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Associations between orthopaedic disturbances and unilateral crossbite in children with asymmetry of the upper cervical spine

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SUMMARY The objective of the present study was to detect possible associations between unilateral crossbite and orthopaedic disturbances in children with asymmetry of the upper cervical spine.

Fifty-five children aged 3–10 years (22 girls and 33 boys) with a unilateral crossbite and 55 gender- and age-matched children with a symmetric occlusion but no crossbite, who served as the control group, were selected from an orthopaedic cohort of 240 patients. In all children, asymmetry of the upper cervical region was confirmed by radiographs and palpation. The following orthopaedic aspects were investigated: oblique shoulder and pelvis, scoliosis, functional leg length difference, and laxity of ligaments of the foot. The differences between the groups were analysed by means of an unpaired *t*-test.

An increased occurrence of orthopaedic parameters in the frontal plane was observed in children with a unilateral malocclusion. A unilateral crossbite was not necessarily combined with a pathological orthopaedic variable, but statistically, children with a unilateral malocclusion showed more often an oblique shoulder ($P = 0.004$), scoliosis ($P = 0.04$), an oblique pelvis ($P = 0.007$), and a functional leg length difference ($P = 0.002$) than children with symmetry.

The results suggest that a unilateral crossbite in children with asymmetry of the upper cervical spine is associated with orthopaedic disturbances. There is no evidence of a causal link.

Introduction

Although the question of correlations occurring between posture, locomotion apparatus, and dentition has been debated since the beginning of the 20th century, 'this issue has gained only scant attention in subsequent research' (Huggare, 1998).

The results from experimental animal studies suggest that alterations in the occlusion evoke changes in many other regions of the body (Festa *et al.*, 1997; Azuma *et al.*, 1999; D'Attilio *et al.*, 2005). Occlusion has an impact on head position, spinal column alignment, and masticatory muscles which control posture and modulate cardiac function via the trigeminal system. After unilateral occlusal destruction, a postural abnormality in terms of inability of head maintenance, T-wave inversion on electrocardiograph, hair loss, changes in tongue mobility, and eating disorders as well as pathologies of the eye have been observed (Festa *et al.*, 1997; Azuma *et al.*, 1999). Recently, a scoliotic curve has been developed after insertion of a unilateral bite plane in rats (D'Attilio *et al.*, 2005). In all the studies, the evoked changes were observed within 1 week of unilateral manipulation and normalized after harmonization of the occlusal plane.

In order to investigate the possible effects of orthopaedic asymmetric disorders on dentofacial development and head posture, interdisciplinary clinical studies have been conducted on patients with scoliosis or torticollis. The statistically elevated prevalence of a unilateral crossbite in those subjects amounted to 26–55 per cent (Pirttiniemi *et al.*, 1989; Huggare *et al.*, 1991; Pećina *et al.*, 1991). Prager (1980) interpreted the crossbite as a transmission of the asymmetry of the body, whereas Hirschfelder and Hirschfelder (1983) considered, although they had not yet clarified transmission, the crossbite to be a new compensatory curvature. Independent of the different offered explanations of the high prevalence of crossbite in those patients, an interdisciplinary treatment approach to alleviate facial asymmetry and to stabilize head posture, initiated as early as possible, has been unanimously recommended (Müller-Wachendorff, 1961; Pirttiniemi *et al.*, 1989; Pećina *et al.*, 1991).

It has been demonstrated in patients, without evident orthopaedic disorders, that craniofacial growth is associated with cervicovertebral anatomy (Huggare and Cooke 1994; Solow and Siersbæk-Nielsen, 1992). It has been shown that the upper cervical region reveals a high potential for adaptation (Huggare, 1998). This may possibly be due to its important role—the cervical spine provides the morphological basis for an extensive freedom of head movement; it serves as a bridge for numerous blood and lymphatic vessels and nerves, linking head, trunk, and upper limb. In this respect, it is important to point out the intimate developmental relationship between the atlas and the cranial base (Ludvig, 1957).

The intention of this study was to investigate the effects of a unilateral crossbite on orthopaedic asymmetries in the

frontal plane. It has been shown that cervical morphology, and particularly that of the upper cervical spine, is linked to dentofacial morphology (Solow and Siersbæk-Nielsen, 1992). As the causes of the observed associations still remain unclear, all participating children suffered from an asymmetric upper cervical spine. Within this sample, children with a unilateral crossbite were compared with children revealing a symmetric occlusion but no crossbite.

