ORIGINAL ARTICLE

Three-dimensional evaluation of skeletal and dental asymmetries in Class II subdivision malocclusions

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The objective of this study was to determine if any significant differences existed with regard to dental and skeletal asymmetries between subjects with Angle Class II subdivision malocclusions and subjects with normal occlusions. The sample consisted of 30 subjects in each of the 2 groups. Each possessed a full complement of permanent teeth, including first molars. The average age of subjects was 15.76 years in the Class II subdivision group and 22.42 years in the normal occlusion group. Measurements were obtained with the use of submentovertex, posteroanterior, and corrected oblique cephalometric radiographs. In the submentovertex radiographs, symmetry was assessed by measuring the relative differences in the spatial positions of dental and skeletal landmarks between the right and the left sides in both anteroposterior and transverse dimensions. Coordinate systems were used to represent the mandible, cranial floor, and the maxilla. In the posteroanterior radiographs, symmetry was assessed similarly by measuring the relative differences in the spatial positions of dental and skeletal landmarks between the right and the left sides. In the corrected oblique radiographs, symmetry was assessed by measuring the differences in size of dental and skeletal structures between the right and the left sides. Variables were analyzed with multivariate logistic regression analysis. The results demonstrated that the primary contributor to the differences between the 2 groups was the distal positioning of the mandibular first molars on the Class II side in patients whose mandibles showed no unusual skeletal or positional asymmetries. A secondary contributor was the mesial positioning of the maxillary first molars on the Class II side. Furthermore, the posteroanterior radiographic analysis showed that the more frequent distal positioning of the mandibular molars on the Class II side, compared with the mesial positioning of the maxillary molars on that side resulted in mandibular dental midline deviation to the Class II side more frequently than the maxillary dental midline to the opposite side. (Am J Orthod Dentofacial Orthop 2001;119:406-18)

Although some studies have already described many characteristics of Class II subdivision malocclusions, some questions persist regarding the origin and etiologic factors of unilateral malocclusions. Alavi et al[1] concluded that the primary factor contributing to an anteroposterior discrepancy in this type of malocclusion was the unilateral distal positioning of mandibular first molars. However, they did not determine whether it was due to dentoalveolar or skeletal asymmetry. Rose et al[2] confirmed the distal positioning of the mandibular first molars in Class II subdivision malocclusions but did not evaluate the anteroposterior positioning of the maxillary first molar as a possible contributing factor to the malocclusion. Maxillary and mandibular dental midline deviation is another concern in the treatment of Class II subdivision malocclusions. It has been reported that, in study models, the frequency of mandibular dental midline deviation is greater than that of maxillary midline deviation in relation to facial midline.[3] However this deviation could not be confirmed on the posteroanterior (PA) radiograph. Furthermore, the simultaneous contribution of several variables in the 3 planes of space to the creation of Class II subdivision malocclusions has not been investigated. Therefore, the objective of this study is to provide some answers to these persistent questions. More specifically, the objective is to determine if any significant differences exist with regard to dental and skeletal asymmetries between subjects with Angle Class II subdivision malocclusions and subjects with

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normal occlusions, when several dentoskeletal variables are simultaneously evaluated.

MATERIAL AND METHODS

Material

The experimental group consisted of 30 subjects (16 males and 14 females) with Class II subdivision malocclusions selected from those who sought orthodontic treatment at the Orthodontic Department of the Bauru Dental School, University of São Paulo. The average age was 15.76 years. The control group consisted of 30 subjects (10 males and 20 females) with normal occlusions selected from the students and the employees of the same dental school who offered to participate in the study. The average age was 22.42 years.

The selection criterion for the 2 groups was that the participants had all of their maxillary and mandibular permanent teeth, including the first molars. The additional criteria for the malocclusion group were as follows: (1) a complete Class I molar relationship on one side of the dental arch with a full Class II relationship on the other side, (2) no previous orthodontic treatment, (3) no lateral mandibular shift during closure, as determined by clinical examination, (4) no history of facial trauma or medical conditions that could have altered the growth of the apical bases,[4] and (5) no crowding, or at most, a symmetrical crowding of up to 3 mm in the maxillary and mandibular dental arches. These criteria were evaluated by means of clinical history and examination.

Method

Four radiographs were obtained from each subject: 1 submentovertex, 1 posteroanterior, and 2 corrected obliques of the right and the left sides. The cephalometric tracings were performed on acetate paper by a single investigator and then digitized (Houston Instrument DT-11; Houston Instruments, Houston, Tex). These data were then stored on a 586 Pentium computer (Intel, Santa Clara, Calif) and analyzed with Dentofacial Planner 7.0 (Dentofacial Planner Software, Toronto, Ontario).

The machine used for the submentovertex radiograph was the TUR D800 (Hermann Matern, Dresden, Germany), with Kodak X-Omat K film (Kodak, Rochester, NY) with an exposure time of 0.125 seconds at 70 kV and 32 mA.[5-8] The distance from the focal point to the metallic ear rods was set at 152 cm, and the distance from the metallic ear rods to the film was set at 16 cm, which yielded a magnification factor of 9.55%. During exposure, the subjects kept their teeth in centric occlusion under light pressure.

Cephalometric structures, lines, planes, and measurements were obtained according to Ritucci and Burstone's analysis,[5,9] with some added modifications.

