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The association between dental and facial symmetry in adolescents

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Introduction: Facial aesthetics have become one of the most important objectives of orthodontic treatment. The correction of dental arches should be performed in accordance with the face. This study explored the association between occlusal and facial asymmetries in adolescents, particularly emphasizing a Class II subdivision. **Methods:** Eighty-one adolescents (43 males, 38 females) with a median age of 15.9 (interquartile range, 15.17-16.33) years were enrolled. Of these patients, 30 had a Class II subdivision (right side, n = 12; left side, n = 18). Three-dimensional facial scans were analyzed using surface- and landmark-based methods. Chin asymmetry was determined using the chin volume asymmetry score. Three-dimensional intraoral scans were analyzed to assess occlusal asymmetry. **Results:** The surface matching scores were 59.0% ± 11.3% for the whole face and 39.0% ± 19.2% for the chin. Chin volume was larger on the right side than on the left side in most patients (n = 51, 63%), and it was associated with a dental midline shift to the corresponding subdivision side. A correlation between dental and facial asymmetries was noted. In addition, the dental midline shifted to the left in patients with a Class II subdivision, regardless of the side, and to the right in those with a symmetrical Class II subdivision. However, several patients did not possess asymmetrical occlusal traits sufficient for statistical analysis. **Conclusions:** Dental asymmetry was weak but significantly correlated with facial asymmetry. (Am J Orthod Dentofacial Orthop 2023;164:340-50)

The human face is asymmetrical by nature. The asymmetry is typically small and clinically nonsignificant but statistically significant.[1] It may or may not be associated with occlusal asymmetry. A Class II subdivision is one of the most commonly observed types of occlusal asymmetry.[2] Therefore, the nature of the asymmetry in patients with a Class II subdivision has been widely investigated using cone-beam computed tomography (CBCT) scans and 2-dimensional radiography.[3-10] Several studies based on 2-dimensional radiographs have suggested the predominantly dental nature of the Class II relationship.[8,10,11] These earlier studies were conducted using submentovertex radiography, which was criticized for its significant distortions.[12] Later, CBCT studies showed conflicting results. Sanders et al[3] observed shorter mandibular lengths and ramus heights in patients with a Class II subdivision, and the skeletal component contributed 61% to the development of a Class II subdivision. Minich et al[4] proposed a Class II subdivision because of a more forward and inferior position in the maxilla and decreased mandibular corpus length. In their study, the skeletal components accounted for less than half of the total discrepancy.[4] Other studies also proposed that the asymmetry in patients with a Class II subdivision was at the glenoid fossa level.[5,7] Furthermore, Huang et al[7] showed that along with the asymmetry of the glenoid fossa, distal positioning and lingual inclination of the mandibular first molar, combined with the mesial positioning of the maxillary first molar, were dental contributors in developing a Class II subdivision.

Facial asymmetry is considered a significant concern for patients. The increased difficulty in treating patients with a Class II subdivision alongside correcting the facial asymmetry has also been reported.[13] Similarly, the association between a Class II subdivision and facial asymmetry has been studied via facial photography.[9,10]

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All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest, and none were reported.
This work was supported by an internal grant from Riga Stradins University.
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Submitted, March 2022; revised and accepted, January 2023.
0889-5406

https://doi.org/10.1016/j.ajodo.2023.01.015

Azevedo et al[9] evaluated patients with a Class II subdivision with visible facial asymmetry and concluded that the subdivision was primarily dentoalveolar with minimal skeletal involvement. Another study analyzed the photographs in a descriptive and rather subjective manner.[10]

Recently, facial 3-dimensional (3D) models, specifically acquired through stereophotogrammetry, have become a valuable tool for assessing facial asymmetry[1,14] and exploring the associated facial changes, for example, with cardiometabolic risk factors[15] and different conditions (asthma[16] and sleep-disordered breathing[17]), because some of these conditions also influence facial appearances.[16,17] Similarly, the importance of precisely acquiring the facial surface morphology and quantifying the facial area has been emphasized for exploring the genetic background of malocclusion.[18] Moreover, stereophotogrammetry is time-saving and has no carcinogenic risk factors. Therefore, stereophotogrammetry in growth studies has replaced facial anthropometry and cephalometry.[19,20] This method provides more precise data regarding facial soft-tissue parameters with or without different conditions and has also been used to evaluate the treatment of Class II malocclusion.[21]

This study aimed to explore facial symmetry in adolescents with a Class II subdivision and compare facial symmetry parameters of patients with a Class II subdivision and those with normal bilateral molar occlusion.

MATERIAL AND METHODS

The Ethics Committee of the Riga Stradins University (6-2/5/1) approved this study. The sample was identified from an ongoing growth study in an average white population.[20] Three hundred randomly selected children born in 2000 were invited to participate. One hundred eighty-one participants attended at least 1 scanning session, and 125 participated regularly. Participants were scanned every 6 months from 10 to 18 years old, resulting in 18 scanning sessions.

The facial scans from the 12th session were chosen to study dental and facial asymmetry. The median age of patients was 15.9 years (interquartile range, 15.17-16.33 years). The exclusion criteria were as follows: patients with previous orthodontic treatment that exceeded 6 months and those with a history of previous craniofacial trauma as well as the presence of craniofacial anomalies, facial disfigurement, clinically evident facial asymmetry, and missing or impacted teeth in the maxillary and mandibular arches through the first permanent molars. The inclusion criteria were Class I, Class II (at least half a cusp) symmetrical, and Class II subdivision left or right occlusal relationships. Finally, 81 adolescents (43 males and 38 females) were enrolled in the study.