Materials and methods

The present investigation was based on data obtained from an interdisciplinary study of 240 children referred to an orthopaedic centre. In all children, an asymmetric upper cervical spine was radiologically and palpatorically confirmed as follows. Anatomical asymmetries (Figure 1) were studied on the basis of an analysis of two radiographs according to Gutmann (1981). The manual palpation of atlas (c1) and axis (c2) was conducted according to Dvorak and Grob (1999). Asymmetric radiographic findings and palpation of the upper cervical spine were classified into the following categories: right-sided asymmetry of the atlas in relation to the cranial base; right-sided asymmetry of the axis in relation to the cranial base; right-sided asymmetry of the atlas and axis in relation to the cranial base, the same classification for the left side (l); and right-sided asymmetry of the atlas and left-sided asymmetry of the axis in relation to the cranial base.

Children with acute inflammation, neurological disorders, and tumours or syndromes were not included in this cohort.

Fifty-five patients (22 girls and 33 boys) between 3 and 10 years of age (mean 7.0 years, standard deviation 2.08 years) with a unilateral crossbite of at least three lateral teeth were selected. Fifty-five gender- and age-matched subjects from the same sample group but without a crossbite of any tooth and coincident midlines served as the control.

Orthopaedic examination

All patients were examined by the same physician, a specialist in manual medicine for children. He was 'blinded' with regard to whether or not the children had a unilateral malocclusion.

The clinical orthopaedic examination was based on standardized methods described in the literature (Buckup, 2005). The parameters were graded either as normal or abnormal, as described below.

1. Examination of the shoulder (Nicolakis *et al.*, 2000): Visual judgement of the height of the shoulders from the dorsal. Differences between the sides exceeding 5 mm were diagnosed as an oblique shoulder.
2. A scoliosis was determined by the forward-bending test according to Adams (Fairbank, 2004; Buckup, 2005). In the Adams forward-bending test, the patient bends forward at the waist with the knees straight and the arms together and hanging downward, and the back parallel to the floor. The examiner looks along the axis of the spine for rotatory asymmetry of the trunk. A difference in height of 8 mm between the sides is considered abnormal.
3. Using the spine test (Grieve, 1988), the sacroiliac (SI) joint was examined for hypomobility and asymmetry (Figure 2A). In addition, the position of the spina iliaca superior was analysed. Differences between the sides of more than 3 mm were interpreted as asymmetric.
4. Functional leg length difference: The Derbolowski's test (Colliton, 1997) screens for asymmetric movement of the two SI joints (Figure 2B).
5. Laxity of ligaments in both feet was analysed when the patient was standing on both feet. A flattening of the medial longitudinal arch of the weight-bearing foot was considered as a flexible flat foot (Jackson and Stricker, 2003). The clinical diagnosis was confirmed by means of a gait analysis.

The intra-observer reproducibility of the assessment parameters was tested by evaluating 25 children three times within a 3-week period. The intra-examiner reliability was computed using weighted kappa for the clinician. The values were as follows: shoulder 0.95, forward-bending test according to Adams 0.86, spine test 0.89, analysis of the position of the spina iliaca 0.87, Derbolowski's test 0.92, and diagnosis of a flexible flat foot 0.81, indicating good correspondence.

Orthodontic examination

The orthopaedic data were not available during the orthodontic examination which was conducted by one orthodontist (HK). No prior orthodontic treatment had been undertaken for any of the children. A unilateral crossbite affecting at least three lateral teeth was diagnosed in the study group, whereas there was no crossbite or midline deviation in the controls. The findings were recorded on extra- and intraoral photographs and study models.

Statistical analysis

Statistical analysis of data was performed using SPSS 12.0 for Windows (SPSS, Chicago, Illinois, USA). A Student's *t*-test for unpaired samples was used to compare the differences in orthopaedic disturbances between the subjects with and without an asymmetric occlusion. The level of significance was set at 95 per cent.

