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Early crossbite correction: a three-dimensional evaluation

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SUMMARY A crossbite (CB) occurs in approximately 4–23 per cent of young children and may lead to mandibular and facial asymmetry. Therefore, early intervention is often necessary to create conditions for normal occlusal and facial development. The aim of this study was to assess facial asymmetry and palatal volume (pre- and post-treatment) in two groups of children, one with a unilateral CB and the other with no crossbite (NCB). Thirty children with CB (13 males, 17 females, mean age 4.9 ± 0.98 years) and 28 children with NCB (17 males, 11 females, mean age 5.3 ± 0.36 years) were included in the study. Those with a CB were treated with an intra-oral expansion appliance. The faces and dental casts of the children were scanned using a three-dimensional (3D) laser scanning device at baseline (T0) and after six months (T1) of treatment. Student's *t*-tests were used to assess differences between the two groups in facial symmetry and palatal volume over the 6 month period.

The CB children had statistically significantly greater asymmetry of the face ($P = 0.042$), especially the lower third ($P = 0.039$), and a significantly smaller palatal volume ($P = 0.045$) than the NCB subjects at baseline. There were no statistically significant differences between the two groups at T1. Treatment of a CB in the primary dentition corrected the facial asymmetry, particularly the lower part of the face. The palatal volume of the CB children increased as a result of orthodontic intervention to similar levels exhibited by the NCB children.

Introduction

Posterior crossbites (CBs) have been reported to be one of the most prevalent malocclusions of the primary dentition in Caucasian children and if left untreated, may lead to craniofacial asymmetry (Pirttiniemi *et al.*, 1990; Kurol and Berglund, 1992; Sonnesen *et al.*, 2001; Thilander and Lennartsson, 2002; Ovsenik *et al.*, 2004).

A unilateral CB is an anomaly that occurs as a result of asymmetrical dental and/or skeletal development. In the primary dentition, a unilateral CB commonly arises as a result of a narrow maxilla that may be the result of genetic or environmental influences, or a combination of both. A unilateral CB often manifests as a discrepancy between the upper and lower centrelines that may also be associated with facial asymmetry (Allen *et al.*, 2003).

Prevention and early treatment is controversial regarding cost-effectiveness and psychosocial benefit (Tschill *et al.*, 1997; Malandris and Mahoney 2004; Proffit, 2006). It has been suggested that the preferred treatment time is in the late mixed dentition period (Viazis, 1995), while others consider that orthodontic treatment in the primary dentition period is desirable (Farčnik *et al.*, 1988; Tschill *et al.*, 1997; Thilander *et al.*, 2001; Ovsenik *et al.*, 2004).

Early orthodontic treatment would be beneficial to enhance skeletal and dental development, and correct deleterious habits such as digit sucking. Incorrect function and malocclusion in the early stages, especially transverse discrepancies, may lead to temporomandibular joint problems or facial asymmetry (Kiyak, 2006; Proffit, 2006).

Although prefect facial symmetry does not exist in nature, asymmetry ranges from clinically undetectable to gross abnormality (Van Eslande *et al.*, 2008). Functional asymmetry in subjects with a unilateral posterior CB can contribute to mandibular skeletal asymmetry, as during growth continuous condylar displacement of the glenoid fossa induces differential growth of the condyles (Inui *et al.*, 1999; Kilic *et al.*, 2008). This asymmetrical function reflects different development of the elevator muscles on each side of the jaws leading to a thinner masseter muscle on the CB side (Kiliaridis *et al.*, 2000). Furthermore, the level of maximum bite force in children with a unilateral posterior CB is smaller compared with those with a neutral occlusion (Sonnesen *et al.*, 2001). Early correction of functional problems should prevent adverse dental and facial development (Ninou and Stephens, 1994; Proffit, 2006). Facial asymmetry due to lateral mandibular displacement in unilateral posterior CB subjects, if not treated in the primary dentition, may lead to undesirable growth modification (Ninou and Stephens, 1994), which results in facial asymmetry of skeletal origin. It has been reported that a symmetrical face is a central part of attractiveness, which has a high impact on psychosocial benefit (Thornhill and Gangestad, 1994), most probably even in young children. Correction of a CB in the primary dentition may improve function or aesthetics (Malandris and Mahoney, 2004).