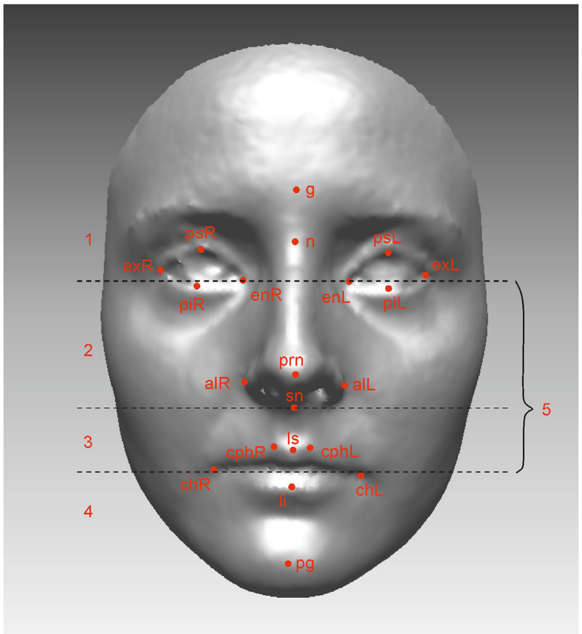

Fig 1. Chosen landmarks for the study include: *g*, glabella, most prominent midline point between the eyebrows; *n*, nasion, midline point of the nasal root; *en*, endocanthion, points at the inner commissures of the eye fissure; *ex*, exocanthion, points at the outer commissures of the eye fissure; *ps*, palpebrale superius, highest points in the middle of the upper eyelids; *pi*, palpebrale inferius, lowest points in the middle of the lower eyelids; *prn*, pronasale, most prominent point of the apex nasi; *sn*, subnasale, the midpoint of the angle in which the upper lip and the nasal septum meet; *al*, alare, most lateral points of alare contours; *ls*, labiale superius, the midpoint of upper vermilion line; *li*, labiale inferius, the midpoint of the lower vermilion line; *cph*, crista philtri, points on the elevated margin of the philtrum above the vermilion line; *ch*, cheilion, points at the labial commissure; *pg*, pogonion, most anterior point of the chin.[22] Facial regions for asymmetry assessment: *1*, forehead (above the inner canthus); *2*, upper middle region, between the inner canthus and subnasale; *3*, mandibular middle region, between the subnasale and cheilion; *4*, lower face; *5*, middle region, between the inner canthus and cheilion.

A 3dMDface System (3dMD, Atlanta, Ga) was used to obtain facial scans. First, on the facial 3D surface, 21 landmarks were identified by a single previously calibrated operator (S.S.) (Figure 1).[22] Then, the position of each landmark was determined on the coordinate axes (x, y, and z). The size of the surfaces was scaled on the basis of these landmarks. Interfering structures, such as the hair and ears, were finally removed by the same operator (S.S.) using the 3dMD Patient software (3dMD).

Subsequently, analysis was conducted by another operator (V.V.) with Rapidform 2006 (INUS Technology, Seoul, South Korea) using the surface-based and landmark-based facial symmetry parameters previously described by Launonen et al[23] and Djordjevic et al.[24] Initially, each image was mirrored: regions above the subnasale of the original and mirrored faces were superimposed using the best-fit registration method.[25] Then, the difference between the original and mirrored faces was measured by average distance.[1] In addition, the symmetry percentage of distances exceeding 0.5 mm between the original and mirrored faces was calculated,[1,23,24] after which asymmetry was assessed for the whole face and each facial region (Fig 1). Finally, pose standardization for the faces was performed by superimposing the facial 3D model and its mirror surface.[25] The symmetry plane of this combination was defined as the sagittal plane. The projection of the midpoint of the left and right endocanthion on the sagittal plane was set as the origin. Finally, the cylinder was fitted to the vertices of the original mirror face structure, and then the model was rotated to achieve the cylinder's axis in a direction parallel to the y-axis. Coronal and transverse planes were set to go through the origin and be perpendicular to the sagittal plane and each other.

The angles between eyes and chin (exL-exR-pg; exR-exL-pg) and between eyes and lips (exRexL-chRchL) were measured (Fig 2).

A new method for measuring chin asymmetry from the facial 3D model (V.V.) was used.[26] First, the chin area was divided into 2 solid objects, and their volumes were calculated (Fig 3). Then, asymmetry was quantified by the ratio of these volumes. Initially, the chin region was separated from the whole facial surface. Two planes were found to define this closed object: one plane goes through the posterior exocanthion point and is parallel with the coronal plane (xy-plane), whereas another plane is drawn through the lower lip midpoint and is in parallel with the transverse plane (xz-plane). Subsequently, the sagittal plane separated this object into 2 parts, after which the volume for these parts was calculated. Later, the larger volume was divided by the smaller one, determining the chin volume asymmetry score (CVAS).[26,27] Finally, these volume ratios were quantified for asymmetry similarly to those used in studies that have performed cranial asymmetry analysis.[27,28]

The distance between the landmarks and the midsagittal plane was measured for landmark-based facial symmetry. The midpoint distance to the midsagittal plane was used for the bilateral landmarks. The direction of asymmetry was determined by the positive or negative value relative to the x-axis.