Results

The results of palpation and the analysis of the radiographs revealed an uneven lateral distribution of left to right = 3:1

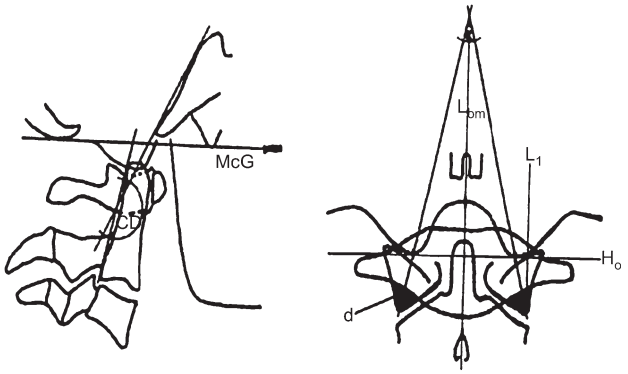

Figure 1 Cephalometric landmarks and lines used for analysis of the posteroanterior and lateral radiographs according to Gutmann (1981): McG = palato-suboccipital line according to McGrecor; CD = clivus dens angle (angle between a tangent to the dorsal surface of the clivus and a tangent to the dorsal surface of the dens axis); H_o = horizontal line zero (connecting the line of the right- and left-sided base of the occipital condyles); L_{om} = rectangular line to H_o (crossing the midpoint of the foramen magnum); K = condyla, cross-angle (angle between two lines that are drawn from the lateral and caudal tip of the massa lateralis atlantis through the right- and left-sided base of the occipital condyles); d = lower caudal triangle of the massa lateralis atlantis; L_1 = line parallel to L_{om} (crossing the deepest point of the occipital condyle).

(Table 1) which was significantly correlated (Student's *t*-test: $P = 0.001$).

In the crossbite group, 33 children (60 per cent) had a right-sided crossbite and 22 children (40 per cent) a left-sided crossbite.

No correlation was found between the laterality of the asymmetric occlusion and palpation or radiographic diagnosis.

When the differences between the children with and without a crossbite were recorded, an increased occurrence of orthopaedic parameters in the frontal plane was observed in children with a unilateral malocclusion (Figure 3). An asymmetric occlusion was not necessarily combined with a pathological orthopaedic variable, but children with a unilateral crossbite had statistically more often, an oblique shoulder ($P = 0.004$), an oblique pelvis ($P = 0.007$), functional leg length differences ($P = 0.002$), and a scoliosis ($P = 0.04$) than children with dental symmetry. An oblique shoulder was diagnosed in 30.9 per cent of the total study group, and in 70.6 per cent of them a unilateral crossbite was observed. Similar findings applied to a functional difference in leg length which was recorded in 25.5 per cent of the total group, while 75 per cent of them had a unilateral malocclusion. Thirty per cent of all subjects were found to have an oblique pelvis, whereas 69.6 per cent also had a crossbite. A scoliosis was diagnosed in 9.1 per cent of the children, 80 per cent of them revealed a unilateral crossbite.

No correlation was found between the laterality of the crossbite side and any orthopaedic asymmetry.

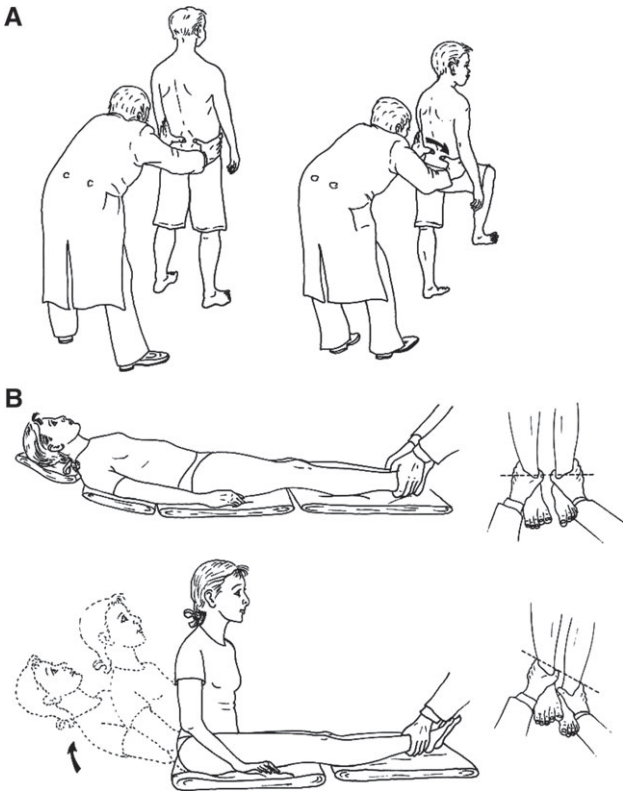

Figure 2 (A) The spine test determines changes of the processus spinosus posterior superior while the patient brings up the flexed knee to the abdomen. (B) The Derbolowski's test. The examiner observes the positions of the medial malleoli while the patient is sitting and supine (modified from Buckup, 2005).

