Three-dimensional evaluation of the association between face and back asymmetry among pre-pubertal subjects

Jasna Primozic, V. Antolic, M. Ovsenik, Jasmina Primozic

University of Ljubljana, Medical Faculty, Ljubljana, Slovenia

e-mail: jasminaprimozic@gmail.com

DOI 10.23804/ejpd.2023.1724

Abstract

Aim The aim was to compare the degree of back symmetry in two groups of subjects with and without pathologic facial asymmetry and to assess any possible associations between face and back asymmetry evaluated on three-dimensional surface face and back scans.

Material and methods The study design consisted of allocation of 70 subjects (35 females, 35 males) aged 6.4±0.5 years, according to the percentage of whole face symmetry assessed on three-dimensional (3D) facial scans into a 'symmetric' (symG; symmetry ≥70%) and 'asymmetric' (asymG; symmetry <70%). The 3D face and back scans were analysed using colour deviation maps and percentages of symmetry of the whole face and back surfaces as well as their three separate areas: forehead, maxillary and mandibular areas for the face and neck, upper and middle trunk areas for the back, were calculated. Non-parametric statistical tests were used for between-group comparisons (Mann-Whitney U test). Within each group, differences between each face or back area were tested with the Friedman test. Correlations between face and back symmetry were assessed with the Spearman rho coefficient.

Results The symG exhibited a significantly higher symmetry in each facial area than the asymG. The mandibular area was the least symmetric area of the face within each group, with significantly smaller values than the maxillary area in the symG and significantly smaller values than the forehead and maxillary area in the asymG. The percentage of whole back symmetry did not significantly differ (p>0.05) between the symG (82.00% [67.4;88.00]) and asymG (74.3% [66.1;79.6]). The only significant between-group difference was observed for the symmetry of the upper trunk area (p=0.021), with lower symmetry values in the asymG. No significant associations were detected between face and back parameters.

Conclusions The percentages of symmetry in each facial area were significantly higher among subjects without pathologic facial asymmetry. The most asymmetric area of the face, regardless of the degree of whole face symmetry, was its mandibular area. No significant differences were detected within different back areas; however, subjects with asymmetric faces showed significantly smaller symmetry of their upper trunk area.

KEYWORDS 3D facial scan, facial symmetry, symG, asymG.

Introduction

Facial symmetry is associated with a state of balance and the correspondence in size, shape, and arrangement of facial structures on opposite sides of the mid-sagittal plane, while asymmetry indicates imbalance [Ercan et al., 2008]. Although asymmetry ranges from clinically undetectable to a distinct abnormality [Stauber et al., 2008, Van Elslande et al., 2008, Djordjevic et al., 2011], minor, non-pathologic facial asymmetry is relatively common [Shah and Joshi, 1978]. The difference in the degree of growth between the right and left sides may be caused by genetic factors, environmental factors, or a combination of both [Lundstrom, 1961, Melnik, 1992], and the development of facial asymmetry can also be related to the functional activity of the skeletal, muscular system [Ferrario et al., 1993, Ras et al., 1995]. It has been claimed that craniofacial growth is associated with the cervico-vertebral anatomy in subjects without evident orthopaedic anomalies [Huggare and Cooke, 1994, Solow and Siersbaek-Nielsen, 1992]. Although some attempts have been made to assess the correlation between asymmetric occlusion and body posture, mainly all the studies were performed on subjects in the pubertal [Sidlauskiene et al., 2015] or post-pubertal phase [Ben-Bassat et al., 2006, Lippold et al., 2012, Lopatiene et al., 2013], with a known spine anomaly [Ben-Bassat et al., 2006, Zhou et al., 2013] using either two-dimensional and invasive methods [Korbmacher et al., 2007]. There is an increased occurrence of orthopaedic disorders among children with unilateral malocclusion [Korbmacher et al., 2007], and a statistically significant correlation between midline deviation and oblique pelvis [Lippold et al., 2000] were reported. On the contrary, a recent study concluded that back asymmetry was not significantly more frequent among subjects with functional posterior crossbite than in subjects with normal occlusion [Primozic et al., 2019]. Moreover, a systematic review of the literature revealed limited evidence to withdraw sound conclusions on the potential effects of malocclusion on body posture [Perinetti et al., 2013].