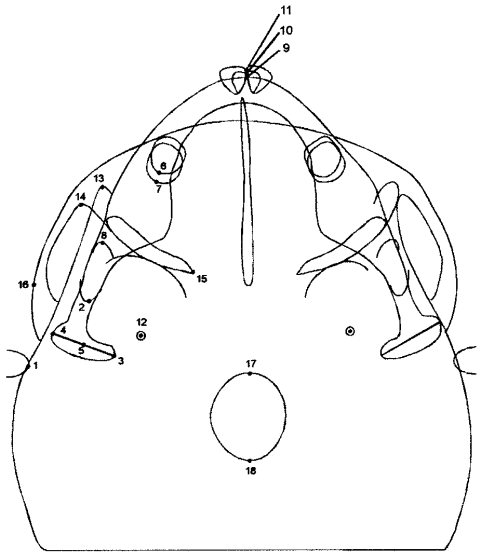

Fig 1. Structures and landmarks of submentovertex radiograph. *1,* Metallic ear rod point, medial center of each metallic ear rod; *2,* gonion point, midpoint mediolaterally on posterior border of each gonial angle; *3,* medial condylar point, tangent point to each medial condylar border of line drawn parallel to each mandibular body line; *4,* lateral condylar point, tangent point to each lateral condylar border of line drawn parallel to each mandibular body line; *5,* condylar midpoint, midpoint between lateral and medial condylar points on each condyle; *6,* distal mandibular first molar point, most distal point in line with central groove on each mandibular first molar; *7,* distal maxillary first molar point, most distal point in line with central groove on each maxillary first molar; *8,* coronoid process point, most anterior point relative to transcondylar axis on each coronoid process; *9,* mandibular midline, most anterior point of mandibular body (skeletal point); *10,* mandibular dental midline, point contact between mesial surfaces of crowns of mandibular central incisors; *11,* maxillary dental midline, point contact between mesial surfaces of crowns of maxillary central incisors; *12,* foramina spinosa points, geometric center of each foramen spinosa; *13,* angulare, most anterior point relative to transpterygomaxillary axis of triangular opacities present at external orbital angle where maxillary and mandibular orbital rims meet and zygomatic arch inserts; *14,* buccale, point on internal surface of each zygomatic arch where arch turns medially and directly starts upon a backward sweep; *15,* pterygomaxillary fissure, most medial and posterior point of each pterygomaxillary fissure; *16,* zygion points, intersections of lateral borders of zygomatic arches with line parallel to transpterygomaxillary axis drawn across section of greatest bizygomatic width; *17,* basion, most anterior point relative to transspinosum axis on border of foramen magnum; *18,* opisthion, most posterior point relative to transspinosum axis on border of foramen magnum.

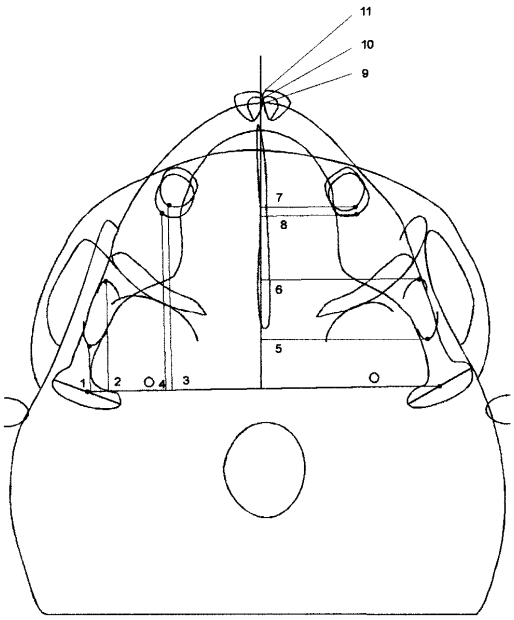

Fig 2. Measurements from the submentovertex radiograph. Mandibular coordinate system. Anteroposterior: *1,* Gonion to transcondylar axis; *2,* coronoid process point to transcondylar axis; *3,* distal mandibular first molar point to transcondylar axis; *4,* distal maxillary first molar point to transcondylar axis. Transverse: *5,* Gonion to intercondylar axis; *6,* coronoid process point to intercondylar axis; *7,* distal mandibular first molar point to intercondylar axis; *8,* distal maxillary first molar point to intercondylar axis; *9,* mandibular midline to intercondylar axis; *10,* mandibular dental midline to intercondylar axis; *11,* maxillary dental midline to intercondylar axis.

The tracings of the submentovertex radiograph included foramen magnum, foramen spinosum, metallic ear rods, mandible (including condyles, gonial angles, and coronoid processes), posterior cranial vault, zygomatic arches, anterior cranial vault, pterygomaxillary fissures, vomer, maxillary and mandibular first molars, and maxillary and mandibular central incisors. The landmarks are defined and illustrated in Fig 1.

The Ritucci and Burstone method[5,9] evaluates the asymmetry of the craniodental structures in relation to different systems of coordinates. The present study used this method with some modifications. The coordinate systems used were the mandibular, the cranial floor, and the zygomaxillary complex. The angular measurements between the abscissa of the coordinate systems were also obtained.

The coordinate system consisted of 2 axes perpendicular to each other. The lateral and the anteroposterior positions of all pertinent structures were evaluated in relation to these axes. The transcondylar axis was established in the mandibular coordinate system, passing through the condylar midpoints. This axis was used to evaluate the symmetry of the anteroposterior positioning of the mandibular structures. In addition, the symmetry of the transverse positioning of these structures was evaluated using the intercondylar axis drawn perpendicular to the transcondylar axis from its midpoint. Similarly, the transspinosum and interspinosum axes were constructed for the coordinate system of the cranial floor, and the transpterygomaxillary and interpterygomaxillary axes were consructed for the zygomaxillary coordinate system. For paired structures, the distance to the reference axis was determined for both landmarks and the difference in the horizontal distance was calculated. For unpaired points, the horizontal distance to the midline was determined. There was a total of 42 variables of the submentovertex radiograph. Fig 2 illustrates the mandibular coordinate system variables.

The posteroanterior radiographs were obtained according to Harvold's method.[10] The machine used for this radiograph, as well as for the corrected oblique, was the Roentax 10090 (Eletro Medicina Indústria e Comércio, São Paulo, Brazil), with Kodak X-Omat K film and an exposure time of 1 second, at 90 kV(p) and 25 mA. In these radiographs, the distance from the focal point to the metallic ear rods was standardized at 152 cm and the distance from the metallic ear rods to the film was fixed at 16 cm, which yielded a magnification factor of 8.91%. During exposure, the subjects kept their teeth in centric occlusion.

The tracings of the posteroanterior radiograph included the following structures: orbits, contours of the nasal cavity, crista galli, zygomatic arches, mandibular contour from one condyle to the other, left and right maxillary contours, lateral aspects of the frontal bone, lateral aspects of the zygomatic bones, maxillary and mandibular central incisors, and maxillary and mandibular first molars. The landmarks are defined and illustrated in Fig 3. The cephalometric measurements were obtained according to the method described by Grummons and Van De Coppello[11] (Fig 4[12]). For paired structures, the distance to the reference midline was determined for both landmarks, and the difference between the distances was calculated. For unpaired points, the horizontal distance to the midline was determined. This part of the analysis yielded 18 variables.

