ORIGINAL ARTICLE

Dentoskeletal treatment changes in Class II subdivision malocclusions in submentovertex and posteroanterior radiographs

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The objective of this study was to evaluate the dentoskeletal changes consequent to orthodontic treatment in subjects with Class II subdivision malocclusions, treated with asymmetric extractions, compared with a normal-occlusion control group. The sample consisted of 3 groups, with 30 subjects in each: normal-occlusion subjects (group 1), untreated Class II subdivision subjects (group 2), and Class II subdivision patients treated with asymmetric extractions (group 3). All subjects had a full complement of permanent teeth at the beginning of treatment. The average ages of the subjects were 22.42, 15.76, and 18.57 years, respectively, in groups 1, 2, and 3. Measurements of relative differences in the spatial position of dental and skeletal bilateral landmarks were obtained from the submentovertex and posteroanterior cephalometric (PA) radiographs. The *t* test for independent samples was used to compare group 1 with groups 2 and 3 at different times. Results from the submentovertex radiograph showed that asymmetric extractions in Class II subdivision malocclusions will maintain the differences in the anteroposterior positions of right and left, maxillary and mandibular first molars, as would be expected with the treatment protocols used. There were no significant skeletal changes that could be attributed to the treatment approaches investigated or transverse collateral effects with the asymmetric mechanics used. It was also demonstrated that treatment of Class II subdivision malocclusions with asymmetric extractions produced corrections of maxillary and mandibular dental midline deviations with the midsagittal plane, without canting the occlusal plane or any other investigated horizontal plane, as seen in the PA radiograph. Treatment of Class II subdivision malocclusions with asymmetric extractions constitutes a beneficial approach to this problem. (Am J Orthod Dentofacial Orthop 2004;126:451-63)

Class II subdivision malocclusion asymmetries are predominantly dentoalveolar and are characterized primarily by distal positioning of the mandibular first molar on the Class II side, in a mandible with no unusual skeletal or positional asymmetries. Secondarily, there is mesial positioning of the maxillary first molars on that side.[1-3] Consequently, in many Class II subdivision patients, the maxillary dental midline will be coincidental or show minimal deviation relative to the clinical facial midline. However, the mandibular dental midline will be displaced toward the Class II side in faces with subclinical asymmetry.[2] In such situations, one of the best treatment options would be to extract 2 maxillary premolars and 1 mandibular premolar on the Class I side, if the patient's profile allows for retraction of the maxillary and mandibular incisors.[1,2,4-10] Another type of Class II subdivision malocclusion, which occurs less frequently, has 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 such malocclusions, the best results are obtained by extracting only 1 maxillary premolar on the Class II side.[2,10]

However, it is speculated that these treatment ap-

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Supported by FAPESP Process #98/00752-0.
This article is based on research submitted by Dr Karina Santana Cruz in partial fulfillment of the requirements for the degree of Master of Sciences in Orthodontics at Bauru Dental School, University of São Paulo, Brazil.
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Submitted, March 2003; revised and accepted, August 2003.
0889-5406/$30.00

doi:10.1016/j.ajodo.2003.08.031

proaches might induce unfavorable dentoalveolar side effects, such as tilting of the occlusal plane, molar extrusion, maxillary and mandibular midline deviation, and skeletal secondary changes in the frontal plane.[4,5,11-16] The facial esthetics and function, the maxillomandibular spatial relationship, and the dental occlusion might be influenced by tilting of the occlusal plane.[11,17-20] Therefore, the objective of this study was to evaluate, through the use of submentovertex and posteroanterior cephalometric radiographs, the dentoskeletal changes consequent to orthodontic treatment of Class II subdivision malocclusion with 2 different asymmetric extraction protocols and to compare them with a control group with normal occlusion.

MATERIAL AND METHODS

The sample consisted of 3 groups of 30 patients each (1 normal-occlusion group and 2 experimental groups), selected from the files of the orthodontic department at Bauru Dental School, University of São Paulo, Brazil. The control group (group 1) consisted of 30 subjects (10 male, 20 female; mean age 22.42 years, range, 15.10 to 41.06 years) with normal occlusions selected from students and employees who offered to participate in the study. Group 2 consisted of 30 subjects (16 male, 14 female, mean age 15.76 years, range, 11.90 to 31.93 years) with untreated Class II subdivision malocclusions, selected from those who sought orthodontic treatment in the orthodontic department. The 30 subjects of group 3 (13 male, 17 female; mean age 18.57 years, range, 14.13 to 26.67 years) had Class II subdivision malocclusions and were treated with asymmetric extractions; they were selected from the patients of the same department. Among the 30 treated patients, only 10 belonged to the untreated Class II subdivision group that subsequently received orthodontic treatment. The patients in group 3 received 1 of 2 types of asymmetric extraction protocols, depending on the characteristics of the Class II subdivision malocclusion: either 2 maxillary premolars and 1 mandibular premolar on the Class I side or only 1 maxillary premolar on the Class II side. All treated patients had good final results. Therefore, 13 patients with extraction of 3 premolars and 17 patients with extraction of 1 maxillary premolar constituted group 3.

The primary selection criterion was that the patients from the experimental groups 2 and 3 (before treatment) should have a complete Class I molar relationship on 1 side of the dental arches and a full Class II relationship on the opposite side. Additional criteria for the subjects were as follows: (1) all maxillary and mandibular permanent teeth present, up to the first molars, (2) no previous orthodontic treatment, (3) no lateral mandibular shift during closure, (4) no history of facial trauma or medical conditions that could have altered the growth of the apical bases,[21] and (5) no crowding, or at most a symmetric crowding of up to 3 mm in the maxillary or mandibular dental arches.[2] These criteria were evaluated with clinical histories and clinical examinations.