There is still a scarcity of knowledge regarding the association between face and back asymmetry, to our best knowledge. Therefore, the aim of the present study was to compare the degree of back symmetry in two groups of subjects with and without pathologic facial asymmetry and to assess any possible associations between face and back asymmetry evaluated on three-dimensional surface face and back scans.

Material and Methods

Ethical approval for this study was obtained (No. 111/12/14) from the National Medical Ethics Committee, and informed consent was obtained from the parents of all subjects before inclusion. The present study was conducted following the ethical standards of the Helsinki Declaration.

The sample size was calculated based on the results reported in a previous study [Primozic et al., 2019], and a sample size of at least 34 subjects per group was necessary for between-group comparisons, with an alpha set at 0.05 and a power of 0.80. Subjects for this study were randomly selected from a larger group of subjects having their face and back scanned in the early mixed dentition period and clustered into two groups, according to the percentage of facial symmetry and regardless of their occlusion condition. Allocation was performed until, in both groups, the sample size of 35 subjects was reached. In the 'symmetric' group (symG), subjects with percentages of facial symmetry equal or greater than 70 percent were included, while subjects with lower percentages were allocated to the 'asymmetric' group (asymG). Finally, the symG consisted of 18 females and 17 males aged 6.4±0.5 years, while in the asymG, there were 17 females and 18 males aged 6.5±0.5 years. Of note, in the symG, the majority of subjects had a normal occlusion (68.6%), 22.9 % had a distal and 8.6 % a mesial jaw relationship. Of the latter, two had a bilateral while one subject had a unilateral crossbite. In the asymG, 62.9% had a normal sagittal jaw relationship with a unilateral functional crossbite, 14.3% a distal and 22.9% a mesial jaw relationship.

Three-dimensional (3D) surface images of the face were obtained using the 3dMDface System (3dMDLtd., United Kingdom) stereophotogrammetric cameras. These devices are eye-safe, with a scanning time of about 0.015 seconds and a reported manufacturing accuracy of 0.2 mm. Natural Head Posture was adopted for this study, as this has been shown to be clinically reproducible. Three-dimensional surface back images were obtained using the ArtecTM MHT 3D Scanner (Artec 3D, Luxembourg) [Ettl et al., 2012]. The scanning procedure was performed by two researchers, one moving the scanner around the subject at a distance of 70-100 cm and the other checking carefully for

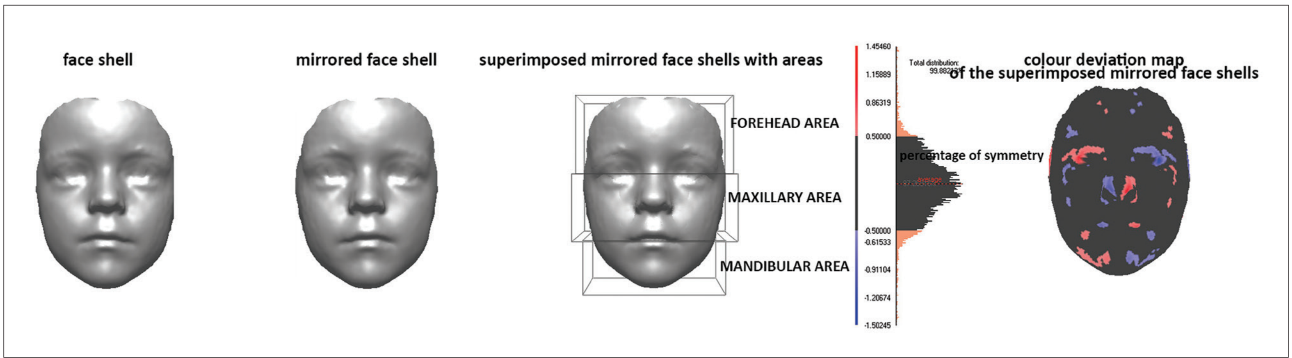

FIG 1 Assessment of symmetry of the whole face and its forehead, maxillary and mandibular areas on colour deviation maps, obtained by superimpositions of three-dimensional mirrored facial shells. Planes through the endocanthions and mouth commissures were used as areas' boundaries. Black colour on the deviation map indicates symmetric areas, while blue and red areas show negative and positive deviations of the mirrored shells, respectively.