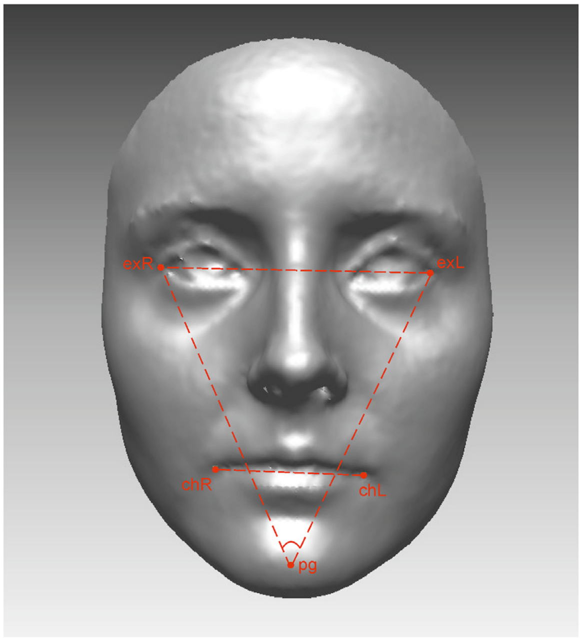

Fig 2. Facial measurements: *exL-exR-pg*, the angle between the eyes and chin; *exRexL-chRchL XY*, the angle between connecting lines of exocanthions and cheilions.

Intraoral scans were performed using a 3Shape Trios scanner (3Shape, Copenhagen, Denmark), and the same operator (K.L.) measured them.

A previously validated interarch digital model method was used to measure dental parameters (K.L.).[29] This method is based on the model measurement method for assessing occlusal asymmetry.[30] The analyses included bilateral canine relationship measurements, bilateral first molar relationships, midline symmetry, overjet and overbite (Fig 4).[29] Bilateral canine relationship measurements were performed by defining the most distal points of the maxillary and mandibular canines. However, the bilateral first molar relationship measurements were done by choosing the most mesial points of the maxillary and mandibular first molars using the method described by Pirttiniemi et al.[30] The points were projected onto perpendicular occlusal planes, and the values were measured with an accuracy of 0.01 mm. A Class I relationship was recorded if the value was between 1 and 3 mm, a Class II relationship was recorded if the value was <1 mm, and a Class III relationship was recorded if the value was >3 mm. The measurements of the left molar and canine positions were distracted from the right molar and canine positions, respectively, to assess the asymmetrical positions of the molars and canines.

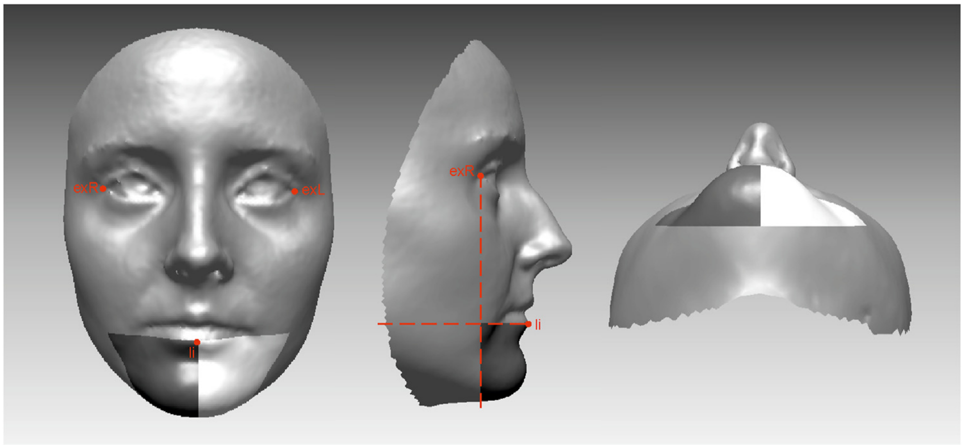

Fig 3. Chin symmetry measurement: coronal (XY-plane) and transverse plane (XZ-plane).