The aim of this study was to assess whether correction of a unilateral CB would result in improvement of facial asymmetry. Further objectives were to compare facial asymmetry and palatal volume in children with and without CBs.

Subjects and methods

Ethical approval for this study was obtained from the Slovenian Ethical Committee at the Medical University in Ljubljana, Slovenia, and informed consent from the parents of all subjects.

A group of 58 Caucasian children [30 with a unilateral CB and 28 controls with no crossbite (NCB)] were recruited. The children with a crossbite were selected from patients referred to the Department of Paedodontics of the Dental Policlinic Kranj, Slovenia. The control group was randomly selected from a local kindergarten in Kranj. The CB group comprised 17 girls and 13 boys aged 3.6–6.6 years [mean 4.9, standard deviation (SD) 0.98]; 16 had a CB on the right side and 14 on the left. In the NCB group, there were 11 girls and 17 boys aged 4.8–6.1 years (mean 5.3, SD 0.36), without a malocclusion.

The CB group was treated using an acrylic plate with a midline screw to expand the maxillary arch. The acrylic appliance with a bite plane was cemented on the upper primary molars. The screw was activated 0.25 mm every 2 days for 4 weeks and was left *in situ* for a further 4 weeks without activation. The appliances were placed in the same week and removed 2 months later. The bite plate was removed and the acrylic plate was then used as a removable retainer for 4 months. After a total treatment period of six months (T1), the occlusion was stable and no relapses were observed.

Facial images

Surface facial images were obtained using two Vivid 910 laser scanners (Konica Minolta, Tokyo, Japan) angled to capture the left and right sides of the face with significant overlap in the anterior part of the face to facilitate registration and merging of the two images to produce one facial shell (Kau *et al.*, 2004). These devices are 'eye safe' and have a scanning time of approximately 2.5 seconds with a reported accuracy of 0.3 mm (http://www.konicaminolta.com). Natural head posture (NHP) was used in this study as this has been shown to be clinically reproducible (Chiu and Clark, 1991). The technique for positioning the patient and image capture has been validated and described previously (Kau *et al.*, 2004).

The three-dimensional (3D) data was imported to a reverse modelling software package, Rapidform® (Inus Technology Inc., Seoul, Korea). Each scan of the face (left and right images) was processed in order to remove unwanted data and then registered and merged to produce a complete facial image (Figure 1). The facial shell was aligned in two planes: the mid-sagittal (*Y*–*Z*) and the inner canthus of the eyes (*X*–*Z*). The facial shell was divided into three parts: the upper was defined as the part of the face above the inner canthus plane, the middle ranged from the inner canthus plane to the plane through the outer commissures of the lips, and the lower was below this plane (Figure 1a). To check for left/right symmetry, the face was mirrored on the mid-sagittal plane at baseline (T0) and at T1. The shell to shell deviation of the mirrored images (average deviation, range, and SD) and the percentage of mirrored shells coinciding within 0.5 mm was recorded. A colour deviation map was generated to show shell–shell deviations of the mirrored images (Figure 1b,c).

Dental cast volume

Study models of the dental arches obtained at T0 and T1 were scanned at a distance of 60 cm with the same laser scanner using a lens with a focus distance of 25 mm. With this lens, the scanner has a reported accuracy of 0.22 mm (Keating, 2004). The volume of the palate was determined using the protocol described by Hoyte (2007). Each scan of