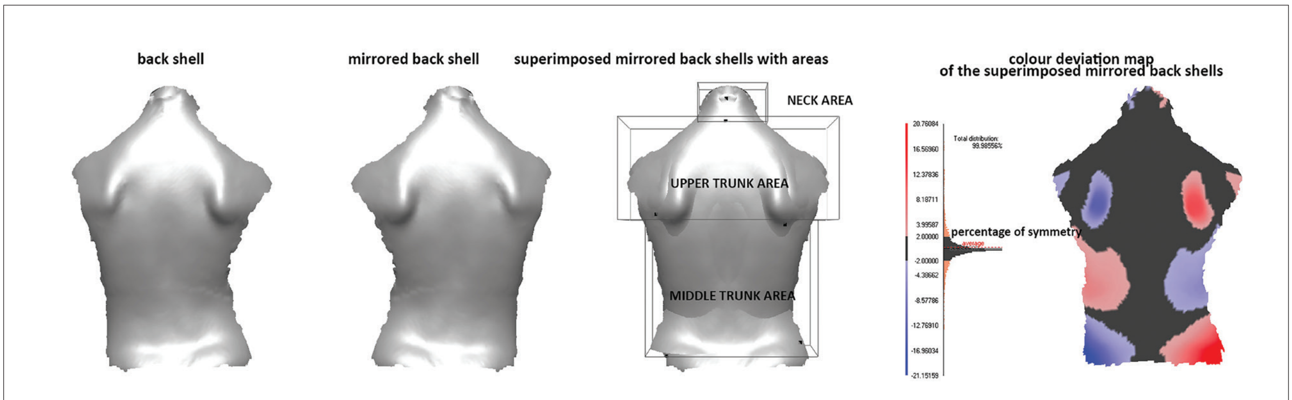

FIG 2 Assessment of symmetry of the whole back and its neck, upper and middle trunk areas on colour deviation maps, obtained by superimpositions of three-dimensional mirrored back shells. Planes through the attachment of the hair and the neck point, through the left and right points at the lower border of the scapula prominence, and below the lower scapula, the plane through the hips were used as areas' boundaries. Black colour on the deviation map indicates symmetric areas, while blue and red areas show negative and positive deviations of the mirrored shells, respectively.

any subject's movements. In case of any subject's movements during scanning, the procedure was repeated. Natural Body Posture with adjacent feet was adopted during scanning.

The 3D face/back data were imported into a reverse modeling software package, Rapidform ™ 2006 (@ INUS Technology Inc, Seoul, Korea). Each scan of the face/back was processed to remove unwanted data and to obtain a face/back shell, correctly aligned to the mid-sagittal (Y-Z) and transverse planes through the left and right endocanthion (for the face) and left and right upper scapula (for the back) points (X-Z). The original face/back shell was flipped horizontally to obtain a mirrored face/back shell, and then the two were superimposed using the best-fit technique, based on the iterative closest point algorithm, to achieve a perfectly symmetric structure. The symmetry plane of this structure was used as the mid-sagittal plane of the original face/back. The face/back was oriented using a vertical cylinder that fits all face/back data points of the original-mirror symmetric face/back structure. To ensure proper vertical orientation in the virtual space, three manually set landmarks for the face (left and right endocanthions and pogonion) and four landmarks for the back (left and right upper scapula point at the most prominent point of the scapulae and left and right hip point), were used. To check for symmetry of the left and right side, colour deviation maps of the superimposed original and mirrored face (Fig. 1) and back (Fig. 2) shells were analysed, and the facial or back area symmetry percentages were calculated. The percentage of facial symmetry was defined as the percentage of the facial surface area of the mirrored shells coinciding within 0.5 mm, while the percentage of back symmetry was defined as the percentage of the back surface area of the mirrored shells coinciding within 2 mm. The face shell was divided into three areas: 1) the forehead area, defined as the area of the face above the endocanthion plane, 2) the maxillary area, from the endocanthion plane to the plane through the outer commissures of the lips, and 3) the mandibular area, below this plane. Percentages of symmetry were calculated for the whole face and each facial area separately. The back shell was also divided into three areas: 1) the neck area, defined as the area between the planes through the attachment of the hair and the neck point, 2) the upper trunk area, between the neck plane and the plane through the left and right points at the lower border of the scapula prominence (lower scapula plane), and 3) the middle trunk area, below the lower scapula plane to the plane through the hips (constructed through the most prominent points of the left and right hip).