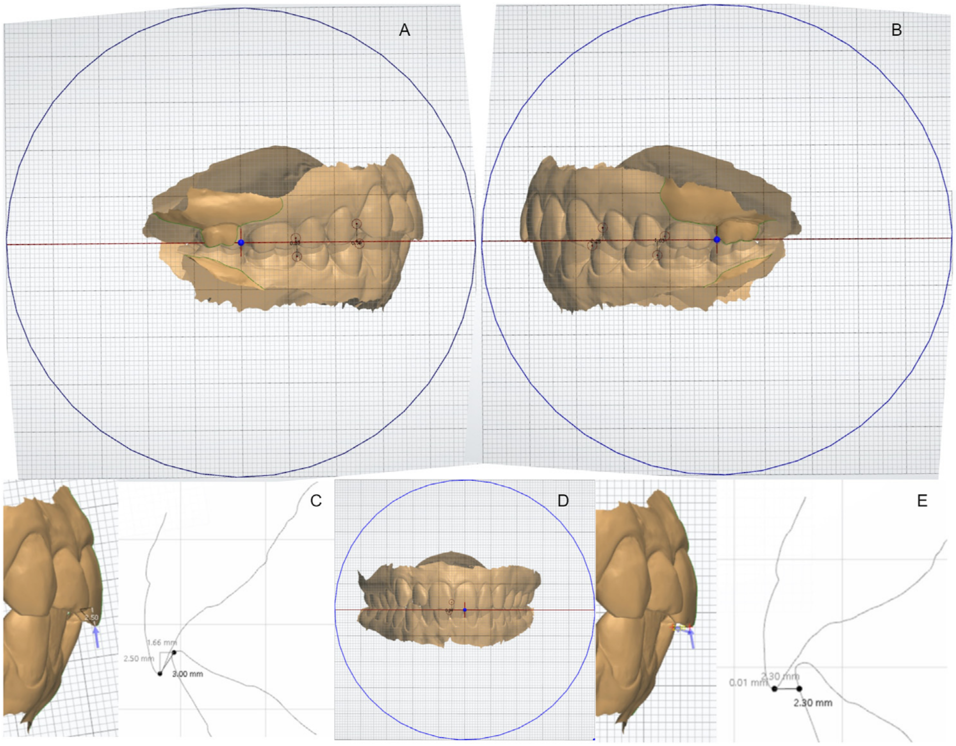

Fig 4. Occlusal measurements: **A,** Molar and canine on the right side; **B,** Molar and canine on the left side; **C,** Overbite from the right central incisor; **D,** Midline; **E,** Overjet from the right central incisor.

Midline asymmetry measurements were performed in the frontal view by defining 2 points: one on the median palatine raphe and another on the mandibular incisal midline. A positive value indicated that the mandibular incisor midline was to the right of the median palatine raphe. In contrast, a negative value showed that it was to the left of the median palatine raphe.

Afterward, the maxilla's transversal dimension was measured (S.S.) using the landmarks placed on the mesiobuccal cusp tips of the molars, buccal cusp tips of the premolars, and cusp tips of the canines. If the tip was worn off, the landmark was placed at the center of that area. Finally, the distances between the corresponding molars, premolars, and canines were measured.[31]

Table I. Occlusal parameters in patients with a Class I and II relationship and Class II subdivision

Measurement	*Class I (n = 30)*	*Class II (n = 21)*	*Class II subdivision right (n = 12)*	*Class II subdivision left (n = 18)*	P *value*[†]
Molar relationship left side	1.87 ± 0.63	−0.65 ± 1.51	1.57 ± 0.54	−0.35 ± 1.44	<0.001*
Molar relationship right side	1.68 ± 0.57	−0.69 ± 1.80	−0.43 ± 1.15	1.65 ± 0.44	<0.001*
Canine relationship left side	2.29 ± 0.80	0.37 ± 2.21	1.80 ± 0.61	−0.25 ± 1.50	<0.001*
Canine relationship right side	1.96 ± 0.74	−0.62 ± 2.31	−0.32 ± 1.82	1.55 ± 1.28	<0.001*
Overjet	2.52 ± 0.95	3.67 ± 2.05	2.74 ± 1.01	3.21 ± 1.58	0.036*
Overbite	2.26 ± 1.46	3.03 ± 1.28	3.07 ± 1.54	3.22 ± 1.96	0.272
Midline	−0.09 ± 1.20	0.80 ± 1.05	−0.26 ± 1.38	−0.89 ± 0.76	<0.001*

Note. Values are in millimeters and are shown as mean ± standard deviation. Negative values indicate to the left of the midline, whereas positive values indicate to the right.
[†]Determined using the Kruskal-Wallis test; *Statistical significance at P <0.05.

Little's irregularity index was used to measure the crowding in the mandibles' frontal region (S.S.). The distances between the adjacent anatomic contact points of the mandibular incisors from the mesial of the right canine to the mesial of the left canine were determined, and the sum of these distances was calculated.[32]

Statistical analysis

Statistical analysis was performed using SPSS (version 23.0; IBM, Armonk, NY) and Microsoft Excel 2013 (Microsoft Corporation, Redmond, Wash). The data were tested for the normality of distribution. Some of the facial and all occlusal measurements had a nonnormal distribution. Differences among more than 2 measured variables were evaluated using Kruskal-Wallis test. When significant differences were detected, pairwise a posteriori comparisons were conducted through the Dunn-Bonferroni post-hoc test.

Furthermore, Fisher exact test was used to compare the chin sides of asymmetry in the groups. Spearman correlation analysis was used to assess the associations. The statistical significance level for the study was set at 0.05.

This study randomly chose 30 facial and intraoral scans to determine their reliability. The facial and intraoral scans were landmarked twice at a 2-week interval. Intraoperator reliability testing was applied to evaluate the reliability of landmarking as previously described.[20] The mean error was generally <0.5 mm, but the following coordinates exceeded the value: g Y, 0.61; n Y, 0.52; alL Z, 0.51; cphR X, 0.51; and pg Y, 0.69.

One examiner independently performed the digital scan measurements and repeated them 2 weeks later. The intraclass correlation coefficient was used to assess the reliability of the occlusal parameters; it ranged from 0.989 to 1.000. For transverse measurements, results ranged from 0.988 to 0.999; for Little's irregularity index, the result was 0.991.