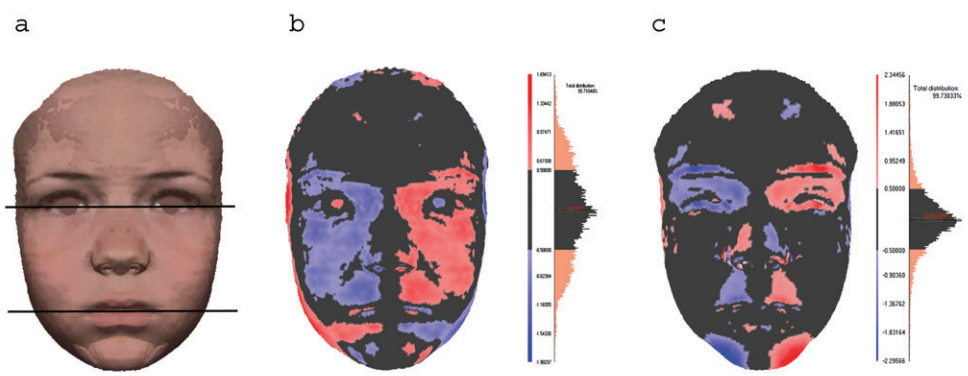

Figure 1 Superimposed mirrored shell. The inner canthus and commissure planes divide the face into thirds (a). Shell to mirrored shell deviation colour map at baseline (b) and after 6 months of treatment (c). Black indicates shell–shell deviations within 0.5 mm, red positive differences, and blue negative differences when the shells are mirrored.

the study cast was preprocessed to remove unwanted data. The gingival and the distal planes were used as boundaries for the palate. The gingival plane (*X–Z*) was created by connecting the midpoints of the dento-gingival junction of all primary teeth and the distal plane (*X–Y*) by joining the two points at the distal of the second primary molar perpendicular to the gingival plane (Figure 2). The volume of the palate was then calculated.

Statistical analysis

The Statistical Package for Social Science (SPSS Inc., Chicago, Illinois, USA) was used for statistical analysis. Data were tested for normal distribution. A paired Student's *t*-test was used to calculate the statistical differences between the CB group and the control group at T0 and T1. Mirrored shell average deviations, SDs, maximum deviations, and percentages were tested to determine statistically significant differences. Furthermore, the difference in palatal volumes and volume change at T1 between the two groups were calculated. The results were considered to be significant at values below $P<0.05$.

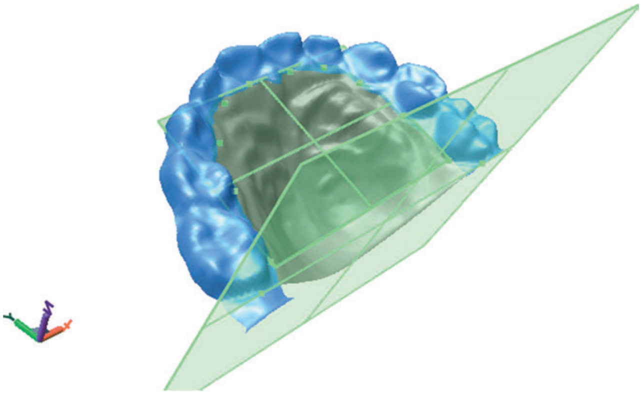

Figure 2 The gingival plane was created by connecting the midpoints of the dento-gingival junction of all primary teeth, and the distal plane by joining the two points of the distal of the second primary molar perpendicular to the gingival plane.

Results

The differences in the mirrored shells at baseline and after 6 months are shown in Table 1. At baseline, there was greater coincidence for the whole shell in the NCB group compared with the CB group (NCB 69.3 per cent, CB 63.5 per cent, $P=0.04$). The greatest contribution to this discrepancy resulted from asymmetry in the lower part of the face (CB 50.3 per cent, NCB 61.8 per cent, $P=0.04$). After treatment, no difference was observed ($P > 0.1$).

Palatal volumes and increases in palatal volume from T0 to T1 are summarized in Table 2. Palatal volume was greater in the NCB group compared with the CB group at T0 (NCB 3008.4 mm^3, CB 2780 mm^3, $P=0.045$). However, this difference was greatly reduced after treatment (NCB 3027.9 mm^3, CB 3119.6 mm^3, $P=0.39$). The increase in palatal volume was statistically significantly greater in the CB compared with the NCB group (CB 339.5 mm^3, NCB 19.4 mm^3, $P < 0.01$).

Discussion

An asymmetric occlusion may result in mandibular and facial asymmetry (Korbmacher *et al.*, 2007). Therefore, early treatment has been advised to create conditions for normal occlusal and craniofacial development (Petrén *et al.*, 2003).