Statistical analysis

Balancing of the groups by age and sex was assessed by a Student t-test and a chi-squared test, respectively. After testing the normality of the data with the Shapiro-Wilk test and Q-Q normality plots of the residuals, and the equality of variance among the datasets using the Levene test, non-parametric methods were used for data analysis. Median and the 25th and 75th percentile values of every tested face or back parameter are reported. The between-group differences for either the face or back parameters were calculated using the Mann-Whitney U test. Within each group, differences in the percentages between each of the three face areas (forehead, maxillary, mandibular) and between each of the three back areas (neck, upper trunk, middle trunk) were assessed using the Friedman test. The Wilcoxon test with Bonferroni's correction was used for pair-wise comparisons. The Spearman rho was used to assess any possible correlations between face and back symmetry.

Method error for each face and back parameter was calculated based on 10 pairs of randomly selected face or back asymmetry assessments performed one week apart. The method of moments variance estimator was used, and mean with 95% confidence interval (CI) values were calculated for each face and back parameter. The Statistical Package for Social Sciences software 21.0 (SPSS® Inc., Chicago, Illinois, USA) was used to perform the statistical analyses, and a p-value less than 0.05 was considered significant.

Results

Method errors were 0.2 (0.1-0.4) for the percentage of symmetry of the whole face, 0.4 (0.2-0.7) for its upper, 0.8 (0.5-1.4) for its middle and 1.3 (0.9-2.4) for its lower area, respectively.

Method errors were 1.9 (1.3-3.5) for the percentage of symmetry of the whole back, 5.4 (3.7-9.8) for its upper, 2.6 (1.8-4.8) for its middle, and 2.8 (1.7-5.1) for its lower area, respectively.

No statistically significant difference was seen between the groups for sex and age distribution.

For the whole group of subjects (symG and asymG pooled together), the percentage of face symmetry was 66.5±13.9 percent. The percentage of symmetry of the forehead area (75.8±10.9 %) was significantly higher (p<0.01) than the percentages of the maxillary (68.1±18.1 %) and mandibular (56.1±21.0 %) areas. Moreover, the percentage of the

Parameter		symG (N=35)	asymG (N=35)	Diff.
Face area symmetry				
forehead (%)		80.99[73.53;87.02]	71.19[65.00;81.22]	p=0.011
maxillary (%)		82.25[73.02;88.21]	54.77[43.59;69.33]a	p<0.001
mandibular (%)		71.80[58.95;82.24]b	47.41[30.9;54.77]a.b	p<0.001
	Diff.	p=0.001	p<0.001	
Back area symmetry				
neck (%)		78.00[61.00;90.00]	69.87[59;87.34]	NS
upper trunk (%)		77.00[68.96;90.00]	72.00[54.52;83.33]	p=0.021
middle trunk (%)		81.08[68.81;89.95]	75.83[62.84;88.47]	NS
	Diff.	NS	NS	

Diff.- difference; NS- not statistically significant; a-significantly different from upper; b- significantly different from middle

TABLE 1 Percentages of symmetry of the face and back areas for the symG and asymG expressed as medians with the 25th and 75th percentiles values and within and between-group differences.

maxillary area was significantly higher ($p<0.001$) than that of the mandibular area. The percentage of back symmetry was 74.8±13.3 %, with no significant differences between the neck (72.9±19.2 %), upper trunk (72.8±17.1 %), and middle trunk (75.9±16.9 %) areas.