RESULTS

In this study, the forehead was the only facial region in which the average distance was statistically different between the males and females (0.46 ± 0.15 vs 0.40 ± 0.13; P = 0.049). Therefore, for further analysis, the groups were pooled together. We observed no correlation between Little's irregularity index and the mandibular dental midline shift (r = 0.003, P = 0.978). Similarly, no difference was observed between Little's irregularity index and transversal measurements among patients with a Class I and II relationship and Class II subdivision. Therefore, the groups were analyzed, disregarding the transversal dimensions and mandibular anterior crowding.

Occlusal parameters are presented in Table I. The patients with a Class II relationship had a 1.2 mm larger overjet than those with a Class I relationship (P = 0.032). The results also showed that the dental midline was centered within patients with a Class I relationship and deviated to the right by 0.80 ± 1.05 mm in patients with a symmetrical Class II relationship. The mandibular dental midline was shifted to the left on the left and right side in patients with a Class II subdivision (Table I). The position of the canines was strongly associated with the position of the molars (r = 0.839 for the right side and r = 0.820 for the left side). Differences between the molar position in patients with a Class II subdivision were 1.99 ± 1.30 mm for a subdivision on the right side and 1.98 ± 1.45 mm for the left side.

The course of facial symmetry is presented in Table II. The surface matching score of the original and mirrored facial surfaces was 61.67% ± 13.55% for patients with a Class II relationship and 56.14% ± 12.20% for those with a Class II subdivision on the right side. Except for the Class I group, all the groups observed the highest correspondence for the forehead. The lowest correspondence was observed for the lower face in all the groups. There was no statistically significant difference among the groups for the surface-based symmetry parameters.

Table II. Course of facial symmetry measured with surface-based variables

Part of the face	*All*	*Class I (n = 30)*	*Class II (n = 21)*	*Class II subdivision right (n = 12)*	*Class II subdivision left (n = 18)*	P *value*
Whole face AD, mm	0.58 ± 0.20	0.56 ± 0.16	0.56 ± 0.24	0.62 ± 0.21	0.57 ± 0.16	0.457
Whole face %	58.99 ± 11.25	58.61 ± 10.52	61.67 ± 13.55	56.14 ± 12.20	59.02 ± 9.25	0.443
Forehead AD, mm	0.43 ± 0.14	0.43 ± 0.15	0.39 ± 0.14	0.41 ± 0.12	0.45 ± 0.16	0.624
Forehead %	68.47 ± 13.97	68.29 ± 13.62	72.47 ± 14.06	67.85 ± 15.06	68.35 ± 15.18	0.658
Upper midface AD, mm	0.44 ± 0.16	0.42 ± 0.12	0.45 ± 0.22	0.48 ± 0.20	0.44 ± 0.13	0.881
Upper midface %	68.05 ± 14.88	69.64 ± 12.27	68.71 ± 17.14	62.97 ± 19.13	67.15 ± 13.74	0.730
Lower midface AD, mm	0.68 ± 0.37	0.65 ± 0.28	0.70 ± 0.37	0.76 ± 0.49	0.61 ± 0.33	0.725
Lower midface %	48.87 ± 22.23	48.48 ± 20.29	48.74 ± 22.91	44.57 ± 24.07	53.06 ± 22.84	0.711
Midface AD, mm	0.52 ± 0.20	0.50 ± 0.16	0.54 ± 0.25	0.57 ± 0.23	0.50 ± 0.17	0.540
Midface %	61.55 ± 15.08	62.13 ± 14.18	61.96 ± 16.96	57.10 ± 16.26	62.67 ± 15.08	0.443
Lower face AD, mm	0.93 ± 0.54	0.87 ± 0.36	0.88 ± 0.59	1.10 ± 0.66	0.92 ± 0.55	0.735
Lower face %	38.99 ± 19.22	36.21 ± 16.70	44.24 ± 21.04	34.09 ± 19.10	39.26 ± 17.14	0.705

AD, average distance.

Table III. Measurements of facial symmetry in patients with a Class I and II relationship and Class II subdivision