Table 1 Mirrored facial shell at baseline (T0) and after six months (T1) in the crossbite (CB) and no crossbite (NCB) groups: average deviation, standard deviation (SD), and maximum deviation and the percentage of mirrored shell coinciding within 0.5 mm.

Shell name	Time	Group	Average deviation (mm)	*P*	SD (mm)	*P*	Maximum deviation (mm)	*P*	% of shell coinciding within 0.5 mm	*P*
Whole shell	T1	CB	0.50	0.081	0.47	0.146	2.58	0.523	63.53	0.042*
		NCB	0.44		0.42		2.43		69.27	
	T2	CB	0.54	0.200	0.52	0.548	3.03	0.651	61.53	0.114
		NCB	0.48		0.49		2.89		66.55	
Upper part	T1	CB	0.42	0.339	0.41	0.170	2.45	0.328	70.90	0.447
		NCB	0.39		0.37		2.23		72.85	
	T2	CB	0.46	0.917	0.45	0.466	2.87	0.467	65.78	0.441
		NCB	0.46		0.48		3.10		68.14	
Middle part	T1	CB	0.50	0.180	0.42	0.339	2.28	0.844	62.46	0.078
		NCB	0.43		0.38		2.23		69.66	
	T2	CB	0.52	0.186	0.45	0.570	2.78	0.811	62.94	0.144
		NCB	0.44		0.42		2.86		69.31	
Lower part	T1	CB	0.67	0.077	0.47	0.537	2.32	0.187	50.25	0.039*
		NCB	0.53		0.44		1.95		61.80	
	T2	CB	0.69	0.709	0.57	0.225	2.88	0.137	52.87	0.609
		NCB	0.65		0.48		2.37		55.62	

*$P < 0.05$.

Table 2 Mean palatal volumes, standard deviation (SD), and *t*-test at baseline (T0) and after six months (T1) in the crossbite (CB) and no crossbite (NCB) groups.

Volume	Group	Mean volume (mm^3)	SD (mm^3)	*t*-test, *P*
T0	CB	2780.03	386.07	0.045*
	NCB	3008.44	475.03	
T1	CB	3119.55	601.06	0.385
	NCB	3027.89	562.00	
Difference	CB	339.52	427.80	0.000*
0–6 months	NCB	19.45	289.11	

*$P < 0.05$.

It has also been suggested that the later CBs are treated, the greater the risk of damage to the temporomandibular joint (Pirttiniemi *et al.*, 1990; Sonnesen *et al.*, 2001). In addition, this malocclusion trait is also associated with asymmetrical muscular function (Ingervall and Thilander, 1975; Ferrario *et al.*, 1999) that affects the elevator muscles and bite force (Sonnesen *et al.*, 2001). It appears that the only indication for correction in the primary dentition is where aesthetics or function may otherwise be compromised (Malandris and Mahoney, 2004).

Different treatment approaches such as selective grinding of teeth, expansion plates, or a quadhelix are used for CB correction (Malandris and Mahoney, 2004). In this study, treatment was started in the primary dentition using a cemented acrylic plate with a midline screw for palatal expansion. After correction, the plate was decemented and used as a removable retention plate, which has been shown to successfully correct 85 per cent of posterior CB in the primary dentition (De Boer and Steenks, 1997).

It is well known that no human face is perfectly symmetric as there are always areas of asymmetry between the left and right sides of the face which are considered to be physiological (Bishara *et al.*, 1994; Proffit, 2000). In order to assess pathologic asymmetry in children with a CB, they were compared in the present study with a group of NCB children, who exhibited 'physiologic' asymmetry.

Diagnosis of facial asymmetry is routinely based on the analysis of patients' frontal photographs, by determining a symmetry plane and measuring linear and planar differences between the hemifaces (Farkas and Cheung, 1981). As photographs show a 3D structure in a two-dimensional perspective, the landmarks used to define the facial midline and to construct the symmetry plane cannot be exactly defined, and thus, the precision of the method is questionable. Therefore, facial asymmetry should be evaluated three-dimensionally. As facial asymmetry of small children is difficult to assess, a 3D imaging system, which has been shown to be accurate for scanning young children was used (Kau *et al.*, 2004). This 3D laser scanning system is a non-invasive and safe method to obtain 3D facial images in less than 10 seconds. Furthermore, the data acquired is accurate to approximately 0.5 mm, depending on the technique used (Arridge *et al.*, 1985; Moss *et al.*, 1987, 1988, 2003; Nute and Moss, 2000; Kau *et al.*, 2005). In this study, Konica Minolta VIVID 910 laser scanners were used with a reported manufacturing accuracy of 0.3 mm for facial and 0.2 mm for study cast (Keating, 2004) scanning. As asymmetry is a discrepancy between the left and right sides, both sides of the face should be assessed for each face individually. In this study, a mirrored shell of the original facial shell was constructed and the asymmetry was then evaluated for each child in the CB and NCB groups.