Two radiographs were obtained from each subject: 1 submentovertex and 1 posteroanterior. Cephalometric tracings were performed on acetate paper by a single investigator (K.S.C.) and then digitized (DT-11 digitizer; Houston Instruments, Houston, Tex). These data were then stored on a personal computer and analyzed with Dentofacial Planner 7.0 (Dentofacial Planner Software, Toronto, Ontario, Canada).

The machine used for the submentovertex radiograph[22-26] 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. The distance from the focal point to the metallic ear rods was set at 152 cm, and the distance from the ear rods to the film was set at 16 cm; this yielded a magnification factor of 9.55%. During exposure, the subjects kept their teeth in centric occlusion under light pressure, and the head was positioned with the Frankfort plane perpendicular to the floor.

Cephalometric structures, lines, planes, and measurements were obtained according to the analysis of Ritucci and Burstone,[22,27] with some added modifications. 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 Figure 1.

The Ritucci and Burstone[22,27] method evaluates the asymmetry of the craniodental structures in relation to different coordinate systems. The present study used this method with some modifications. The coordinate systems used were the mandibular, the cranial floor, the zygomaxillary complex, and the dental system.

The coordinate system consisted of 2 axes perpendicular to each other. The anteroposterior and lateral 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 symmetry in the anteroposterior plane of dentoalveolar and skeletal structures to the mandible. In addition, the symmetry in the transverse plane of these

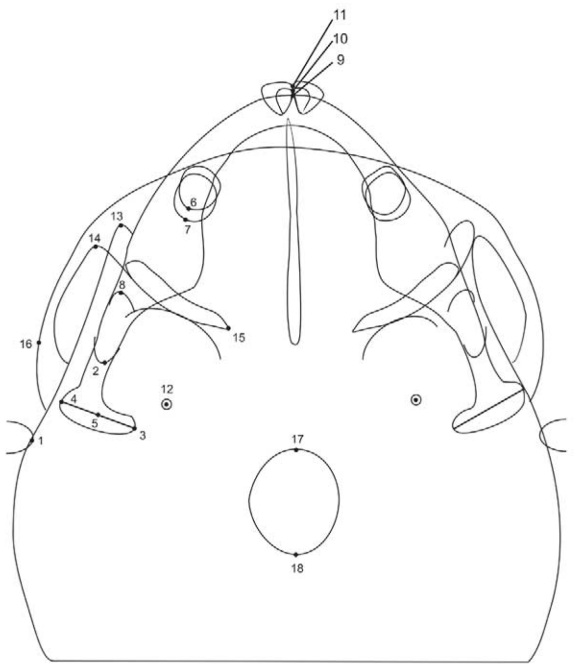

Fig 1. Structures and landmarks of submentovertex radiograph. *1*, Metallic ear rod point: medial center of each ear rod; *2*, gonion point: midpoint mediolaterally on posterior border of each gonial angle; *3*, medial condylar point: tangent point to each medial condylar border of line drawn parallel 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 points, relative to transpterygomaxillary axis, of triangular opacities at external orbital angle where upper and lower orbital rims meet and zygomatic arch inserts; *14*, buccale: point on internal surface of each zygomatic arch where arch turns medially and directly starts on 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, which is drawn across section of greatest bizygomatic width; *17*, basion: most anterior point, relative to trans-spinosum axis, on border of foramen magnum; *18*, opisthion: most posterior point, relative to trans-spinosum axis, on border of foramen magnum.

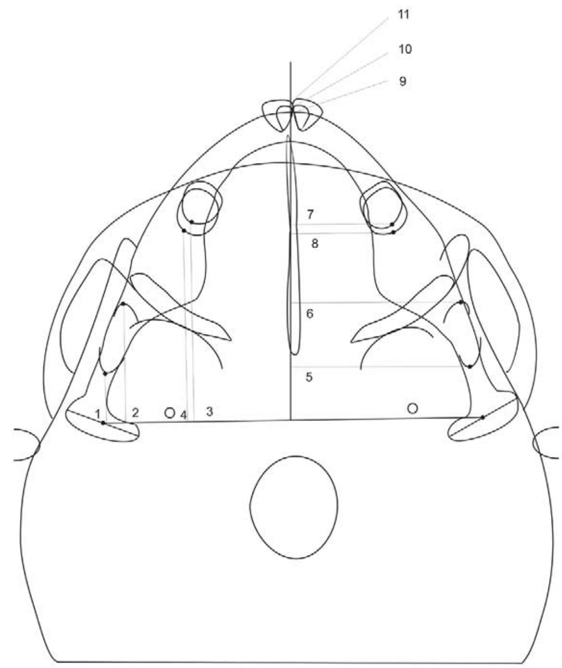

Fig 2. Measurements from submentovertex radiograph. Mandibular coordinate system variables. Anteroposterior: *1*, gonion to transcondylar axis; *2*, coronoid process point to transcondylar axis; *3*, distal mandibular first molar point to transcondylar axis; *4*, distal maxillary first molar point to 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.

structures was evaluated with the intercondylar axis drawn perpendicular to the transcondylar axis from its midpoint. Similarly, the trans-spinosum and interspinosum axes were constructed for the coordinate system of the cranial floor; the transpterygomaxillary and interpterygomaxillary axes for the zygomaxillary coordinate system; and the maxillary and mandibular transmolar and intermolar axes were constructed for the dental coordinate systems. For paired structures, the distance to the reference axis was determined for both landmarks, and the difference in the horizontal distance was