The percentage of whole face symmetry was significantly higher ($p<0.001$) for the symG (77.79 % [72.93;81.92]) than for the asymG (57.51 % [46.84;64.18]). Percentages of symmetry of each facial area (forehead, maxillary and mandibular) according to the group along with p-values indicating significant differences if present are reported in Table 1. The symG exhibited a significantly higher symmetry in each facial area than the asymG. The mandibular area was the least symmetric area of the face within each group, with significantly smaller values than the maxillary area in the symG and significantly smaller values than the forehead and maxillary area in the asymG. Of note, in the symG, the most symmetric areas were the forehead and maxillary areas, while in the asymG, the significantly most symmetric was only the forehead area.

The percentage of whole back symmetry did not significantly differ ($p>0.05$) between the symG (82.00% [67.4;88.00]) and asymG (74.3% [66.1;79.6]). The percentage of symmetry of each back area (neck, shoulder-scapula, and trunk-pelvis) according to group and p-values indicating significant differences are reported in Table 1. The only between-group significant difference was observed for the upper trunk area ($p=0.021$), with the asymG (72%) having a significantly lower percentage of symmetry in that area compared to the symG (77%). No specific back area exhibited a significantly different percentage of symmetry within each group compared to the others. Moreover, no significant correlations were detected between face and back parameters.

Discussion

The present study did not evidence any significant differences in the percentages of back symmetry among subjects with or without facial asymmetry. Moreover, no significant correlations were detected between face and back symmetry percentages, based on the assessment of three-dimensional face and back scans.

In the present study, subjects were allocated either the symG or asymG according to the percentage of whole face symmetry; faces exhibiting coincidence of the left and right side in 70% or more of their surface within a tolerance level of 0.5 mm, were considered as symmetric. A previous longitudinal study [Primozic et al., 2012] on subjects undergoing the transition from the primary to the mixed dentition phase using a landmark independent three-dimensional method reported that the percentage of facial asymmetry considered as non-pathologic is around 30% among growing subjects with normal occlusion.

The whole face symmetry was significantly smaller in the asymG than in the symG, mainly due to the allocation protocol. However, the mandibular area was significantly less symmetric than the forehead and maxillary areas in both groups. This would be in accordance with previous studies reporting higher percentages of facial asymmetry in the mandibular area [Djordjevic et al., 2011, Primozic et al., 2012]. Among the causes of facial asymmetry, either skeletal or functional, several are related to malocclusion [Lundstrom, 1961]. In particular, facial asymmetry at early developmental phases has been associated with functional activities of the masticatory musculoskeletal system [Ferrario et al., 1993, Ras et al., 1995], including asymmetric mastication or functional mandibular shifts [Primozic et al., 2013], leading to a smaller percentage of symmetry in the mandibular area as seen in the present study.

Moreover, in subjects with unilateral malocclusion, a higher frequency of orthopaedic anomalies in the transverse plane has been reported [Korbmacher et al., 2007]. Although an increasing number of patients with malocclusion are seeking at the same time treatment for postural disorders [Michelotti et al., 2007], only a few studies have investigated the possible relationship of an asymmetric occlusion and trunk asymmetry in patients without known pathological orthopaedic anomalies [Dußler et al., 2002, Lippold et al., 2012, Zepa et al., 2003], reporting contrasting results. On the one hand, children with unilateral functional crossbite showed more often an oblique shoulder, scoliosis, an oblique pelvis, and a functional leg length difference than children without this malocclusion [Lippold et al., 2012]. Therefore, it has been claimed that crossbite could reflect the asymmetry of the body [Prager, 1980] or a compensatory body curvature [Hirschfelder and Hirschfelder, 1983]. On the other hand, unilateral crossbite was not necessarily combined with a pathological orthopaedic variable [Primozic et al., 2019], and there is no correlation between crossbite and leg length inequality [Michelotti et al., 2007].