It was necessary to evaluate the submentovertex radiograph to obtain the corrected oblique radiographs. Through the submentovortex radiograph, it was possible to measure the angle of incidence of the x-rays for the corrected oblique radiographs on each subject's head. This allowed for a parallel projection of each side

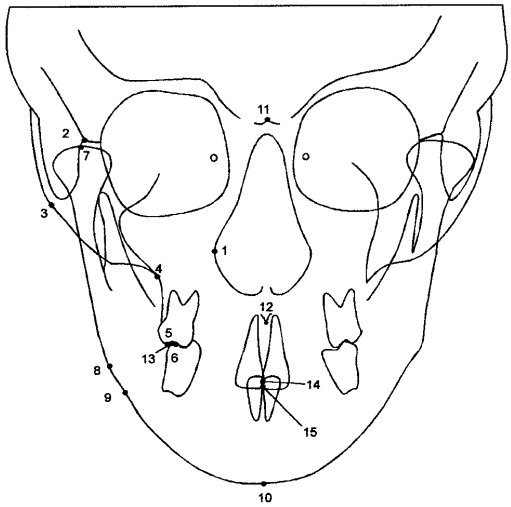

Fig 3. Structures and landmarks of the posteroanterior radiograph. *1,* Most lateral point on outline of nasal orifice in region of each piriform aperture; *2,* superolateral reference point, point located at lateral aspect of each frontozygomatic suture; *3,* lateral aspect of each zygomatic arch centered vertically; *4,* point located at depth of concavity of each lateral maxillary contour at junction of maxilla and zygomatic buttress; *5,* buccal cusp tip of each maxillary first molar; *6,* buccal cusp tip of each mandibular first molar; *7,* point located on the superior surface of head of each condyle centered mediolaterally; *8,* point located at each gonial angle of mandible; *9,* point located at each antegonial notch; *10,* menton, most inferior point on anterior border of mandible at symphysis; *11,* most superior point of crista galli located ideally in skeletal midline; *12,* tip of anterior nasal spine; *13,* mean contact point between each maxillary and mandibular first molar; *14,* midpoint between maxillary central incisors; *15,* midpoint between mandibular central incisors.

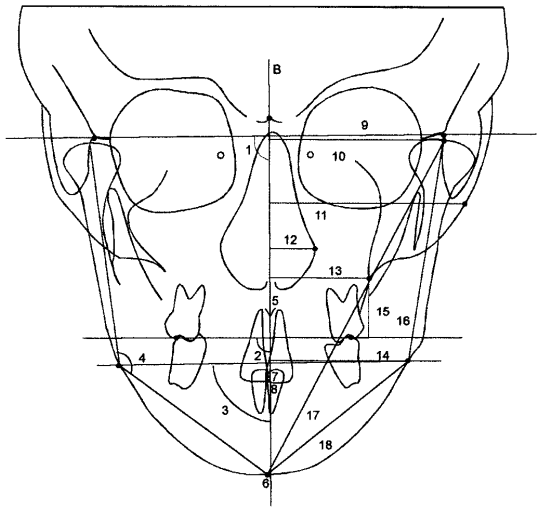

Fig 4. Angular and linear measurements from the posteroanterior radiograph. *1,* Z plane angle, angle between Z plane and Cg–ANS line; *2,* occlusal plane angle, angle between occlusal plane and Cg–ANS line; *3,* antegonial plane angle, angle between antegonial plane and Cg–ANS line; *4,* antegonial angle, angle between mandibular ramus and mandibular body; *5,* anterior nasal spine deviation, horizontal distance between anterior nasal spine and X-line (vertical line representing medial plane drawn at right angle to Z plane through root of crista galli);[12] *6,* mandibular deviation, horizontal distance between menton and X-line; *7,* maxillary dental midline deviation, horizontal distance between dental maxillary midline and X-line; *8,* mandibular dental midline deviation, horizontal distance between dental mandibular midline and X-line; *9,* frontozygomatic suture to X-line distance, horizontal distance between frontozygomatic suture and X-line; *10,* condylion to X-line distance, horizontal distance between condylion and X-line; *11,* zygoma distance, distance between zygomaxillary arch and X-line; *12,* piriform aperture to X-line distance, horizontal distance between lateral wall of piriform aperture and X-line; *13,* maxillary buttress to X-line distance, horizontal distance between maxillary buttress and X-line; *14,* antegonial notch to X-line distance, horizontal distance between antegonial notch and X-line; *15,* maxillary first molar height, vertical distance between maxillary buttress and buccal cusp tip of maxillary first molar; *16,* condylion to antegonial notch distance, size of mandibular ramus from condylion to antegonial notch; *17,* condylion to menton distance, mandibular length from condylion to menton; *18,* menton to antegonial notch distance, mandibular body size from menton to antegonial notch.

of the mandible on the film. The proper rotation of the cephalostat for the corrected oblique radiographs was calculated so that each side of the mandible stayed parallel to the film. The sagittal axis was traced on the submentovertex radiographs passing through the better superimposition of the midpoints of oval and spinosum foramens and basion and opisthium, perpendicular to a line connecting the midpoint of the ear rods, the transporionic axis (Fig 5, *line A*). Another line, C, was traced from the midpoint of each condyle to the symphysis. Lines x and z were traced, one from each side, perpendicular to line C from the intersection of the midsagittal plane with the transporionic axis (line A). Angles 3 and 4, formed by lines A and x and A and z, respectively, determined the necessary rotation of the cephalostat so that the corresponding mandibular body stayed parallel to the film when the corrected oblique radiograph was taken (Fig 5, *angles 3* and *4*).