Measurement	*Class I (n = 30)*	*Class II (n = 21)*	*Class II subdivision right (n = 12)*	*Class II subdivision left (n = 18)*	P *value*[†]
mid-ex (mm)	−0.19 ± 0.10	0.61 ± 0.59	0.26 ± 0.25	−0.22 ± 0.49	0.012*
mid-prn (mm)	0.00 ± 0.99	−0.47 ± 1.05	−0.57 ± 0.73	0.18 ± 0.78	0.072
mid-sn (mm)	0.30 ± 0.65	−0.21 ± 0.79	−0.04 ± 0.32	0.44 ± 0.62	0.024*
mid-al (mm)	−0.01 ± 0.45	−0.35 ± 0.61	−0.14 ± 0.31	0.10 ± 0.44	0.113
mid-ch (mm)	−0.30 ± 0.98	−0.69 ± 0.98	−0.77 ± 0.99	0.18 ± 0.79	0.026*
mid-chp (mm)	−0.14 ± 0.86	−0.19 ± 1.03	−0.22 ± 0.72	0.33 ± 0.70	0.207
mid-ls (mm)	0.14 ± 0.98	−0.25 ± 1.02	−0.34 ± 0.85	0.21 ± 0.72	0.238
mid-li (mm)	0.19 ± 1.13	−0.26 ± 1.13	−0.35 ± 0.98	0.43 ± 0.86	0.110
mid-pg (mm)	−0.02 ± 1.62	−0.63 ± 1.34	−0.63 ± 1.59	0.43 ± 1.61	0.084
exR-exL-pg 3D (°)	65.29 ± 1.67	64.61 ± 1.17	65.35 ± 1.22	65.51 ± 1.49	0.073
exR-exL-pg XY (°)	64.14 ±1.84	63.73 ± 1.36	64.62 ± 1.18	64.71 ± 1.76	0.105
exL-exR-pg 3D (°)	64.86 ± 1.41	65.12 ± 1.13	65.84 ± 1.61	63.85 ± 1.54	0.007*
exL-exR-pg XY (°)	63.96 ± 1.52	64.42 ± 1.21	65.12 ± 1.63	63.07 ± 1.69	0.008*
n-sn-pg 3D (°)	162.47 ± 4.95	157.82 ± 8.53	158.94 ± 4.17	159.91 ± 4.32	0.083
n-sn-pg XY (°)	180.40 ± 2.14	181.06 ± 1.74	180.71 ± 1.77	180.81 ± 1.91	0.769
n-prn-pg 3D (°)	127.66 ± 3.73	124.06 ± 9.78	125.92 ± 3.54	125.94 ± 3.76	0.405
n-prn-pg XY (°)	181.58 ± 3.37	178.22 ± 20.68	182.65 ± 2.66	181.71 ± 2.44	0.479
exRexL-chRchL 3D (°)	1.81 ± 1.00	1.81 ± 1.06	1.88 ± 0.89	2.05 ± 1.27	0.955
exRexL-chRchL XY (°)	−0.36 ± 1.18	−0.49 ± 1.05	0.16 ± 1.39	−0.91 ± 0.91	0.060

Note. Values are presented as mean ± standard deviation. Negative values indicate to the right of the midpoint, whereas positive values indicate to the left.
[†]Determined from analysis of variance test; *Statistical significance at $P < 0.05$.

Table III summarizes the landmark-based symmetry parameters by groups. Midpoints moved to the corresponding subdivision side in patients with a Class II subdivision. The results showed that lip symmetry parameters differed between patients with a Class II relationship and those with a Class II subdivision on the left side ($P = 0.048$ for the mid−ch). A minor but significant shift of the mid-ex to the left in patients with a Class II subdivision on the left side compared with those with a Class I relationship ($P = 0.040$) and patients with a Class II subdivision on the right side ($P = 0.043$) was observed.

The angle between eyes and chin on the right side (exL-exR-pg) (Fig 2) was decreased in patients with a Class II subdivision on the left side compared with those with a Class II relationship ($P = 0.044$, measured in 3D) and those with a Class II subdivision on the right side ($P = 0.008$, measured in 3D; $P = 0.009$ measured in the coronal plane).

Weak but significant correlations between the dental midline shift and the maximum distance between the mirrored and original faces were observed for the lower midface ($r = 0.274$, $P \leq 0.05$) and the lower face ($r = 0.234$, $P \leq 0.05$). Weak but statistically significant correlations between the differences in the position of the contralateral canines and the facial midpoint position (from $r = 0.217$ to $r = 0.326$) were observed for all structures except the midpoint of the subnasale. The results also showed that the increased asymmetry in the canine position was correlated with a decrease in the facial angles (Fig 2), with the correlation coefficients ranging from $r = -0.358$ for the exRexL-pg 3D angle to $r = -0.320$ for the exRexL-pg XY angle. The asymmetrical molar position was associated with shifts in dental midlines ranging from $r = 0.233$ for mid-li to $r = 0.243$ for mid-ch and a decrease in the exRexL-pg 3D angle ($r = -0.224$). Furthermore, the shift of the mandibular dental midline was weakly associated with a dislocation of the facial midpoints to the corresponding side, ranging from $r = 0.235$ ($P \leq 0.05$) for mid-al to $r = 0.393$ ($P \leq 0.01$) for mid-ch.

The mean CVAS was 1.08 ± 0.06, ranging from 1.00 to 1.29. Fifty-one (63%) patients had a larger right side of the chin, whereas 30 had a larger left side. The dental midline shift was associated with larger chin volume asymmetry ($P = 0.005$).

DISCUSSION

Males and females were pooled for further analysis because the initial evaluation did not detect any difference in the asymmetry parameters between them, thus confirming the results of other studies.[24,33,34] In contrast, some studies have reported sexual dimorphism in facial asymmetry, with males being more asymmetrical.[35,36]

Patients aged 10 years with apparent facial asymmetry were excluded at the beginning of the growth study because the evident facial asymmetry before the pubertal growth spurt would have been a sign of distortion in growth.[27] No patients were excluded afterward.