There were no differences between the two groups for the upper or middle part of the face, either at T0 or T1. Children with a CB exhibited greater asymmetry of the lower part of the face, either due to a mandibular shift or true asymmetry that occurs in CB. However, at T1, this discrepancy decreased with no statistically significant differences between the two groups. Although previous research has demonstrated the benefits of early CB correction (Kurol and Berglund, 1992; Viazis, 1995), this is the first study that shows the correction of facial asymmetry in small children in three dimensions.

Until recently, CB correction was evaluated on study casts mostly by measuring the intercanine and intermolar distances (Sillman, 1964; Thilander and Lennartson, 2002; Petrén and Bondemark, 2008). However, this method could not exclude bias in assessing the success of CB correction due to tipping of the buccal teeth. To overcome this problem, palatal volume was measured in the present research.

Children with a CB had a statistically significant smaller palatal volume than the NCB group. However, after treatment and retention, there were no differences between the two groups. The increase in palatal volume in the treated CB children was significantly greater than that due to growth in the NCB group. This is the first study that shows differences in palatal volume in children with and without a CB and an increase of palatal volume due to early CB correction.

The results of this research are in agreement with other studies that show successful correction of CBs and lateral mandibular displacement, resulting in normal transverse relationships after treatment in the primary dentition (Schröder and Schröder, 1984; Lindner 1989).

Conclusions

Treatment of a CB in the primary dentition period corrects the mandibular shift, leading to an improvement in facial symmetry. The palatal volume in the CB children increased as a result of treatment to similar levels exhibited by NCB children. However, long-term follow-up of these children will be necessary in order to evaluate the cost-benefits of early treatment.

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References

Allen D, Rebellato J, Sheats R, Ceron A M 2003 Skeletal and dental contributions to posterior crossbites. Angle Orthodontist 73: 515–524

Arridge S R, Moss J P, Linney A D, James D R 1985 Three dimensional digitization of the face and skull. Journal of Maxillofacial Surgery 13: 136–143

Bishara S E, Burkey P S, Kharouf J G 1994 Dental and facial asymmetries: a review. Angle Orthodontist 64: 89–98

Chiu C S, Clark R K 1991 Reproducibility of natural head position. Journal of Dentistry 19: 130

De Boer M, Steenks M 1997 Functional unilateral posterior crossbite. Orthodontic and functional aspects. Journal of Oral Rehabilitation 24: 614–623

Farčnik F, Korpar M, Premik M, Zorec R 1988 An attempt at numerically evaluating dysgnathias in the deciduous dentition. Stomatologie der DDR 38: 386–391

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

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

Hoyte T A 2007 Monitoring three dimensional changes in treated and untreated dentitions. Thesis, Cardiff University, Wales

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

Inui M, Fushima K, Sato S 1999 Facial asymmetry in temporomandibular joint disorders. Journal of Oral Rehabilitation 26: 402–406

Kau C H, Scheer R, Zhurov A I, Bouwman S, Richmond S 2004 The feasibility of measuring three-dimensional facial morphology in children. Orthodontics and Craniofacial Research 7: 198–204

Kau C H *et al.* 2005 Reliability of measuring facial morphology with a 3-dimensional laser scanning system. American Journal of Orthodontics and Dentofacial Orthopedics 128: 424–430

Keating A P 2004 An evaluation of virtual and actual three-dimensional occlusal records. Thesis, Cardiff University, Wales