The corrected right and left oblique radiographs were obtained by positioning each subject in the cephalo-

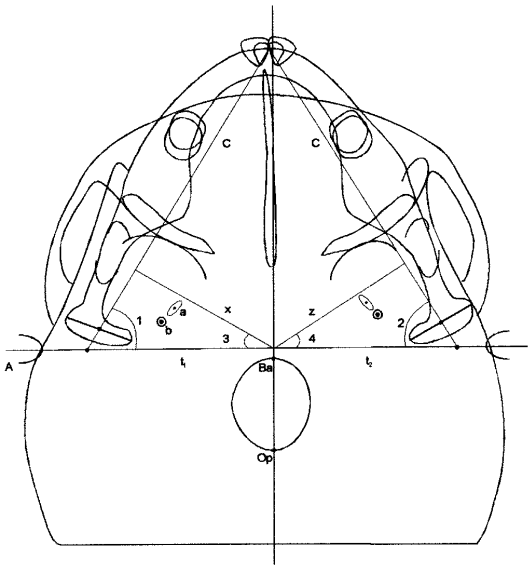

Fig 5. *a,* Foramen ovale; *b,* foramen spinosa; t_1, hypotenuse of right triangle; t_2, hypotenuse of left triangle; *1,* angle used to calculate actual size of x; *2,* angle used to calculate actual size of z; *3,* angle that determined cephalostat rotation for right oblique radiograph; *4,* angle that determined cephalostat rotation for left oblique radiograph; *Ba,* basion; *Op,* opisthion.

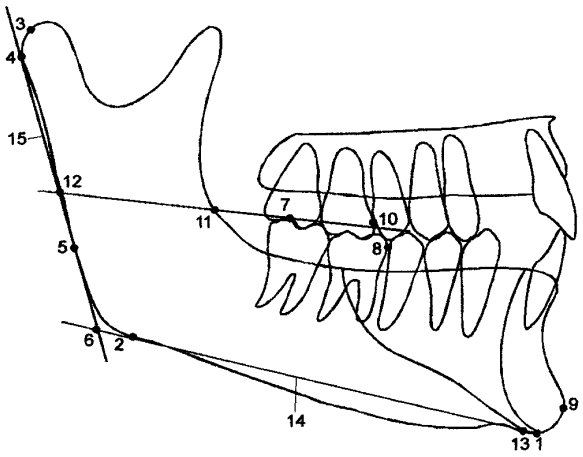

Fig 6. Anatomical structures, landmarks, and lines of the corrected oblique radiograph. *1,* C, menton, lowest point on anterior portion of mandibular body; *2,* D, gonion point, most posterior point of mandibular body next to gonion; *3,* condylion, most posterior and superior point of condylar head; *4,* H, highest contact point of tangent to mandibular ramus; *5,* S, lowest contact point of tangent to mandibular ramus; *6,* B, point of intersection between tangent to mandibular body (line C-D) and tangent to mandibular ramus (line H-S); *7,* distobuccal cusp of mandibular second molar; *8,* mesial mandibular first molar point, most mesial point of mandibular first molar crown; *9,* pogonion, point where line perpendicular to C-D line touches front portion of symphysis; *10,* mesial maxillary first molar point, most mesial point of maxillary first molar crown; *11,* anterior ramus point, intersection between line that passes through cusp tip of mandibular second premolar and distal cusp of mandibular second molar, and anterior border of ramus; *12,* posterior ramus point, intersection between line that passes through cusp tip of mandibular second premolar and distal cusp of mandibular second molar, and posterior border of ramus; *13,* actual symphysis,[19] point on lowest portion of mandibular symphysis; *14,* line C-D, line that passes through points C and D and represents lower border of mandible; *15,* line H-S, line that passes through points H and S and represents posterior border of mandible.

stat with the Frankfort plane parallel to the floor and the cephalostat rotated according to the angle obtained on the submentovertex radiograph.[13,14] Each side of the mandible was parallel to the film in that projection.[15]

The tracing of each corrected oblique radiograph included the following: anterior contour of the symphysis, mandibular body, ascending ramus, condyle, coronoid process, height of the alveolar bone, maxillary first molar, mandibular first molar, mandibular second molar, contour of the maxilla, and mandibular second premolar. The anatomical structures, landmarks, lines, and cephalometric measurements of the right and the left sides of the mandible were obtained according to Barber et al,[14] Woodside,[16] Woodside and Harvold,[17] and Melnik,[18] with some modifications. There were a total of 11 variables for the corrected oblique radiograph (Figs 6[19] and 7).

The following method, described by Harvold,[15] allows the assessment of the actual mandibular size through calculations of the right and the left mandibular sides measured from condylion to mandibular symphysis.

In the submentovertex radiograph, the actual distances from the axis of symmetry to the body of each side of the mandible (actual x and z) were measured because of their importance for the final calculation of mandibular size.

First, measurements t_1 and t_2 (Fig 5) were adjusted according to the magnification factor (MF):

actual $t_1 = t_1 - t_1$ (MF)

actual $t_2 = t_2 - t_2$ (MF)

At this time, the actual x and z could be calculated by the following formula:

actual x = actual $t_1 \times$ sine 1

actual z = actual $t_2 \times$ sine 2

On the corrected oblique radiographs, the right and the left mandibular lengths were measured (from condyle to mandibular symphysis) and these measurements were adjusted according to the magnification factor:

Measured right mandibular length = MRML
Measured left mandibular length = MLML

$$\frac{\text{Actual mandibular length}}{\text{Measured mandibular length}} = \frac{\text{FpO (Focal point-object)}}{\text{FpI (Focal point-image)}}$$

$$\text{Actual right mandibular length} = \frac{\text{(FpO + actual x) MRML}}{\text{FpI}}$$

$$\text{Actual left mandibular length} = \frac{\text{(FpO + actual z) MLML}}{\text{FpI}}$$

Absolute values for the 3 radiographs were used for the differences between the measurements of the right and the left sides and for the horizontal distances to the reference midplanes. This eliminated the possibility of positive and negative values canceling themselves out in the calculation of actual means for each group.[20]

Statistical analyses

Twenty-four randomly selected radiographs from 6 subjects were retraced, redigitized, and remeasured by the same examiner. The casual error was calculated according to Dahlberg's formula ($S^2 = \Sigma d^2/2n$),[21] and the systematic error with a dependent *t* test, for $P < .05$.[22-26]