The sample was retrieved from an ongoing growth study. The initial purpose of the data collection was to explore facial growth. This sample was monitored for oral health parameters. During clinical examination, a high incidence of malocclusions was noted. It was decided to perform intraoral scanning. The measurements were made, data obtained, and many patients with a Class II subdivision were found. Thus, a decision was made to study the association between facial asymmetry and Class II subdivision. Because radiation was not involved, the sample size could have been larger, but one of the exclusion criteria was orthodontic treatment exceeding 6 months. At this age, many adolescents already have had orthodontic treatment. In contrast, facial asymmetry could be assessed if there were any patients with asymmetric occlusion at the end of growth. A previous study has shown that facial asymmetry does not change with growth.[24]

We observed no difference in Little's irregularity index among the groups. Similarly, no correlation was observed between Little's irregularity index and the dental midline shift. Therefore, the irregularities of the mandibular incisors were not considered when analyzing the midline shift and Class II subdivision. A limitation of grouping the patients on the basis of the Angle classification is that it might be affected by the rotations of teeth.[37] Minich et al[4] observed the asymmetric position of the maxillary molars in patients with maxillary crowding. In contrast, the increased mandibular arch length is proposed to be associated with the Class II subdivision side.[3] The results have also shown that the dental Class II measurement for the Class II subdivision obtained in this study was −0.4 mm, which was not consistent with the data reported in other studies because of the differences in the measurement methods used.[3,4] The clinically nonsignificant midline shift to the left in patients with a Class II subdivision on the right side, combined with a larger standard deviation, could indicate a low correspondence of the molar relationship with the mandibular midline in some patients. The results of this study are in agreement with the suggestion that a type 1 Class II subdivision is relatively more common.[3,10] Notably, patients with a symmetrical Class II relationship had their midline shift to the right by 0.80 mm. However, we could not find any other study supporting this finding. Nevertheless, Alavi et al[8] reported a mandibular midline shift of 0.94 mm in patients with a symmetrical Class I relationship. It has been suggested that the midline shift in symmetrical patients might be associated with the different mesiodistal dimensions of the teeth.[38] In contrast, Dindaroğlu et al[39] found low morphologic deviations in teeth size between the left and right sides among patients with different malocclusions.

The exRexL-chRchL XY angle (Fig 2) was negative in all groups except patients with a Class II subdivision on the right side. However, the differences were not statistically significant ($P = 0.06$). A narrower exRexL-chRchL XY angle could indicate a shorter face on the respective side.

We found that the asymmetry at the lips level was less pronounced than that at the level of the mandibula's border. Thus, we assumed that these differences could indicate a bigger asymmetry at the lower border level, represented by the chin volume in this study, because of inherited imprecision of landmarking at that region.

In this study, the surface-based measurements revealed significant facial asymmetry, whereas the landmark-based measurements showed clinically insignificant deviations from the midline. Alqattan et al[40] demonstrated that landmark-based and surface-based symmetry analysis methods have limitations. Landmark-based analysis might not identify the asymmetry located in the regions underrepresented by landmarks. For instance, one side of the face is larger than the other, but only some landmarks in the middle are shifted.

Various methods for analyzing facial asymmetry using 3D data have been developed, but no one method has been universally accepted.

The iterative closest point procedure is a widely used method for registration, providing a rigid transformation and searching for the closest points between 2 shapes.[41] The disadvantage of this method is that it does not guarantee structural correspondence. However, it does work well if the asymmetry is not immense.[42] As an alternative, the thin-plate-splines method, this being a nonrigid transformation, might be incorporated. This method can find corresponding points from both sides of the face. It is based on homologous point coordinates measured on both shapes.[43] A potential error might be the sliding of the semilandmarks beyond their intended place, particularly if the variability of the shapes is larger.[42,43] In the study by Chen et al,[41] iterative closest points have been used after the thin-plate-splines.

Several approaches have been proposed to analyze facial asymmetry in the typical population or growth disturbances caused by congenital syndromes or trauma. These populations differ in the size and aims of the assessment; therefore, the approaches are adopted to achieve these aims. In a general population, asymmetries are subtle and directional asymmetry, and antisymmetry and fluctuating asymmetry should be recorded in big samples. For these purposes, a spatially-dense 3D facial asymmetry assessment could be employed.[42,44] The dense correspondence analysis enables data analysis as a whole and allows for capturing the subtle structures of the face, allowing for more discrete face analysis. This approach has been widely used in face recognition, with the development of a set of reference shapes.[36,42,44] Dense correspondence is required to represent global shape changes in patients with morphing. These approaches can rely on methods that use mirrored images.[45,46] We attempted to quantify the directional facial asymmetry, which, as we assumed, could be associated with an asymmetrical occlusion. We know that more subtle asymmetry features could be recorded by a method on the basis of the dense correspondence approach. In contrast, in the surface-based method, symmetry is assessed on the patients' own mirrored image, avoiding problems of comparing faces of different sizes and facial expressions. However, we consider this a study that adds some evidence to the decision-making process for treatment planning. We tended to focus on the possible asymmetry in facial structures that patients or clinicians recognize, such as the corners of the lips or chin. Of course, a protocol applicable to typical and disordered growth patterns would be ideal.[42]

Comparing the results of the studies on facial asymmetry are difficult because they are done with different in-house written assessment protocols. Djordjevic et al,[24] in their study of facial asymmetry among growing adolescents, used surface- and landmark-based methods. The means of landmark deviations from the midsagittal plane were similar to this study, consistently showing values <1 mm, whereas the amount of 3D symmetry for the lower face of this study was lower than that and other studies.[1,23,24,47] We did not find any statistical difference among the groups, but it must be noted that patients with a Class II relationship showed the highest correspondence between the mirrored and original images. Furthermore, differences between the original and mirrored faces did not reach statistically significant differences between patients with a Class II subdivision or between those with a Class I and II relationship. Therefore, this finding proposes that the soft tissues of the face compensate for dental asymmetry. In addition, weak but statistically significant correlations between the dental midline shift and maximum distance between the mirrored and original faces were observed for the lower midface, midface, and lower face. In this sample, the overall correspondence between the original and mirrored faces for the lower face was low (39%). It has earlier been shown that the maxillomandibular components of bilateral incongruence were mostly the same for patients with a Class I, II, or III relationship.[48]