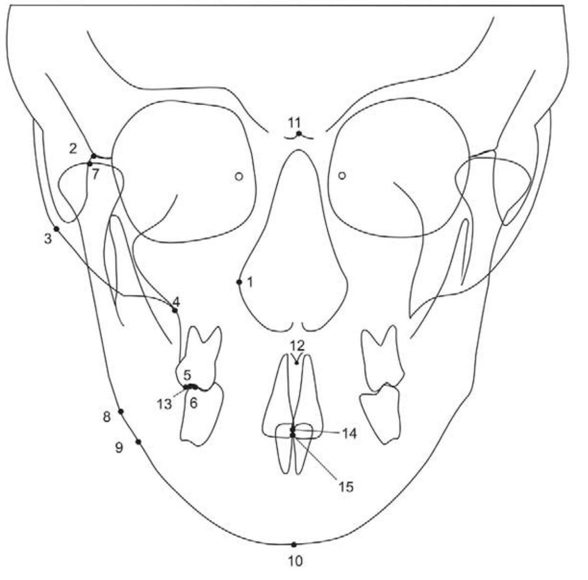

Fig 3. Structures and landmarks of posteroanterior radiograph. *1*, Most lateral point on outline of nasal orifice in region of each pyriform aperture; *2*, superolateral reference point, a point located at lateral aspect of each fronto-zygomatic suture; *3*, lateral aspect of each zygomatic arch, centered vertically; *4*, a point located at depth of concavity of each lateral maxillary contour, at junction of maxilla and the zygomatic buttress; *5*, buccal cusp tip of each maxillary first molar; *6* buccal cusp tip of each mandibular first molar; *7* point located on 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, the 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.

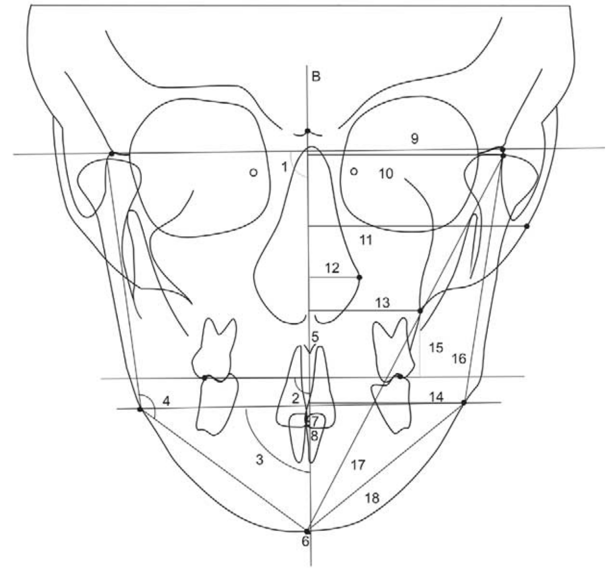

Fig 4. Angular and linear measurements from posteroanterior radiograph. *1*, Z plane angle: angle between Z plane and Cg-ANS line; *2*, occlusal plane angle: angle between occlusal plane and Cg-ANS line; *3*, antegonial plane angle: angle between antegonial plane and Cg-ANS line; *4*, antegonial angle: 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)[40,41,44]; *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*, pyriform aperture to X-line distance: horizontal distance between lateral wall of pyriform 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.

calculated. For unpaired points, the horizontal distance to the midline was determined. There were 36 variables for the submentovertex radiograph (Tables I to IV). Figure 2 illustrates the mandibular coordinate system variables.

The posteroanterior radiographs were obtained according to Harvold,[28,29] with the forehead and nose lightly touching the film cassette. The machine used for this radiograph 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 ear rods was standardized at 152 cm, and the distance from the ear rods to the film was fixed at 16 cm; this 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 1 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 Figure 3, and the cephalometric measurements were obtained according to Grummons and Van De Coppello[30] (Fig 4). 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 (Table V).

For the 2 radiographs, absolute values were used for the differences between the measurements of the right and left sides and for the horizontal distances to the reference midplanes. This prevented any positive and negative values canceling themselves out in the calculation of actual means for each group.[31]

Statistical analysis

Twenty randomly selected radiographs, from 10 subjects, were retraced, redigitized, and remeasured by the same examiner (K.S.C.). The casual error was calculated according to Dahlberg's formula[32] ($S^2 = \Sigma d^2/2n$) and the systematic error with dependent *t* test,[33-37] for $P < .05$.

Means and standard deviations for all measurements were calculated to enable characterization of the different sample groups.[38] The *t* test for independent samples was used for normal distributions (verified by the Kolmogorov-Smirnov test) to compare group 1 with groups 2 and 3 at different times (Tables I to V). Results of the Kolmogorov-Smirnov test were not statistically significant for all variables, showing therefore that the *t* test could be used. Results were considered statistically significant at $P < .05$. Groups 1 and 2 were compared in a previous investigation by multivariate logistic regression analysis.[2] In the present study, the same data were used and analyzed with the *t* test to help with interpretation of the changes that occurred in this malocclusion with the extraction protocols used.

Because the treated Class II subdivision group comprised 17 patients with 1 maxillary premolar extraction and 13 patients with 2 maxillary extractions and 1 mandibular premolar extraction, it was decided to study the influence of these extraction protocols as compared with the normal-occlusion group, separately, by means of the *t* test, as a pilot study. Therefore, group 3 was divided into 2 subgroups: the 17 patients treated with 1 maxillary premolar extraction on the Class II side (subgroup A) and the 13 patients treated with 2 maxillary premolars and 1 mandibular premolar in the Class I side (subgroup B). It was considered that group 3 and subgroups A and B had shown improvement in asymmetries if the same variables that in group 2 had shown statistically significant differences with group 1 were not statistically different from the normal-occlusion group at the end of treatment.