The means and SDs for all measurements were calculated to enable characterization of the different sample groups. Because it is possible for a variety of factors acting together to influence the manifestation of a Class II subdivision malocclusion or a normal occlusion, multivariate logistic regression analysis was used. With a dichotomous dependent or outcome variable, logistic regression has the particular advantage of permitting assessment of the significance, magnitude, and direction of individual predictor variables when the effects of other predictor variables are controlled or held constant. Even when the complete proposed model does not present a high explanatory power, the multivariate logistic regression analysis allows the independent effect of a smaller number of variables, potentially favorable, to be subsequently analyzed. The final model was based on regressive selection criterion. These analyses were performed with the use of the program Statistica (Statistica for Windows 4.3B; Statsoft, Tulsa, Okla), on a 586 Pentium computer.[27]

RESULTS

Means and SDs for the differences between the right and the left sides for all variables in both groups are listed in Tables I through IV. Of the 71 variables, only 8 presented a casual error slightly above 1 mm. All the others were below 1 mm or 1°. The paired *t* test on differences between the replications showed significant differences for only 2 variables.

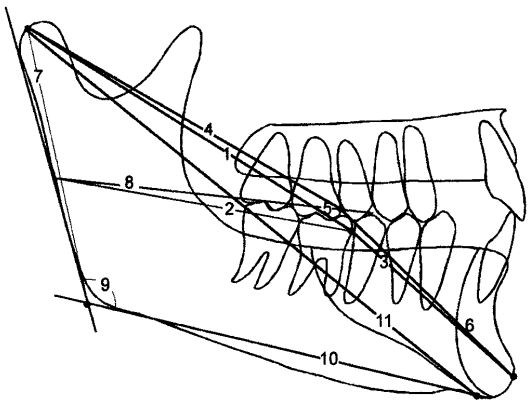

Fig 7. Measurements of corrected oblique radiograph. *1,* Mesial mandibular first molar point to condylion; *2,* mesial mandibular first molar point to posterior ramus point; *3,* mesial mandibular first molar point to pogonion; *4,* mesial maxillary first molar point to condylion; *5,* mesial maxillary first molar point to posterior ramus point; *6,* mesial maxillary first molar point to pogonion; *7,* ramus length, length of mandibular ramus from B point to condylion; *8,* ramus width, width of mandibular ramus from anterior ramus point to posterior ramus point; *9,* gonial angle formed by lines H-S and C-D; *10,* mandibular body length from B point to actual symphysis point; *11,* actual mandibular length.

The multivariate logistic regression analysis was conducted with the variables of the 3 radiographs together and then individually. Tables V through VIII list the classification results of the regression analyses with the standardized function coefficients for the variables listed in decreasing order of importance on the basis of absolute magnitude.

When the variables of the 3 radiographs were analyzed simultaneouly, the most important variable was the distal mandibular first molar point to the transcondylar axis (Table V).

Table VI shows the regression analysis performed only with the submentovertex variables. It demonstrates that the most important variable was the distal mandibular first molar point to the transspinosum axis.

Tables VII and VIII show the results of the regression analysis for the corrected oblique and the PA radiographs, respectively. Table VII shows that the greatest participation in the equation is provided by the mesial mandibular first molar point to the posterior ramus point. Table VIII shows that the most

Table I. Means and SDs of asymmetry measurements (differences between measurements of right and left sides and for distances of unpaired structures to reference midplanes) for submentovertex radiograph in millimeters

	Normal occlusion		*Class II subdivision*	
	Mean	*SD*	*Mean*	*SD*
Mandibular coordinate system				
Anteroposterior:				
Gonion to transcondylar axis	1.21	1.22	1.33	0.98
Coronoid process point to transcondylar axis	1.32	0.85	1.57	1.07
Distal mandibular first molar point to transcondylar axis	0.96	0.64	2.62	1.56
Distal maxillary first molar point to transcondylar axis	0.96	0.72	1.48	0.93
Transverse:				
Gonion to intercondylar axis	1.95	1.25	2.59	2.30
Coronoid process point to intercondylar axis	2.58	1.82	2.05	1.80
Distal mandibular first molar point to intercondylar axis	2.94	2.04	3.63	2.91
Distal maxillary first molar point to intercondylar axis	2.69	1.84	3.31	2.39
Mandibular midline to intercondylar axis	1.88	1.50	2.68	2.70
Mandibular dental midline to intercondylar axis	1.72	1.24	2.20	1.88
Maxillary dental midline to intercondylar axis	1.55	1.12	1.93	1.75
Cranial floor coordinate system				
Anteroposterior:				
Condylar midpoint to transspinosum axis	1.59	1.27	1.58	1.33
Gonion to transspinosum axis	1.63	1.42	1.90	1.40
Coronoid process point to transspinosum axis	1.68	1.28	2.08	1.42
Distal mandibular first molar point to transspinosum axis	1.04	0.84	2.89	1.57
Distal maxillary first molar point to transspinosum axis	1.02	0.90	1.27	1.00
Transverse:				
Condylar midpoint to interspinosum axis	0.95	0.68	1.45	1.13
Gonion to interspinosum axis	1.78	1.31	2.70	2.06
Coronoid process point to interspinosum axis	2.74	1.92	2.58	2.05
Distal mandibular first molar point to interspinosum axis	3.26	2.41	3.96	2.99
Distal maxillary first molar point to interspinosum axis	2.86	2.15	3.54	2.42
Mandibular midline to interspinosum axis	2.13	1.87	3.39	2.48
Mandibular dental midline to interspinosum axis	1.90	1.67	2.52	2.14
Maxillary dental midline to interspinosum axis	1.94	1.32	2.40	1.55
Basion to interspinosum axis	1.37	1.17	1.84	1.66

important variable in the PA is the mandibular dental midline deviation.

DISCUSSION

The fact that the groups included male and female subjects in different proportions is not critical because Arnold et al,[20] in establishing normal patterns in the submentovertex radiographs, did not find statistically significant asymmetry differences between gender. Melnik,[18] in 45° oblique radiographs, concluded that after the age of 14 there were no statistically significant gender differences regarding asymmetries. Ponyi et al[28] conducted direct measurements in ancient European skulls and did not find significant gender differences in asymmetry. Additionally, another study on asymmetry did not specify gender.[1] The age differences between the groups did not seem to be a problem because, in a study of mandibular asymmetry, Melnik[18] verified that an equal probability exists for asymmetry to improve or worsen with growth. Thus, considering particularly the females in which the major part of maturation has occurred, the nearly complete maturation of the males in the Class II subdivision group, and the equal probability of improvement of craniofacial asymmetry with growth, the age difference between the groups should not interfere with this type of evaluation.