Nevertheless, the present study aimed to assess differences in the percentages of back symmetry among subjects with symmetric and asymmetric faces and evaluate any possible associations between face and back symmetry, regardless of the occlusion condition. Using a landmark independent method, which takes into account all available facial/back points and allows a full face or back symmetry assessment [Meyer-Marcotty et al., 2010, Djordjevic et al., 2011, Primozic et al., 2012], no significant differences were seen regarding back symmetry between subjects with symmetric and asymmetric faces. The only exception was related to the upper trunk asymmetry, which was significantly larger among subjects with asymmetric faces. This finding would be in contrast with previous studies, reporting that a moderate trunk asymmetry did not affect facial asymmetry [Dußler et al., 2002, Prager, 1980, Zepa et al., 2003]. The contrasting results of the present and previous studies could be related to the assessment of the upper and middle trunk areas separately, which might have evidenced a more localized asymmetry. Nevertheless, confirming the results of other studies, no association was seen between face and back symmetry [Prager, 1980, Zepa et al., 2003]. It should be further noted that, the present study included only subjects in the pre-pubertal growth phase, which is indeed a novelty, however, worsening either of the face or back asymmetry at later developmental phases could not be excluded. In fact, during the pubertal growth spurt, accelerated mandibular as well as body growth might lead to a worsening of either facial or back asymmetry in selected subjects, resulting in an association which remains undetectable during the pre-pubertal growth phase.

Conclusions

The percentages of symmetry in each facial area (forehead, maxillary, mandibular) were significantly higher among subjects without pathologic facial asymmetry. The most asymmetric area of the face, regardless of the degree of whole face symmetry, was its mandibular area. No significant differences were detected within different back areas; however, subjects with asymmetric faces showed a significantly smaller percentage of back symmetry in their upper trunk area.

Funding

The research was funded by the Slovenian Research Agency (Ref. No. J3-2520, J3-8199 and P3-0374).

Conflict of interest

The authors declare that they have no conflict of interest concerning this article.