These analyses were performed with Statistica software (Statistica for Windows 4.3B; Statsoft, Tusla, Okla) on a personal computer.

RESULTS

Means and standard deviations for the differences between right and left sides for all variables in the 3 groups and the results of the *t* test between them are listed in Tables I through V. Because subgroups A and B were relatively small, the power of the statistical tests for each variable was calculated. The power of 80% was able to detect mean differences of 1.38 (mm or °, range, 0.42 to 2.68) and 1.50 (range, 0.46 to 2.91) for subgroups A and B, respectively, when compared with the normal-occlusion group. This must be considered when the results are evaluated. Of the 54 variables, 25 had a casual error slightly greater than 1 mm or 1°, but only 6 were greater than 1.5 mm or 1.5°. All the others were less than 1 mm or 1°. The paired *t* test on differences between the replications showed significant differences for only 6 variables.

DISCUSSION

Evaluation of the results obtained from the comparison of group 3 and subgroups A and B with the normal-occlusion group was based on the asymmetries of Class II subdivision patients before treatment and that are represented in the first 2 group columns of Tables I to V.

The 3 groups consisted of mixed growing and nongrowing subjects with different mean ages. However, mixing growing and nongrowing subjects in the groups should not be a problem because Melnik,[39] in his study of mandibular asymmetry, verified that an equal probability exists for asymmetry to improve or worsen with growth. Consequently, an increase in asymmetry in 1 subject would be balanced by a decrease in another. Additionally, considering the female subjects in particular, in whom most maturation had occurred, the almost complete maturation of the male subjects of the Class II subdivision groups, and

Table I. Submentovertex radiograph: mandibular coordinate system (mm)

	Normal occlusion (group 1)		*Untreated Class II subdivision (group 2)*			*Treated Class II subdivision (group 3)*			*Class II, subdivision treated with 1 UPM extraction (subgroup A)*			*Class II, subdivision treated with 3 PM extractions (subgroup B)*		
Variables	*Mean*	*SD*	*Mean*	*SD*	P	*Mean*	*SD*	P	*Mean*	*SD*	P	*Mean*	*SD*	P
Anteroposterior														
Gonion to transcondylar axis	1.21	1.22	1.33	0.98	.69	1.31	1.08	.75	1.12	1.05	0.80	1.54	1.11	.41
Coronoid process point to transcondylar axis	1.32	0.85	1.57	1.07	.32	1.73	1.46	.18	1.43	1.53	0.74	2.12	1.32	.02*
Mandibular molar distal point to transcondylar axis	0.96	0.64	2.62	1.56	.00*	3.60	2.55	.00*	2.07	1.86	0.00*	5.61	1.86	.00*
Maxillary molar distal point to transcondylar axis	0.96	0.72	1.48	0.93	.01*	3.12	2.23	.00*	4.42	1.89	0.00*	1.40	1.29	.16
Transverse														
Gonion to intercondylar axis	1.95	1.25	2.59	2.30	.18	2.45	1.93	.23	2.80	2.04	0.08	2.00	1.73	.92
Coronoid process point to intercondylar axis	2.58	1.82	2.05	1.80	.26	2.01	1.42	.18	1.94	1.56	0.23	2.10	1.26	.40
Mandibular molar distal point to intercondylar axis	2.94	2.04	3.63	2.91	.29	3.55	2.56	.31	3.47	2.48	0.43	3.64	2.76	.35
Maxillary molar distal point to intercondylar axis	2.69	1.84	3.31	2.39	.26	2.87	2.05	.72	3.15	1.99	0.42	2.50	2.14	.76
Mandibular midline to intercondylar axis	1.88	1.50	2.68	2.70	.16	1.75	1.57	.74	1.78	1.30	0.82	1.71	1.92	.75
Mandibular dental midline to intercondylar axis	1.72	1.24	2.20	1.88	.24	1.99	1.53	.45	2.17	1.44	0.26	1.76	1.68	.93
Maxillary dental midline to intercondylar axis	1.55	1.12	1.93	1.75	.32	1.85	1.46	.38	1.97	1.46	0.28	1.69	1.51	.74

Independent *t* test results between normal occlusion group and following groups: untreated Class II subdivision (group 2), treated Class II subdivision (group 3), Class II subdivision treated with 1 maxillary premolar extraction (subgroup A), and Class II subdivision treated with 3 premolar extractions (subgroup B).
UPM, Maxillary premolar; *PM*, premolar; *SD*, standard deviation.
*$P < .05$.

the equal probability of improvement of craniofacial asymmetry with growth, the age difference between the groups should not interfere with this type of evaluation.

Submentovertex radiograph: mandibular, cranial floor, and zygomaxillary coordinate systems

There was a significant difference for the variable coronoid process point to transcondylar axis, suggesting a slight skeletal asymmetry of the coronoid process in subgroup B after treatment (Table I). It is very unlikely that the treatment protocol of this subgroup might have produced this skeletal asymmetry that was not evident initially, because orthodontic mechanics do not have a direct effect in this structure. This difference might be attributed to an inherent characteristic of the patients of this subgroup. However, the trend toward this anteroposterior asymmetry does not seem to be very high because there was no statistically significant difference when the asymmetry of this structure was evaluated in relation to the trans-spinosum axis (Table II).

Tables I, II, and III also show that the variables that had statistically significant differences with the normal-occlusion group were those concerning the anteroposterior positions of the mandibular and maxillary molars to the transcondylar, trans-spinosum, and transpterygomaxillary axes. These differences were expected for group 3 because the treatment protocols for subgroups A and B would tend to maintain the anteroposterior discrepancies between the right and left mandibular and maxillary molars observed before treatment (Figs 5 and 6). Ideally, it would have been better to select a larger group that had undergone only 1 treatment protocol. However, the random inclusion of these 2 treatment protocols is a consequence of the characteristics usually found in Class II subdivision groups randomly selected.