The submentovertex radiographs were taken in centric occlusion. Ideally, they should be taken in centric relation to detect any functional mandibular deviation that might interfere with the evaluation of mandibular asymmetry in relation to the maxilla and the cranial base.[5,9,29-31] However, in this study, one of the prerequisites for individuals of both groups was that they did not have any lateral functional mandibular deviation. The elimination of such "postural" asymmetries ensured an accuracy in the evaluation of mandibular asymmetry in relation to the maxilla and the cranial

Table II. Means and SDs of asymmetry measurements (differences between measurements of right and left sides and for distances of unpaired structures to reference midplanes) for submentovertex radiograph in millimeters

	Normal occlusion		*Class II subdivision*	
	Mean	*SD*	*Mean*	*SD*
Zygomaxillary coordinate system				
Anteroposterior:				
Buccale to transpterygomaxillary axis	2.27	1.73	2.47	1.90
Zygion to transpterygomaxillary axis	1.25	1.80	2.33	2.85
Angulare to transpterygomaxillary axis	2.27	1.88	2.22	1.96
Distal mandibular first molar point to transpterygomaxillary axis	1.27	0.95	3.15	1.92
Distal maxillary first molar point to transpterygomaxillary axis	1.23	0.90	1.33	0.99
Transverse:				
Buccale to interpterygomaxillary axis	2.42	1.87	2.28	1.38
Zygion to interpterygomaxillary axis	1.91	1.47	2.71	3.22
Angulare to interpterygomaxillary axis	2.89	1.81	2.36	1.78
Distal mandibular first molar point to interpterygomaxillary axis	2.52	2.66	3.17	2.16
Distal maxillary first molar point to interpterygomaxillary axis	2.26	2.61	2.57	1.79
Maxillary dental midline to interpterygomaxillary axis	1.82	1.85	1.75	1.21
Mandibular midline to interpterygomaxillary axis	1.94	1.92	2.41	2.30
Mandibular dental midline to interpterygomaxillary axis	1.76	1.91	2.15	1.78
Angular measurements between the abcissa of the coordinate system (°):				
Interspinosum axis to intercondylar axis	0.81	0.64	0.81	0.71
Transspinosum axis to transcondylar axis	0.84	0.65	0.85	0.75
Transpterygomaxillary axis to transcondylar axis	1.23	0.84	1.25	0.93
Transpterygomaxillary axis to transspinosum axis	1.46	1.02	1.01	1.02

base. The corrected oblique and PA radiographs were obtained in centric occlusion for the same reasons.

The simultaneous regression analysis of the 3 radiographs demonstrated that the variables that presented the largest contribution were those concerning the anteroposterior positioning of the mandibular and maxillary molars (Table V). The analyses of the variables of the submentovertex and corrected oblique radiographs also demonstrate a strong participation of the anteroposterior positioning of the mandibular and maxillary molars in the equation (Tables VI and VII). These results are similar to other studies and lead to the conclusion that distal positioning of the mandibular first molars occurs more frequently than mesial positioning of the maxillary first molars in Class II subdivision patients.[1,2] It has been shown in study models that the mandibular arch presents a greater frequency of anteroposterior asymmetry than the maxillary arch.[3] The present study supports this observation. It should be emphasized that most of the variables in Table V are dentoalveolar, and only some are skeletal. This demonstrates the predominantly dentoalveolar nature of the differences between the 2 groups. There was no participation in any of the equations of the variables that indicate a positional asymmetry of the mandible in relation to the cranial floor or to the zygomaxillary structures, which suggests the absence of a positional mandibular asymmetry.

There was participation of some skeletal variables, such as the mandibular body length and the gonial angle. The maxillary dental midline deviation obtained on the PA radiograph presented a minor contribution and occupied fifth place, whereas the contribution of the mandibular midline deviation was indefinite (Table V). These results were very similar to those reported by Alavi et al.[1] It is interesting to note that the results demonstrate a certain skeletal collaboration in the differentiation between the groups. The mandibular midline deviation, which showed the greatest contribution to the equation when the variables of the PA radiograph were analyzed separately (Table VIII), contributed little to the regression equation of the 3 radiographs when they were analyzed simultaneously. This probably occurred because its contribution is strongly influenced by the anteroposterior position of the mandibular first molars, which contributed greatly to the equation. When the mandibular molars are more distally positioned on the Class II side, there will consequently be a deviation of the mandibular dental midline to that side. Therefore, the involvement of the mandibular dental midline will be implicit in the more distal positioning of the mandibular molars. This is the reason that this variable contributed little to the complete equation. This does not occur when only the PA radiograph is analyzed because the anteroposterior posi-

Table III. Means and SDs of asymmetry measurements (differences between measurements of right and left sides and for horizontal distances of unpaired structures to reference midline) for posteroanterior radiograph in millimeters

	Normal occlusion		*Class II subdivision*	
	Mean	*SD*	*Mean*	*SD*
Z plane angle (°)	89.90	1.27	89.69	1.94
Occlusal plane angle (°)	89.34	1.74	89.84	2.14
Antegonial plane angle (°)	88.63	1.51	88.47	2.48
Anterior nasal spine deviation	1.33	0.84	1.70	1.48
Mandibular deviation	2.71	1.63	3.10	2.26
Maxillary dental midline deviation	1.40	0.90	2.07	1.39
Mandibular dental midline deviaton	1.58	0.97	2.41	1.79
Antegonial angle (°)	2.40	1.51	3.18	2.40
Frontozygomatic suture to X-line distance	1.77	1.24	2.01	1.78
Condylion to X-line distance	3.20	2.42	3.62	2.39
Zygoma to X-line distance	2.86	1.96	3.51	2.87
Pyriform aperture to X-line distance	2.51	1.57	3.11	2.34
Maxillary buttress to X-line distance	2.47	1.65	3.39	2.52
Antegonial notch to X-line distance	4.25	3.19	4.00	3.48
Maxillary first molar height	1.37	1.05	1.72	1.54
Condylion to antegonial notch distance	2.70	2.10	3.31	2.65
Condylion to menton distance	2.26	2.21	2.51	2.24
Menton to antegonial notch distance	2.28	1.92	2.90	2.18