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

Kilic N, Kiki A, Oktay H 2008 Condylar asymmetry in unilateral posterior crossbite patients. American Journal of Orthodontics and Dentofacial Orthopedics 133: 382–387

Kiyak H A 2006 Patients' and parents' expectations from early treatment. American Journal of Orthodontics and Dentofacial Orthopedics 129: S50–S54

Korbmacher H, Koch L, Eggers-Stroeder G, Kahl-Nieke B 2007 Associations between orthopaedic disturbances and unilateral crossbite in children with asymmetry of the upper cervical spine. European Journal of Orthodontics 29: 100–104

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

Lindner A 1989 Longitudinal study on the effect of early interceptive treatment in 4-year old children with unilateral crossbite. Scandinavian Journal of Dental Research 97: 432–438

Malandris A, Mahoney E K 2004 Aetiology, diagnosis and treatment of posterior cross-bites in the primary dentition. International Journal of Pediatric Dentistry 14: 155–166

Moss J P, Grindrod S R, Linney A D, Arridge S R, James D R 1988 A computer system for the interactive planning and prediction of maxillofacial surgery. American Journal of Orthodontics and Dentofacial Orthopedic 94: 469–475

Moss J P, Ismail S F, Hennessy R J 2003 Three-dimensional assessment of treatment outcomes on the face. Orthodontics and Craniofacial Research 1: 126–131

Moss J P, Linney A D, Grindrod S R, Arridge S R, Clifton J S 1987 Three-dimensional visualization of the face and skull using computerized tomography and laser scanning techniques. European Journal of Orthodontics 9: 247–253

Ninou S, Stephens C 1994 The early treatment of posterior cross-bites: a review of continuing controversies. Dental Update 21: 420–426

Nute S J, Moss J P 2000 Three-dimensional facial growth studied by optical surface scanning. Journal of Orthodontics 27: 31–38

Ovsenik M, Farčnik F, Verdenik I 2004 Comparison of intra-oral and study cast measurements in the assessment of malocclusion. European Journal of Orthodontics 26: 273–277

Petrén S, Bondemark L 2008 Correction of unilateral posterior crossbite in the mixed dentition: a randomized controlled trial. American Journal of Orthodontics and Dentofacial Orthopedics 133: 790.e7–e13

Petrén S, Bondemark L, Söderfeldt B 2003 A systematic review concerning early orthodontic treatment of unilateral posterior crossbite. Angle Orthodontist 73: 588–596

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

Proffit W R 2000 The soft tissue paradigm in orthodontic diagnosis and treatment planning: a new view for a new century. Journal of Esthetic Dentistry 12: 46–49

Proffit W R 2006 The timing of early treatment: an overview. American Journal of Orthodontics and Dentofacial Orthopedics 120: S47–S49

Schröder U, Schröder I 1984 Early treatment of unilateral posterior crossbite in children with bilateral contracted maxilla. European Journal of Orthodontics 6: 65–69

Sillman J H 1964 Dimensional changes of the dental arches: longitudinal study from birth to 25 years. American Journal of Orthodontics 50: 824–884

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, Lennartsson B 2002 A study of children with unilateral posterior crossbite, treated and untreated, in the deciduous dentition–occlusal and skeletal characteristics of significance in predicting the long-term outcome. Journal of Orofacial Orthopedics 63: 371–383

Thilander B, Pena L, Infante C, Parada S S, Mayorga C 2001 Prevalence of malocclusion and orthodontic treatment need in children and adolescents in Bogota, Colombia. An epidemiological study related to different stages of dental development. European Journal of Orthodontics 23: 157–176

Thornhill R, Gangestad S W 1994 Human fluctuating asymmetry and sexual behaviour. Psychological Science 5: 297–302

Tschill P, Bacon W, Sonko A 1997 Malocclusion in the deciduous dentition of Caucasian children. European Journal of Orthodontics 19: 361–367

Van Eslande D C, Russett S J, Major P W, Flores-Mi C 2008 Mandibular asymmetry diagnosis with panoramic imaging. American Journal of Orthodontics and Dentofacial Orthopedics 134: 183–192

Viazis A D 1995 Efficient orthodontic treatment timing. American Journal of Orthodontics and Dentofacial Orthopedics 108: 560–561

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