The separate analysis of subgroup A shows that the variables mandibular molar distal point to transcondylar, trans-spinosum, and transpterygomaxillary axes had a statistically significant difference from the normal-occlusion group (Tables I to III). This suggests that even when the Class II subdivision malocclusion is

Table II. Submentovertex radiograph: cranial floor coordinate system (mm)

	Normal occlusion (group 1)		Untreated Class II subdivision (group 2)			Treated Class II subdivision (group 3)			Class II, subdivision treated with 1 UPM extraction (subgroup A)			Class II, subdivision treated with 3 PM extractions (subgroup B)		
Variables	*Mean*	*SD*	*Mean*	*SD*	P	*Mean*	*SD*	P	*Mean*	*SD*	P	*Mean*	*SD*	P
Anteroposterior														
Condilar midpoint to trans-spinosum axis	1.59	1.27	1.58	1.33	.97	1.84	1.46	.48	1.76	1.75	.70	1.95	1.04	.37
Gonion to trans-spinosum axis	1.63	1.42	1.90	1.40	.46	1.76	1.67	.73	1.27	1.39	.40	2.41	1.84	.13
Coronoid process point to trans-spinosum axis	1.68	1.28	2.08	1.42	.24	1.93	1.48	.48	1.58	1.29	.81	2.38	1.64	.13
Mandibular molar distal point to trans-spinosum axis	1.04	0.84	2.89	1.57	.00*	3.73	2.78	.00*	1.88	1.59	.02*	6.15	2.03	.00*
Maxillary molar distal point to trans-spinosum axis	1.02	0.90	1.27	1.00	.30	3.08	2.07	.00*	4.30	1.79	.00*	1.50	1.12	.14
Transverse														
Gonion to interspinosum axis	1.78	1.31	2.70	2.06	.04*	2.52	2.13	.11	2.89	2.50	.05	2.04	1.48	.57
Coronoid process point to interspinosum axis	2.74	1.92	2.58	2.05	.75	2.25	1.78	.30	2.49	1.63	.65	1.93	1.98	.21
Mandibular molar distal point to interspinosum axis	3.26	2.41	3.96	2.99	.32	3.88	3.03	.38	3.55	3.21	.73	4.31	2.85	.22
Maxillary molar distal point to interspinosum axis	2.86	2.15	3.54	2.42	.25	3.29	2.19	.44	3.21	2.55	.62	3.40	1.69	.42
Mandibular midline to interspinosum axis	2.13	1.87	3.39	2.48	.03*	2.22	1.61	.84	1.75	1.45	.48	2.83	1.67	.25
Mandibular dental midline to interspinosum axis	1.90	1.67	2.52	2.14	.21	2.19	1.51	.48	1.93	1.56	.94	2.53	1.44	.24
Maxillary dental midline to interspinosum axis	1.94	1.32	2.40	1.55	.22	2.15	1.48	.57	1.95	1.57	.98	2.40	1.38	.30

$^*P < .05$.

caused by the mesial positioning of the maxillary molar on the Class II side, the mandibular molars also have a slight anteroposterior difference between themselves, reflecting the strong predominance of this etiologic factor for Class II subdivision malocclusions.[1-3] Maxillary molar distal point to transcondylar, trans-spinosum, and transpterygomaxillary axes showed a statistically significant difference. This difference was expected because the Class II subdivision malocclusion in this group was caused by a mesial positioning of the maxillary molar on the Class II side and therefore was treated by extracting only 1 maxillary premolar on that side. Consequently, the maxillary first molar on the other side remained in a Class I relationship (Fig 5). The separate analysis of this subgroup also explains the larger value for this variable as compared with the untreated Class II subdivision group.

In subgroup B, the variables mandibular molar distal point to transcondylar, trans-spinosum, and transpterygomaxillary axes showed a statistically significant difference when compared with the normal-occlusion group (Tables I to III). This occurred because the Class II subdivision malocclusion in this group was caused by a distal positioning of the mandibular molar on the Class II side and therefore was treated by extracting 2 maxillary premolars and 1 mandibular premolar on the Class I side. Consequently, a Class II relationship remained in 1 side, because of a distally positioned mandibular molar (Fig 6). The separate analysis of this subgroup also explains the larger value for these variables as compared with the untreated Class II subdivision group. The variables maxillary molar distal point to transcondylar and trans-spinosum axes did not show a statistically significant difference because the maxillary molars are usually symmetrically positioned in this subgroup of Class II subdivision. This is why bilateral maxillary premolar extractions were performed. However, there was a statistically significant difference for the variable maxillary molar distal point to transpterygomaxillary axis (Table III); this shows that there might be a small contribution of this variable to produce a Class II subdivision malocclusion, even in patients in whom the primary causative factor is a more distally positioned mandibular molar.