Discussion

The investigation techniques of manual therapy have been repeatedly criticized as being unreliable. However, a number of studies have proved that the conducted tests possess sufficient specificity and sensibility (Jull *et al.*, 1988, 1997; Sandmark and Nisell, 1995).

All studies dealing with functional asymmetry have the difficulty of determining the exact contribution of each factor involved. Therefore, an orthopaedic sample was chosen and the effect of the additional diagnosis 'unilateral crossbite', which is presumably skeletal in origin, was investigated.

The finding of a left-sided dominance of the asymmetric cervical spine in this study is in accordance with a detected pattern of trunk asymmetry: there is a tendency to the right on the thoracic level and to the left on the lumbar and cervical level (Nissinen *et al.*, 2000). The investigated predominance of right-sided midline deviation was in agreement with the results of Zepa *et al.* (2003).

The results of the present study suggest that dental asymmetries correlate with orthopaedic asymmetries in the frontal plane. Of the children who revealed an asymmetric upper cervical spine, those with a unilateral crossbite had, significantly more often, an oblique shoulder, an oblique

Table 1 Distribution of the diagnostic findings of the palpation and radiographic analysis for the total sample.

	Atlas right	Axis right	Atlas and axis right	Atlas left	Axis left	Atlas and axis left	Crossbite asymmetry
Palpation	6	8	10	14	39	33	0
Radiographs	7	2	13	12	39	35	2

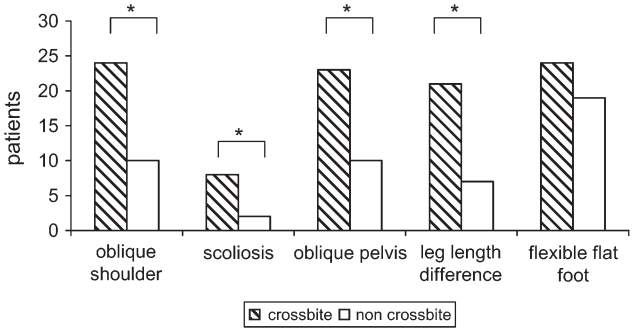

Figure 3 Orthopaedic disturbances in children with and without a unilateral crossbite. *$P \leq 0.05$.

pelvis, functional leg length differences, and scoliosis compared with children with a symmetric occlusion.

The association of crossbite with scoliosis is in agreement with other interdisciplinary studies on scoliotic patients (Prager, 1980, Hirschfelder and Hirschfelder, 1983; Huggare *et al.*, 1991) where no lateral correlation was found between crossbite and curvature of the spine (Huggare *et al.*, 1991; Prager, 1980).

The close interrelationship between the masticatory muscles and the muscles supporting the head has been demonstrated in patients requiring stomatognathic treatment (Huggare and Raustia, 1992). Apart from distinct cephalometric characteristics, such as an extended head posture, a flattened cranial base, and a smaller size of the upper cervical vertebrae, after stomatognathic treatment a straightening of the lordosis of the cervical spine was observed. Recently, it has been shown that occlusal interference can cause dysfunction of both the cervical spine and the SI joint (Fink *et al.*, 2003). Those authors recommended that the cervical spine and lumbar and pelvic regions should also be investigated in patients with craniomandibular dysfunction.

Only a few studies have investigated the possible relationship of an asymmetric occlusion and trunk asymmetry in patients without pathological orthopaedic conditions (Lippold *et al.*, 2000; Dußler *et al.*, 2002; Zepa *et al.*, 2003). They reported deviating findings: Lippold *et al.* (2000) also found a statistically significant correlation between midline deviation and oblique pelvis as well as leg length differences. The other two studies (Dußler *et al.*, 2002; Zepa *et al.*, 2003) showed that moderate trunk asymmetry did not affect facial asymmetry or *vice versa*. With regard to the study design and the investigated patients, the three studies can hardly be compared: one (Dußler *et al.*, 2002) compared 29 children with a right-sided midline shift with 28 children with a symmetric occlusion, Lippold *et al.* (2000) investigated midline discrepancies in 50 patients, aged 4–55 years, who were recruited from physiotherapy appointments, while Zepa *et al.* (2003) analysed frontal cephalograms and compared them with rib hump or lumbar prominence and spinal posture.

