Joondeph D R, Kennedy D B 1997 Changes in condylar position and occlusion associated with maxillary expansion for correction of functional unilateral posterior crossbite. American Journal of Orthodontics and Dentofacial Orthopedics 111: 410–418

Hewitt A B 1975 A radiographic study of facial asymmetry. British Journal of Orthodontics 2: 37–40

Infante P F 1976 An epidemiologic study of finger habits in preschool children as related to malocclusion, socioeconomic status, race, sex and size of community. Journal of Dentistry for Children 1: 33–38

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

Kantomaa T 1988 The shape of the glenoid fossa affects the growth of the mandible. European Journal of Orthodontics 10: 249–254

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

Kurol J, Bergland L 1992 Longitudinal study and cost–benefit analysis of the effect of early treatment of posterior crossbites in the primary dentition. European Journal of Orthodontics 14: 173–179

Kutin G, Hawes R R 1969 Posterior crossbites in the deciduous and mixed dentitions. American Journal of Orthodontics 56: 491–504

Lam P, Sadowsky C, Omerza F 1999 Mandibular asymmetry and condylar position in children with unilateral posterior crossbite. American Journal of Orthodontics and Dentofacial Orthopedics 115: 569–575

Leighton B C 1966 The early development of crossbites. Dental Practitioner and Dental Record 17: 145–152

Letzer G M, Kronman J H 1967 A posteroanterior cephalometric evaluation of craniofacial asymmetry. Angle Orthodontist 37: 205–211

Lundström A 1961 Some asymmetries of the dental arches, jaws and skull, and their etiological significance. American Journal of Orthodontics 47: 81–106

Melnik A K 1992 A cephalometric study of mandibular asymmetry in a longitudinal followed sample of growing children. American Journal of Orthodontics and Dentofacial Orthopedics 101: 355–366

Michler L, Bakke M, Møller E 1987 Graphic assessment of natural mandibular movements. Journal of Craniomandibular Disorders and Facial Oral Pain 1: 97–114

Mongini F, Schmid W 1987 Treatment of mandibular asymmetries during growth. A longitudinal study. European Journal of Orthodontics 9: 51–67

O'Byrn B, Sadowsky C, Schneider B, BeGole E 1995 An evaluation of mandibular asymmetry in adults with unilateral posterior crossbite. American Journal of Orthodontics and Dentofacial Orthopedics 107: 394–400

Pirttiniemi P, Kantomaa T, Lahtela P 1990 Relationship between craniofacial and condyle path asymmetry in unilateral crossbite patients. European Journal of Orthodontics 12: 408–413

Santos Pinto A, 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

Schmid W, Mongini F, Felisio A 1991 A computer-based assessment of structural and displacement asymmetries of the mandible. American Journal of Orthodontics and Dentofacial Orthopedics 100: 19–34

Schroder U, Schroder I 1984 Early treatment of unilateral posterior crossbite in children with bilaterally contracted maxillae. European Journal of Orthodontics 6: 65–69

Shah S M, Joshi M R 1978 An assessment of asymmetry in the normal craniofacial complex. Angle Orthodontist 48: 141–148

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

Thilander B 1986 Temporomandibular joint dysfunction in children. In: Graber L W (ed.) Orthodontics, state of the art, essence of the science. C V Mosby, St. Louis, pp. 342–351

Thilander B, Wahlund S, Lennartsson B 1984 The effect of early interceptive treatment in children with posterior crossbite. European Journal of Orthodontics 6: 25–34

Throckmorton G S, Buschang P H, Hayasaki H, Santos Pinto A 2001 Changes in the masticatory cycle following treatment of posterior unilateral crossbite in children. American Journal of Orthodontics 5: 521–529

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

Vig P S, Hewitt A 1975 Asymmetry of the human facial skeleton. American Journal of Orthodontics 45: 125–129