Although we observed slight deviations in the facial midpoints of the corresponding subdivision side in patients with a Class II subdivision, these deviations were statistically significant only for the upper lip and nose. It has been shown that the most asymmetrical regions were near the eyes, the lateral aspects of the nose, and the labiomental region.[36] This sample showed that the mid-pg point deviated from the midsagittal plane by <1 mm. Djordjevic et al[1] reported similar results in a noncategorized population. Even patients with a Class II subdivision did not show clinically significant deviations in the mid-pg. It has also been demonstrated with a sample of dentofacial deformities that asymmetry was less frequently observed among patients with a Class II relationship.[49] Simultaneously, the correlations between their facial midpoint positions and positional differences between the contralateral molars and canines were recorded. Notably, more frequent and higher correlations between the dental and facial parameters were observed when differences between the sides were expressed at the canine level, which was an anticipated finding.

The origin of asymmetry might be at the gonial region or ramus length.[3,7,48,50] Sanders et al[3] found that the total mandibular length and ramus height were shorter in the corresponding subdivision side among patients with a Class II subdivision. However, the differences they observed were <2 mm. They suggested shortening the face on the Class II subdivision side. Their data corresponded with our findings that the exR-exL-pg angle was larger for patients with a Class II subdivision on the left side. In addition, the exL-exR-pg angle was larger for patients with a Class II subdivision on the right side.

Moreover, this study found that the middle and lower face landmarks were dislocated to the corresponding subdivision side, but the difference reached statistical significance only for the upper lip measurements among the patients with a Class II subdivision on the left side. These results supported the findings of Minich et al,[4] who suggested that the main skeletal components of Class II subdivision were the position of the maxilla relative to the cranial base and the mandibular corpus length measured between the foramen mentalis and mandibular foramen. These measurements contributed to the skeletal asymmetry by 1 mm, constituting a difference too small to be noticeable on the face.

Li et al[5] suggested that a Class II subdivision was due to the functional shift in one third of the patients. Other studies supported this finding, showing asymmetrical positions of the temporomandibular joints.[6,7] These patients are proposed to have contributed to the shift of the facial midpoints more than they did to actual skeletal differences. Similarly, Azevedo et al[9] investigated patients with asymmetrical Class II subdivision and found that the main contributors to Class II subdivision were dentoalveolar, thus supporting the results of other studies.[9,10]

It is well known that mild facial asymmetries are common in typical growth and development, and most studies have demonstrated right-side dominance.[36,50-52] Lum et al,[36] indeed, reported right-side dominance in all patients except 1. In this study, the right side dominance was assessed by the CVAS, which was recorded in 63% of patients. The dental midline shift was associated with increased CVAS on the respective side.

To our knowledge, this is the first study to have investigated the influence of Class II subdivision on external facial symmetry features. Although the nature of the skeletal involvement in a Class II subdivision is important, facial symmetry is the main concern of patients.

Because 3 patients with severe facial asymmetry and posterior crossbite were initially excluded from the sample, the sample may possess some selection bias. However, the transversal dimensions did not seem to be associated with the development of a Class II subdivision. Furthermore, this study assessed facial asymmetry mostly in the frontal plane. Lum et al[36] proposed a dense correspondence technique that assessed facial symmetry in all 3 planes. Besides, the sample size was not large enough to detect differences for patients with a Class II subdivision on the right side.

Class II subdivisions were insignificantly represented on the face. This finding would support the suggestion by Janson et al[53] that the most unheralded option for treating type 1 Class II subdivision is to limit the treatment to solely dental movements. This approach is most effective when obtaining a midline correction with reduced incisor retraction.[13] As previously proposed, the observed mandible's upward and backward rotation in some patients with a Class II subdivision also indicated the usefulness of functional appliances for treating these patients.[10] However, Class II molar and canine relationships may be more difficult to correct on the right side than on the left, provided there is no compensation from the glenoid fossa position or the maxillary dentition.[54] This might result from the right side is naturally more dominant and the Class II subdivision on the right side possibly indicating a more severe discrepancy.

CONCLUSIONS

1. Dental asymmetry was weakly but significantly correlated with facial asymmetry.
2. Facial midline points were shifted to the subdivision side in patients with a Class II subdivision.
3. The chin volume was greater on the side toward which the dental midline shifted.

AUTHOR CREDIT STATEMENT

Signe Silinevica contributed to conceptualization, original draft preparation, methodology, validation, investigation, resources, and manuscript review and editing; Kristine Lokmane contributed to methodology, validation, investigation, resources, and manuscript review and editing; Ville Vuollo contributed to software, formal analysis, data curation, and visualization; Gundega Jakobsone contributed to original draft preparation, project administration, and supervision; and Pertti Pirttiniemi contributed to manuscript review and editing and supervision.

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