Table III. Submentovertex radiograph: zygomaxillary coordinate system (mm)

Variables	Normal occlusion (group 1)		Untreated Class II subdivision (group 2)			Treated Class II subdivision (group 3)			Class II, subdivision treated with 1 UPM extraction (subgroup A)			Class II, subdivision treated with 3 PM extractions (subgroup B)		
	Mean	SD	Mean	SD	P	Mean	SD	P	Mean	SD	P	Mean	SD	P
Anteroposterior														
Mandibular molar distal point to transpterygomaxillary axis	1.27	0.95	3.15	1.92	.00*	3.63	2.93	.00*	2.03	1.63	.04*	5.73	2.97	.00*
Maxillary molar distal point to transpterygomaxillary axis	1.23	0.90	1.33	0.90	.70	3.75	2.26	.00*	4.88	2.13	.00*	2.27	1.43	.00*
Transverse														
Mandibular molar distal point to interpterygomaxillary axis	2.52	2.66	3.17	2.16	.30	2.81	2.49	.66	2.62	2.34	.90	3.06	2.75	.54
Maxillary molar distal point to interpterygomaxillary axis	2.26	2.61	2.57	1.79	.59	2.59	2.21	.60	3.08	2.35	.29	1.94	1.91	.69
Mandibular midline to interpterygomaxillary axis	1.94	1.92	2.41	2.30	.39	2.02	1.47	.86	2.01	1.47	.89	2.03	1.54	.88
Mandibular dental midline to interpterygomaxillary axis	1.76	1.91	2.15	1.78	.42	2.03	1.35	.53	1.77	1.43	.99	2.37	1.22	.29
Maxillary dental midline to interpterygomaxillary axis	1.82	1.85	1.75	1.21	.86	1.97	1.29	.70	1.79	1.27	.95	2.21	1.33	.49

$P < .05$.

Transversely, in general, in the mandibular and zygomaxillary coordinate systems, mechanotherapy did not produce any change in the variables, independently of the asymmetric extraction approach used (Tables I and III). However, in the cranial floor coordinate system (Table II), the treated group and subgroups did not show any statistically significant differences in relation to the normal-occlusion group; this contrasts with the asymmetry in the untreated group for the variables gonion and mandibular midline to interspinosum axis. It is unlikely that the mechanics used could have altered these skeletal structures. The explanation could be that the treated patients were not exactly the same as in the pretreatment stage and therefore could have different skeletal characteristics that were not evident. Nevertheless, the significant skeletal differences between the untreated group and the normal-occlusion group were limited to only a few variables that in general were considered not to play a very important role in the etiology of Class II subdivision malocclusions.[1-3]

Submentovertex radiograph: dental coordinate system

All the variables of the treated group (Table IV) showed statistically significant differences in relation to the normal-occlusion group. Because there was a combination of 2 different types of Class II subdivision patients, and consequently 2 types of treatment, these variables behaved similarly to when the untreated Class II subdivision was compared with the normal-occlusion group.

In patients with 1 maxillary premolar extraction on the Class II side (subgroup A), the measurements to the mandibular intermolar axis did not show statistically significant differences, whereas those to the maxillary intermolar axis did. This confirms that in these patients, malocclusions were really caused by a more mesial positioning of the maxillary molar on the Class II side. Therefore, the central structures present a greater symmetry in relation to the mandibular molars, which are symmetrically positioned anteroposteriorly, whereas the maxillary molars are not.

In the Class II subdivision patients treated with 3 premolar extractions (subgroup B), there were opposite results—statistically significant differences for the variables related to the mandibular intermolar axis and not for those related to the maxillary intermolar axis. The explanation for this is analogous to that previously mentioned. Conversely, this confirms that, in these patients, malocclusions were really caused by a more distal positioning of the mandibular molar on the Class

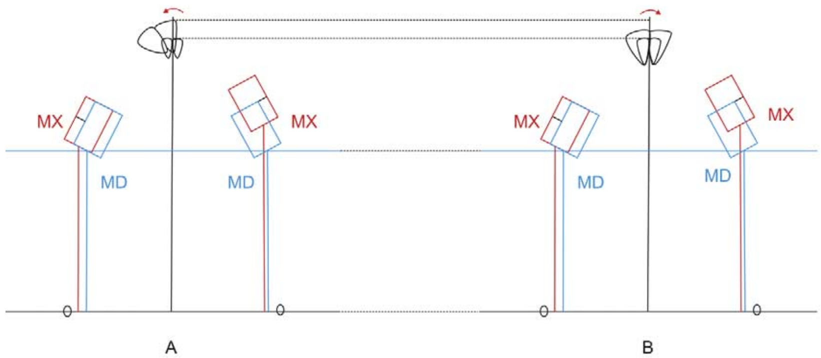

Fig 5. Submentovertex schematic illustration of treatment changes of Class II subdivision malocclusion treated with extraction of 1 maxillary premolar (on viewer's right side). **A**, Before treatment; **B**, after treatment.

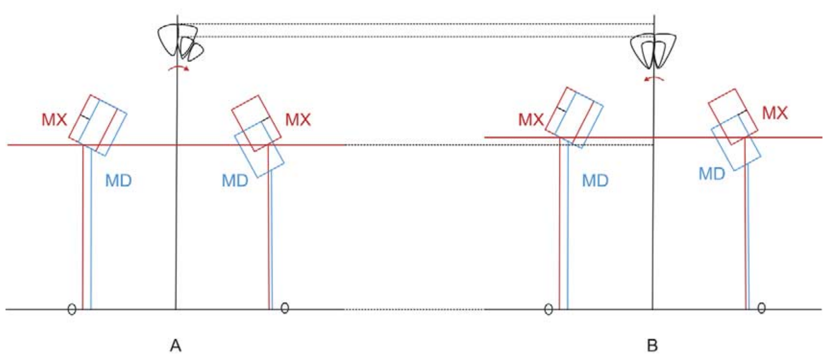

Fig 6. Submentovertex schematic illustration of treatment changes of Class II subdivision malocclusion treated with extraction of 2 maxillary premolars and 1 mandibular premolar (on viewer's left side). **A**, Before treatment; **B**, after treatment.

II side. Therefore, the central structures have greater symmetry in relation to the maxillary molars, which are symmetrically positioned anteroposteriorly, whereas the mandibular molars are not.