Table IV. Means and SDs of asymmetry measurements (differences between measurements of right and left sides) for corrected oblique radiographs in millimeters

	Normal occlusion		*Class II subdivision*	
	Mean	*SD*	*Mean*	*SD*
Mesial mandibular first molar point to condylion	2.10	1.45	2.01	2.01
Mesial mandibular first molar point to posterior ramus point	1.10	0.89	2.28	1.68
Mesial mandibular first molar point to pogonion	1.25	0.97	1.23	0.95
Mesial maxillary first molar point to condylion	1.98	1.34	1.89	1.21
Mesial maxillary first molar point to posterior ramus point	1.05	1.00	2.29	1.85
Mesial maxillary first molar point to pogonion	1.26	0.96	2.36	1.48
Ramus length	2.09	1.60	2.37	1.80
Ramus width	1.28	0.98	1.56	1.40
Gonial angle (°)	1.97	1.45	2.60	1.67
Mandibular body length	2.21	2.13	2.30	1.68
Actual mandibular length	2.63	1.97	2.12	1.99

tioning of the mandibular molars cannot be measured because of their location on another plane (Table VIII). Consequently, the mandibular dental midline deviation presents the greatest involvement in the regression equation and in the differentiation of the groups when the PA radiograph is analyzed separately. This information is very important and matches clinical observations of patients with Class II subdivision.

Results of the separate analysis of the PA radiograph support, in a way, clinical observations of the deviation of the mandibular dental midline in relation to the facial midline in most patients with Class II subdivision malocclusions (Table VIII). Maxillary dental midline deviation was ranked in sixth place. Although the individual contribution of any variable at this level is difficult to evaluate, it also matches clinical observations of the less frequent deviation of the maxillary dental midline in relation to the facial midline in Class II subdivision cases. When the mandibular dental midline is deviated, it is toward the Class II side, whereas the maxillary dental midline deviation is toward the Class I side. Results in study models point to a greater frequency of deviation of the mandibular dental midline than of the maxillary in Class II subdivision malocclusions; this supports the observations that the deviation of the dental midline is the effect of an asymmetric positioning of the

Table V. Results of multivariate logistic regression analysis of simultaneous evaluation of submentovertex (SMV), posteroanterior (PA), and corrected oblique (CO) radiographs

Loss: Least squares

Final loss: 0.000000000 R = 1.00 Variance explained: 100.00%

	Estimate
Constant BO	–420.22
Distal mandibular first molar point to transcondylar axis (SMV)	131.28
Mesial mandibular first molar point to pogonion (CO)	–87.62
Mesial maxillary first molar point to posterior ramus point (CO)	76.40
Mandibular body length (CO)	–71.74
Maxillary dental midline deviation (PA)	64.54
Distal maxillary first molar point to transcondylar axis (SMV)	59.08
Mesial maxillary first molar point to pogonion (CO)	53.10
Gonial angle (CO)	32.75
Maxillary first molar height (PA)	22.63
Anterior nasal spine deviation (PA)	–22.29
Mandibular dental midline deviation (PA)	18.47
Mesial mandibular first molar point to posterior ramus point (CO)	–8.15

mandibular or maxillary molars on the Class II side in Class II subdivision malocclusions.[3]

The difference in mandibular length between the 2 sides of the mandible did not play a very important role in the regression analysis of this study. This finding is similar to that reported by Alavi et al,[1] who verified that mandibular asymmetry occupied the eighth place in their discriminating analysis. In light of the present results, it can be inferred that individuals who have an asymmetry between the sides of the mandible might have a tendency to demonstrate a Class II molar relationship on the shorter side, as stated by Williamson and Simmons.[30] These authors reported that individuals with 3 mm or more of mandibular asymmetry show a tendency toward a Class II relationship on the shorter side of the mandible. However, this does not imply that individuals with a Class II relationship on one side will also have a smaller mandibular length on that side. We could speculate that Class II subdivision malocclusions originate from a similar but less severe type of unilateral condylar hypoplasia that could result in a smaller mandibular length on the subdivision side. However, these results, and those reported by Rose et al,[2] did not demonstrate statistically significant differences between the groups regarding the presence of skeletal mandibular asymmetry.

Table VI. Results of multivariate logistic regression analysis of complete submentovertex radiograph

Loss: Least squares

Final loss: 1.000000000 R = 0.96 Variance explained: 93.33%

	Estimate
Constant BO	–362.0
Distal mandibular first molar point to transspinosum axis	119.3
Distal maxillary first molar point to transcondylar axis	117.5
Distal mandibular first molar point to intercondylar axis	92.0
Distal maxillary first molar point to intercondylar axis	–86.3
Mandibular dental midline to interspinosum axis	–62.8
Distal maxillary first molar point to transpterygomaxillary axis	50.7
Distal maxillary first molar point to interspinosum axis	49.6
Distal maxillary first molar point to transspinosum axis	–35.5
Mandibular dental midline to interpterygomaxillary axis	–34.6
Distal mandibular first molar point to transpterygomaxillary axis	30.3
Condylar midpoint to interspinosum axis	–19.5
Gonion to interspinosum axis	–16.0
Zygion to transpterygomaxillary axis	12.5
Basion to interspinosum axis	–9.5
Coronoid process point to interspinosum axis	–9.0

General considerations

This study demonstrated that the main components contributing to the asymmetric anteroposterior relationship in the Class II subdivision are dentoalveolar when compared with subjects with normal occlusion. This is in agreement with studies by Alavi et al[1] and Rose et al.[2] Although they found a greater dentoalveolar involvement in producing Class II subdivision, they suggested the involvement of skeletal factors as well. In this study with several variables, the participation of skeletal asymmetries in patients with Class II subdivisions was very small, compared with subjects with normal occlusions. As the dentoalveolus acts as a region of compensation for skeletal disharmonies, the possibility remains that subtle skeletal asymmetries are accommodated in the dentoalveolar compartment. In this scenario, a skeletal asymmetry, the primarily structural asymmetry, remains subtle.