References

- Ben-Bassat Y, Yitschaky M, Kaplan L, Brin I. Occlusal patterns in patients with idiopathic scoliosis. Am J Orthod Dentofacial Orthop 2006;130:629-33.
- Djordjevic J, Toma AM, Zhurov AI, Richmond S. Three-dimensional quantification of facial symmetry in adolescents using laser surface scanning. Eur J Orthod 2011.
- Dußler E, Raab P, Kunz B, Kirschner S, Witt E. Mandibuläre Mittellinienverschiebungen und Asymmetrien des Halte- und Bewegungsapparates bei Kindern und Jugendlichen . . Manuelle Medizin 2002;40
- Ercan I, Ozdemir ST, Etoz A, Sigirli D, Tubbs RS, Loukas M, Guney I. Facial asymmetry in young healthy subjects evaluated by statistical shape analysis. J Anat 2008;213:663-9.
- Ettl S, Arold O, Yang Z, Hausler G. Flying triangulation--an optical 3D sensor for the motion-robust acquisition of complex objects. Appl Opt 2012;51:281-9.
- Ferrario VF, Sforza C, Miani A, Jr., Serrao G. Dental arch asymmetry in young healthy human subjects evaluated by Euclidean distance matrix analysis. Arch Oral Biol 1993;38:189-94.
- Hirschfelder U, Hirschfelder H. Auswirkungen der Skoliose auf den Gesichtsschädel. Fortschritte der Kieferorthopädie 1983 44:457 – 467.
- Huggare JA, Cooke MS. Head posture and cervicovertebral anatomy as mandibular growth predictors. Eur J Orthod 1994;16:175-80.
- Korbmacher H, Koch L, Eggers-Stroeder G, Kahl-Nieke B. Associations between orthopaedic disturbances and unilateral crossbite in children with asymmetry of the upper cervical spine. Eur J Orthod 2007;29:100-4.
- Lippold C, Ehmer U, van den Bos L. Beziehungen zwischen kieferorthopädischen und orthopädischen Befunden. Manuelle Medizin 2000;38
- Lippold C, Moiseenko T, Drerup B, Schilgen M, Vegh A, Danesh G. Spine deviations and orthodontic treatment of asymmetric malocclusions in children. BMC musculoskeletal disorders 2012;13:151.
- Lopatiene K, Smailiene D, Sidlauskiene M, Cekanauskas E, Valaikaite R, Pribuisiene R. An interdisciplinary study of orthodontic, orthopedic, and otorhinolaryngological findings in 12-14-year-old preorthodontic children. Medicina 2013;49:479-86.
- Lundstrom A. Some Asymmetries of the Dental Arches, Jaws, and Skull, and their etiological Significance. Am J Orthod Dentofacial Orthop 1961;47:81-106.
- Melnik AK. A cephalometric study of mandibular asymmetry in a longitudinally followed sample of growing children. Am J Orthod Dentofacial Orthop 1992;101:355-66.
- Meyer-Marcotty P, Alpers GW, Gerdes AB, Stellzig-Eisenhauer A. Impact of facial asymmetry in visual perception: a 3-dimensional data analysis. Am J Orthod Dentofacial Orthop 2010;137:168 e1-8.
- Michelotti A, Farella M, Buonocore G, Pellegrino G, Piergentili C, Martina R. Is unilateral posterior crossbite associated with leg length inequality? Eur J Orthod 2007;29:622-6.
- Perinetti G, Primozic J, Manfredini D, Di Lenarda R, Contardo L. The diagnostic potential of static body-sway recording in orthodontics: a systematic review. Eur J Orthod 2013;35:696-705.
- Prager A. Vergleichende Untersuchungen über die Häufi gkeit von Zahnstellungs- und Kieferanomalien bei Patienten mit Deformitäten der Wirbelsäule. Fortschritte der Kieferorthopädie 1980;41:163 – 168.
- Primozic J, Perinetti G, Richmond S, Ovsenik M. Three-dimensional evaluation of facial asymmetry in association with unilateral functional crossbite in the primary, early, and late mixed dentition phases. Angle Orthod 2013;83:253-8.
- Primozic J, Perinetti G, Zhurov A, Richmond S, Ovsenik M. Assessment of facial asymmetry in growing subjects with a three-dimensional laser scanning system. Orthod Craniofac Res 2012;15:237-44.
- Primozic J, Perinetti G, Zhurov A, Richmond S, Ovsenik M, Antolic V, Primozic J. Three-dimensional assessment of back symmetry in subjects with unilateral functional crossbite during the pre-pubertal growth phase: a controlled study. Eur J Orthod 2019;41:250-257.
- Ras F, Habets LL, van Ginkel FC, Prahl-Andersen B. Longitudinal study on three-dimensional changes of facial asymmetry in children between 4 to 12 years of age with unilateral cleft lip and palate. Cleft Palate Craniofac J 1995;32:463-8.
- Shah SM, Joshi MR. An assessment of asymmetry in the normal craniofacial complex. Angle Orthod 1978;48:141-8.
- Sidlauskiene M, Smailiene D, Lopatiene K, Cekanauskas E, Pribuisiene R, Sidlauskas M. Relationships between Malocclusion, Body Posture, and Nasopharyngeal Pathology in Pre-Orthodontic Children. Medical science monitor : international medical journal of experimental and clinical research 2015;21:1765-73.
- Solow B, Siersbaek-Nielsen S. Cervical and craniocervical posture as predictors of craniofacial growth. Am J Orthod Dentofacial Orthop 1992;101:449-58.
- Stauber I, Vairaktaris E, Holst A, Schuster M, Hirschfelder U, Neukam FW, Nkenke E. Three-dimensional analysis of facial symmetry in cleft lip and palate patients using optical surface data. J Orofac Orthop 2008;69:268-82.
- Van Elslande DC, Russett SJ, Major PW, Flores-Mir C. Mandibular asymmetry diagnosis with panoramic imaging. Am J Orthod Dentofacial Orthop 2008;134:183-92.
- Zepa I, Hurmerinta K, Kovero O, Nissinen M, Kononen M, Huggare J. Trunk asymmetry and facial symmetry in young adults. Acta odontologica Scandinavica 2003;61:149-53.
- Zhou S, Yan J, Da H, Yang Y, Wang N, Wang W, Ding Y, Sun S. A correlational study of scoliosis and trunk balance in adult patients with mandibular deviation. PloS one 2013;8:e59929.