Posteroanterior radiograph

In general, treatment with asymmetric extractions in group 3 improved the maxillary and mandibular dental midline deviation in relation to the sagittal midplane that the Class II subdivision patients had before treatment (Table V). However, the patients treated with extraction of only 1 maxillary premolar (subgroup A) persisted in showing a maxillary dental midline deviation in relation to the X-line, significantly larger than in the normal group, in the posteroanterior radiograph. This probably occurred because, even in these patients, in whom the primary cause of the Class II subdivision is the more mesial positioning of the maxillary molar on the Class II side, there is still some contribution of an asymmetric positioning of the mandibular molars. If the mandibular molars are asymmetrically positioned, this will also produce a certain deviation of the mandibular dental midline, in relation to the X-line. When the mechanics establish the coincidence of both dental midlines with themselves at the end of treatment, they might still show a deviation from the X-line. The mandibular dental midline deviation did not show a statistically significant difference in relation to the normal-occlusion group, probably because the obtained mean and standard deviation for this variable in the normal-occlusion group are larger than those of the maxillary dental midline deviation, and this could have had a favorable effect in the statistical test. Viloria[40] and Traque[41] found that the maxilla shows varying degrees of rotation in relation to the X-line in subjects with random occlusions. However, it has been shown that Class II subdivision malocclusions do not have more maxillary rotation in relation to the cranial skeleton than normal-occlusion subjects.[2] Therefore, this resulting larger dental midline deviation in this

Table IV. Submentovertex radiograph: dental coordinate system

	Normal occlusion (group 1)		Untreated Class II subdivision (group 2)			Treated Class II subdivision (group 3)			Class II, subdivision treated with 1 UPM extraction (subgroup A)			Class II, subdivision treated with 3 PM extractions (subgroup B)		
Variables	*Mean*	*SD*	*Mean*	*SD*	P	*Mean*	*SD*	P	*Mean*	*SD*	P	*Mean*	*SD*	P
Mandibular dental midline to mandibular intermolar axis	0.63	0.52	1.18	0.82	.00*	2.93	2.90	.00*	0.53	0.41	.51	6.06	1.16	.00*
Maxillary dental midline to mandibular intermolar axis	0.73	0.49	3.43	1.40	.00*	3.05	2.91	.00*	0.67	0.64	.71	6.16	1.21	.00*
Mandibular midline to mandibular intermolar axis	0.88	0.68	1.91	1.52	.00*	2.50	2.18	.00*	0.94	1.02	.80	4.54	1.49	.00*
Mandibular dental midline to maxillary intermolar axis	0.62	0.52	2.31	1.12	.00*	3.08	2.20	.00*	4.86	0.92	.00*	0.76	0.53	.44
Maxillary dental midline to maxillary intermolar axis	0.55	0.47	0.98	0.70	.00*	3.23	2.38	.00*	5.20	0.77	.00*	0.66	0.54	.48
Mandibular midline to maxillary intermolar axis	0.89	0.74	2.26	1.82	.00*	3.09	1.91	.00*	4.40	1.22	.00*	1.37	1.11	.10

*$P < .05$.

subgroup could not be explained by rotation of the maxilla.

On the other hand, patients with 3 premolar extractions (subgroup B) did not show statistically significant differences for these variables because in cases of Class II subdivision caused by a more distal positioning of a mandibular molar, the maxillary molars are symmetrically positioned, and the maxillary midline is coincident with the midsagittal plane. Because at the end of treatment both dental midlines should be coincident, they will also be aligned with the midsagittal plane.

Other important results were that there was no tilting of the occlusal plane and no unfavorable skeletal changes in the frontal plane with the asymmetric mechanics used to correct these patients. Therefore, these results do not support previous speculation that asymmetric extractions and mechanics cause tilting of the occlusal plane, extrusion of the molars, maxillary and mandibular dental midline deviation, apical discrepancies, and unfavorable skeletal changes in the frontal plane.[4,5,11-16] These results could be consequent to the mechanics used in the subgroups, which had little or no canting effect on the investigated horizontal planes. In subgroup A, anchorage reinforcement was provided by a transpalatal bar, associated with asymmetric extraoral appliance, during anterior teeth retraction. This procedure does not tend to cause any canting of the horizontal planes.[10] In subgroup B, a transpalatal bar and a symmetric extraoral appliance were used in the maxillary arch to reinforce anchorage during anterior tooth retraction, which also does not tend to cause canting of the horizontal planes.[42] In the mandibular arch, unilateral retraction of the anterior teeth does not tend to produce canting of the horizontal planes. In both subgroups, some patients needed additional Class II elastics on the Class II side and anterior diagonal elastics, which might tend to produce canting of the horizontal planes.[4,5,11] However, probably because they were used only for short periods, no canting effects on the horizontal planes could be seen. Similar studies with more patients in each subgroup would be interesting to confirm these results.

Clinical implications

The extraction approaches used in the Class II subdivision patients of the treated group were based on suggestions in the literature.[1,2,4-10] Treatment of 17 patients was based on deviation of the maxillary dental midline to the opposite side of the Class II side in relation to the midsagittal plane and coincidence of the mandibular dental midline with this plane (Fig 5). This type of Class II subdivision malocclusion was less frequent in a recent study.[2] However, in this sample, there were more patients with these characteristics because they were completely finished when the study began. Treatment of these patients consisted of extracting only 1 premolar on the Class II side and finishing with a Class II molar relationship on this side but with coincidence of the dental midlines with themselves and with the midsagittal plane.[2,10] Asymmetric extraoral anchorage was necessary to obtain a Class I canine