Clinical and experimental studies (Poikela *et al.*, 1997) on dental asymmetries revealed a high level of asymmetry in craniofacial or temporomandibular structures and muscle function. In patients with a unilateral malocclusion, asymmetric condylar position with an asymmetric condylar path (Pirttiniemi *et al.*, 1990; Nerder *et al.*, 1999), reduced condylar growth (Tadej *et al.*, 1998), and an asymmetric mandibular ramus length shorter on the crossbite side (Schmid *et al.*, 1991; Santos Pinto *et al.*, 2001) have been observed. Based on the findings that asymmetric structures can be corrected only after early correction of a unilateral crossbite (Mimura and Deguchi, 1994; Pirttiniemi *et al.*, 1991; Santos Pinto *et al.*, 2001), it is suggested that a persisting asymmetric occlusion results in growth restriction that leads to mandibular and facial asymmetry (Schmid *et al.*, 1991; O'Bryrn *et al.*, 1995; Hesse *et al.*, 1997; Langberg *et al.*, 2005).

Conclusions

The observed associations between unilateral crossbite and orthopaedic disturbances in the frontal plane in this young orthopaedic group suggest a possible link between the occlusion and the locomotor orthopaedic system in the frontal plane.

It is important to stress that these findings were observed in children with asymmetry of the upper cervical spine. Further studies are required on children without any orthopaedic disturbances in order to clarify the effect of a unilateral crossbite on the locomotor system and *vice versa*.

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References

Azuma Y, Maehara K, Tokunaga T, Hashimoto M, Ieoka K, Sakagami H 1999 Systemic effects of the occlusal destruction in guinea pigs. In Vivo 13: 519–524

Buckup K 2005 Klinische tests an Knochen, Gelenken und Muskeln, 3rd Auflage. Thieme, Stuttgart, pp. 1–60

Colliton J 1997 Managing back pain during pregnancy. Medscape Womens Health 2: 2

D'Attilio M, Filippi M R, Femminella B, Festa F, Tecco S 2005 The influence of an experimentally-induced malocclusion on vertebral alignment in rats: a controlled pilot study. Journal of Craniomandibular Practice 23: 119–129

Dußler E, Raab P, Kunz B, Kirschner S, Witt E 2002 Mandibuläre Mittellinienverschiebungen und Asymmetrien des Halte- und Bewegungsapparates bei Kindern und Jugendlichen. Manuelle Medizin 40: 116–119

Dvorak J, Grob D 1999 Halswirbelsäule—Diagnostik und Therapie. Georg Thieme Verlag, Stuttgart, pp. 61–75

Fairbank J 2004 Historical perspective: William Adams, the forward bending test, and the spine of Gideon Algernon Mantell. Spine 29: 1953–1955

Festa F, D'Attilio M, Vecchiet F 1997 Effects of a horizontal oscillation of the mandible on the spinal column of the rat *in vivo* using radiographic monitoring. Orthognatodonzia Italia 6: 539–550

Fink M, Stiesch-Scholz M, Tschernitschek H 2003 The functional relationship between the craniomandibular system, cervical spine, and the sacroiliac joint: a preliminary investigation. Journal of Craniomandibular Practice 21: 202–208

Grieve G P 1988 Common vertebral joint problems. Churchill Livingstone, London, pp. 497–498

Gutmann G 1981 Funktionelle Pathologie und Klinik der Wirbelsäule. Bd 1: Die Halswirbelsäule. Teil 1: Die funktionsanalytische Röntgendiagnostik der Halswirbel und der Kopfgelenke. Fischer, Stuttgart

Hesse K L, Årtun J, Joondeph D R, Kennedy D B 1997 Changes in the 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

Hirschfelder U, Hirschfelder H 1983 Auswirkungen der Skoliose auf den Gesichtsschädel. Fortschritte der Kieferorthopädie 44: 457–467

Huggare J 1998 Postural disorders and dentofacial morphology. Acta Odontologica Scandinavica 56: 383–386

Huggare J A, Raustia A M 1992 Head posture and cervicovertebral and craniofacial morphology in patients with craniomandibular dysfunction. Journal of Craniomandibular Practice 10: 173–177