The results of this study indicate that Class II subdivision malocclusions are more often characterized by a distal positioning of the mandibular first molar on the Class II side and less often by a mesial positioning of

Table VII. Results of multivariate logistic regression analysis of corrected oblique radiograph

Loss: Least squares

Final loss: 3.000000000 R = 0.89 Variance explained: 80.00%

	Estimate
Constant BO	–122.7
Mesial mandibular first molar point to posterior ramus point	137.1
Mesial maxillary first molar point to pogonion	96.1
Mesial maxillary first molar point to condylion	–83.0
Mesial mandibular first molar point to condylion	–76.8
Actual mandibular length	–70.1
Mesial mandibular first molar point to pogonion	–68.1
Gonial angle	61.1
Ramus length	43.9
Mesial maxillary first molar point to posterior ramus point	38.0
Mandibular body length	–34.0
Mandibular ramus width	10.8

Table VIII. Results of multivariate logistic regression analysis of posteroanterior radiograph

Loss: Least squares

Final loss: 6.000000002 R = 0.77 Variance explained: 60.00%

	Estimate
Constant BO	26.38
Mandibular dental midline deviation	174.17
Z plane angle	–93.52
Occlusal plane angle	90.85
Anterior nasal spine deviation	–79.21
Frontozygomatic suture to X-line distance	–77.33
Maxillary dental midline deviation	–58.82
Pyriform aperture to X-line distance	55.92
Condylion to menton distance	–44.11
Antegonial notch to X-line distance	–42.13
Condylion to antegonial notch distance	34.17
Mandibular deviation	30.41
Zygoma to X-line distance	23.78
Condylion to X-line distance	22.08
Menton to antegonial notch distance	9.30
Antegonial angle	5.63

the maxillary molar on the Class II side. It is possible that these anteroposterior discrepancies in the position of the first molars may contribute to the observed deviations of the dental midline. It is known that an alteration in some portion of the craniofacial complex produces an equal alteration in another part and, sometimes, in the opposite direction.[32] In this case, as a result of molar alterations, what alterations in other parts would occur? The deviation of the dental midlines in relation to facial midline, visible on the PA radiograph, is probably such an alteration. There were therefore dentoalveolar—not skeletal—compensatory alterations due to the craniofacial complex's intrinsic propensity to compensate for regional growth alterations and enable the development of harmonious facial proportions.[32]

It was shown that Class II subdivision malocclusions did not present a significant skeletal asymmetry as compared with normal occlusion subjects. However, the Class II subdivision sample was randomly selected, chosen primarily for the anteroposterior asymmetric positioning of the molars. Thus, it included subsamples of subjects with distal positioning of the mandibular first molar as a primary cause for the Class II relationship on one side, others with mesial positioning of the maxillary first molar as a primary cause for the unilateral Class II relationship, as well as subjects in which the unilateral Class II relationship was caused by a combination of both. As a consequence, subtle skeletal asymmetries in one of these subsamples could have been weakened by the other subsamples, resulting in the absence of differences when compared with the normal group. Therefore, it would be interesting to independently compare subdivision subjects of the first 2 subsamples mentioned with the subjects with normal occlusions to investigate whether the contribution of skeletal asymmetries would be greater.

Clinical implications for treatment

It can be concluded that, in a large number of Class II subdivision cases, the maxillary dental midline will be coincidental, or present a minimal deviation, to the clinical facial midline. However, the mandibular dental midline will be displaced toward the Class II side in faces with subclinical asymmetry.[33] In this case, one of the best treatment options would be the extraction of 2 maxillary premolars and 1 mandibular premolar on the Class I side,[1,34-38] provided that the patient's profile allows for retraction of the maxillary and mandibular incisors. If incisor retraction is contraindicated, the treatment would basically consist of obtaining an anteroposterior correction on the Class II side with the use of unilateral intermaxillary Class II elastics, as well as a diagonal anterior elastic, which could be difficult.

In patients that require treatment without extraction, there may still be characteristics of a Class II subdivision associated with an asymmetry in mandibular size.[39] For these patients, Williamson[39] stated that it is difficult to obtain a Class I relationship of the canines with asymmetric elastics and that it is acceptable to finish treatment with a slight Class II relationship on the affected side, as well as a consequent slight midline deviation. If the patient has discrete mandibular asym-

metry and can be treated with asymmetric extractions, the dental midline may be corrected more easily. Nevertheless, mandibular asymmetry will remain.

In growing patients who have Class II subdivision malocclusions and mandibular skeletal asymmetry with the Class II relationship on the smaller mandibular side, the use of a functional appliance could be considered, with the objective of obtaining greater development on the shorter side, through glenoid fossa remodeling or at least a redirection of mandibular dentoalveolar growth.[40,41]

Another type of a Class II subdivision malocclusion, which occurs less frequently but was also seen in this study, is the one with a deviation of the maxillary dental midline and coincidence of the mandibular dental midline in relation to the clinical facial midline in patients without maxillary or mandibular crowding. In this case, the best results would be provided by the extraction of only 1 maxillary premolar on the Class II side. With cooperative patients in the growing stage, correction with the use of asymmetric extraoral forces would be possible. All of these aspects must be considered when planning the treatment of Class II subdivision malocclusions.

CONCLUSIONS

1. The components that contributed to the asymmetric anteroposterior relationship in the Class II subdivision malocclusion were mainly dentoalveolar. The contribution of skeletal asymmetries in the differences between the groups was negligible. The amount of positional skeletal asymmetries in Class II subdivision was similar to that in normal occlusion.
2. The primary contributor to the differences between the 2 groups was the distal positioning of the first mandibular molars on the Class II side in mandibles without unusual skeletal or positional asymmetries.
3. A secondary contributor was a mesial positioning of the first maxillary molars on the Class II side.
4. As a consequence of the more frequent distal positioning of the mandibular molars on the Class II side, as opposed to the mesial positioning of the maxillary molars on that side, the mandibular dental midline also presented a deviation to the Class II side more frequently than did the maxillary dental midline to the opposite side, as evaluated on the PA radiograph.

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