Table V. Posteroanterior radiograph

Variables	Normal occlusion (group 1)		Untreated Class II subdivision (group 2)			Treated Class II subdivision (group 3)			Class II, subdivision treated with 1 UPM extraction (subgroup A)			Class II, subdivision treated with 3 PM extractions (subgroup B)		
	Mean	*SD*	*Mean*	*SD*	P	*Mean*	*SD*	P	*Mean*	*SD*	P	*Mean*	*SD*	P
Z plane angle (°)	89.90	1.27	89.69	1.94	.61	90.04	1.33	0.67	90.18	1.11	0.45	89.86	1.59	0.92
Occlusal plane angle (°)	89.34	1.74	89.84	2.14	.32	89.72	2.53	.50	89.64	2.62	.64	89.83	2.51	.46
Antegonial plane angle (°)	88.63	1.51	88.47	2.48	.76	89.25	2.49	.24	89.35	2.40	.21	89.12	2.71	.44
Anterior nasal spine deviation (mm)	1.33	0.84	1.70	1.48	.23	1.20	0.90	.57	1.19	.90	.60	1.21	0.94	.69
Mandibular deviation (mm)	2.71	1.63	3.10	2.26	.44	2.33	1.81	.39	2.37	2.15	.54	2.27	1.33	.40
Maxillary dental midline deviation (mm)	1.40	0.90	2.07	1.39	.03*	1.92	1.52	.11	2.12	1.51	.04*	1.66	1.56	.50
Mandibular dental midline deviation (mm)	1.58	0.97	2.41	1.79	.02*	2.03	1.61	.19	2.10	1.48	.15	1.93	1.83	.40
Antegonial angle (°)	2.40	1.51	3.18	2.40	.13	3.08	2.35	.19	3.12	2.81	.25	3.01	1.68	.24
Frontozygomatic suture to X-line distance (mm)	1.77	1.24	2.01	1.78	.54	2.04	1.58	.46	2.21	1.36	.26	1.81	1.86	.92
Condylion to X-line distance (mm)	3.20	2.42	3.62	2.39	.49	3.27	2.76	.91	3.25	2.54	.94	3.30	3.13	.91
Zygoma distance (mm)	2.86	1.96	3.51	2.87	.30	2.98	2.76	.84	3.10	2.58	.72	2.82	3.07	.96
Pyriform aperture to X-line distance (mm)	2.51	1.57	3.11	2.34	.24	2.54	1.83	.09	2.74	2.01	.67	2.29	1.62	.67
Maxillary buttress to X-line distance (mm)	2.47	1.65	3.39	2.52	.10	2.72	1.95	.59	2.75	2.21	.62	2.69	1.63	.69
Antegonial notch to X-line distance (mm)	4.25	3.19	4.00	3.48	.77	3.63	2.88	.43	2.95	2.91	.17	4.50	2.70	.80
First maxillary molar height (mm)	1.37	1.05	1.72	1.54	.31	1.89	1.26	.09	1.75	1.18	.25	2.06	1.40	.08
Condylion to antegonial notch distance (mm)	2.70	2.10	3.31	2.65	.32	3.19	2.93	.46	3.38	2.73	.34	2.93	3.27	.77
Condylion to menton distance (mm)	2.26	2.21	2.51	2.24	.66	2.70	2.57	.47	2.38	2.65	.86	3.13	2.51	.26
Menton to antegonial notch distance (mm)	2.28	1.92	2.90	2.18	.24	3.34	2.77	.09	3.04	1.91	.19	3.73	3.66	.09

$^*P < .05$.

relationship and correction of any mild anteroposterior crowding on this side.

The other 13 patients showed the maxillary dental midline coincident or with a small deviation in relation to the midsagittal plane, whereas the mandibular dental midline was deviated to the Class II side in relation to the midsagittal plane. Therefore, in these patients, the protocol consisted of extracting 2 maxillary premolars and 1 mandibular premolar on the Class I side[1,2,7,9,10,43] because the patients' profiles allowed a certain amount of maxillary and mandibular incisor retraction[2,43] (Fig 6). Extracting 1 mandibular premolar on the Class I side relocates the canine to a more distal position, adequately relating it with the opposing teeth. Concurrently, extracting 2 maxillary premolars allows the maintenance of the maxillary dental midline coincidence with the midsagittal plane. These treatment mechanics minimize the use of intermaxillary and anterior diagonal elastics and simplify treatment and correct the dental asymmetries.[2,43] Consequently, the final occlusion will show the original Class I side in a molar and canine Class I relationship, whereas on the Class II side the molars will have a Class II relationship and the canines a Class I relationship, with coincidence of the maxillary and mandibular midlines with themselves and with the midsagittal plane. Correcting the mandibular dental midline deviation with this treatment approach is easier because it can be obtained concurrently with the space-closing procedure of the mandibular arch.[2]

This study has demonstrated that the changes from these 2 different asymmetric extraction protocols are essentially dentoalveolar. These changes are predominantly favorable, without the undesirable secondary effects mentioned in the literature.[4,5,12,13] Nevertheless, to obtain similar results, it is necessary to have a correct treatment plan, based on the initial characteristics of the Class II subdivision malocclusion.

CONCLUSIONS

1. The asymmetric extraction protocols in Class II subdivision malocclusions maintained the differences in the anteroposterior positions of right and left, maxillary and mandibular first molars.
2. There were no significant skeletal changes that could be attributed to the treatment approaches investigated or transverse secondary effects with the asymmetric mechanics used.
3. Class II subdivision malocclusion treatment with asymmetric extractions produced corrections of maxillary and mandibular dental midline deviations relative to the midsagittal plane, without canting the occlusal plane or any other investigated horizontal plane.
4. The treatment protocols with asymmetric extractions did not induce undesirable dentoskeletal effects in the frontal plane.

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