Huggare J A V, Cooke M S 1994 Head posture and cervicovertebral anatomy as mandibular growth predictors. European Journal of Orthodontics 16: 175–180

Huggare J, Pirttiniemi P, Serlo W 1991 Head posture and dentofacial morphology in subjects treated for scoliosis. Proceedings of the Finnish Dental Society 87: 151–158

Jackson J F, Stricker SJ 2003 Pediatric foot notes: A review of common congenital foot deformities. International Pediatrics 18: 133–140

Jull G, Bogduk N, Marsland A 1988 The accuracy of manual diagnosis for cervical zygapophysial joint pain syndromes. The Medical Journal of Australia 148: 233–236

Jull G, Zito G, Trott P, Potter H, Shirley D, Richardson C 1997 The inter-examiner reliability to detect painful upper cervical joint dysfunction. Australian Journal of Physiotherapy 43: 125–129

Langberg B L, Arai K, Miner R M 2005 Transverse skeletal and dental asymmetry in adults with unilateral posterior crossbite. American Journal of Orthodontics and Dentofacial Orthopedics 127: 6–16

Lippold C, Ehmer U, van den Bos L 2000 Beziehungen zwischen kieferorthopädischen und orthopädischen Befunden. Manuelle Medizin 38: 346–350

Ludvig K S 1957 Die Frühentwicklung des Atlas und der Occipitalwirbel beim Menschen. Acta Anatomica 30: 444–461

Mimura H, Deguchi T 1994 Relationship between craniofacial and condyle path asymmetry in unilateral crossbite patients. Journal of Craniomandibular Practice 12: 161–166

Müller-Wachendorff R 1961 Untersuchungen über die Häufigkeit des Auftretens von Gebißanomalien in Verbindung mit Skelettdeformierungen mit besonderer Berücksichtigung der Skoliosen. Fortschritte der Kieferorthopädie 22: 399–408

Nerder P H, Bakke M, Solow B 1999 The functional shift of the mandible in unilateral posterior crossbite and the adaptation of the temporomandibular joints: a pilot study. European Journal of Orthodontics 21: 155–166

Nicolakis P, Nicolakis M, Piehslinger E, Ebenbichler G, Vachuda M, Kirtley C 2000 Relationship between craniomandibular disorders and poor posture. Journal of Craniomandibular Practice 18: 106–111

Nissinen M J, Heliövaara M M, Seitsamo J T, Kononen M H, Hurmerintaa K A, Poussa M S 2000 Development of trunk asymmetry in a cohort of children ages 11 to 22 years. Spine 25: 570–574

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

Pećina M, Lulić-Dukić O, Pećina-Hrnčević A 1991 Hereditary orthodontic anomalies and idiopathic scoliosis. International Orthopedics 15: 57–59

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

Pirttiniemi P, Lahtela P, Huggare J, Serlo W 1989 Head posture and dentofacial asymmetries in surgically treated muscular torticollis patients. Acta Odontologica Scandinavica 47: 193–197

Pirttiniemi P, Raustia A, Kantomaa T, Pyhtinen J 1991 Relationships of bicondylar position to occlusal asymmetry. European Journal of Orthodontics 12: 441–445

Poikela A, Kantomaa T, Pirttiniemi P 1997 Craniofacial growth after a period of unilateral masticatory function in young rabbits. European Journal of Oral Science 105: 331–337

Prager A 1980 Vergleichende Untersuchungen über die Häufigkeit von Zahnstellungs- und Kieferanomalien bei Patienten mit Deformitäten der Wirbelsäule. Fortschritte der Kieferorthopädie 41: 163–168

Sandmark H, Nisell R 1995 Validity of five common manual neck pain provoking tests. Scandinavian Journal of Rehabilitation Medicine 27: 131–136

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: 13–20

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

Solow B, Siersbæk-Nielsen S 1992 Cervical and craniocervical posture as predictors of craniofacial growth. American Journal of Orthodontics and Dentofacial Orthopedics 101: 449–458

Tadej G, Engström C, Borrman H, Christiansen E L 1989 Mandibular condyle morphology in relation to malocclusions in children. Angle Orthodontist 59: 187–194

Zepa I, Hurmerinta K, Kovero O, Nissinen M, Könönen M, Huggare J 2003 Trunk asymmetry and facial symmetry in young adults. Acta Odontologica Scandinavica 61: 149–153