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Research Article

Vertical characteristics of posterior teeth in untreated malocclusions

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A B S T R A C T

Objective: Understanding the influence of tooth eruption on skeletal growth patterns can contribute to development of timely and effective orthodontic treatment protocols. In this retrospective cross-sectional study, our objective was to use a previously published cephalometric method to measure the maxillary and mandibular molar and premolar dentoalveolar heights from an untreated sample of Class II and Class III subjects and compare them to untreated Class I normodivergent.
Materials and Methods: A total of 218 subjects with full permanent dentition that met the defined inclusion, exclusion, and grouping criteria were analyzed. The sample of 13- to 56-year-old subjects was diverse in ethnic backgrounds and representative of an urban practice setting. Using cephalometric grouping criteria, subjects were assigned to one of five groups: Class I normodivergent (control), Class II or Class III hyperdivergent or hypodivergent. Cephalometric images were traced and data were analyzed using independent *t*-tests, one-way analysis of variance, and Bonferroni post hoc tests ($P < 0.05$).
Results: The study showed strong trends of short maxillary dentoalveolar heights in Class II hypodivergent subjects and short mandibular dentoalveolar heights in Class III hyperdivergent subjects. Statistically significant differences ranged from 1.11 mm to 4.55 mm. The results of this study indicate gender dimorphism.
Conclusions: This study suggests that posterior dentoalveolar characteristics differ among the established malocclusions. There is likely an interplay between tooth eruption and vertical growth of the jaws. One factor can influence the severity of another, as the dentition and skeleton develop simultaneously. Clinical treatment approaches to minimize divergence from the normal skeletal pattern can be established for growing patients.

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1. Introduction

Understanding dento-craniofacial development and being able to perform prediction to assess growth potential are important factors in the orthodontic treatment planning process. Knowledge on the environmental factors that lead to the establishment of a facial growth pattern is an ongoing effort in the discipline of orthodontics. Aside from its basic scientific value, this knowledge also impacts establishment and selection of appropriate treatment modalities in the clinical setting.

Many of the cephalometric measurements that orthodontists routinely use to evaluate the facial growth pattern involve skeletal landmarks in the anterior part of the face. These measurements are used to categorize horizontal and vertical growth patterns. Increased focus on the posterior components, namely the posterior dentition, could provide better insight into how to improve patient treatment. The orthodontic community knows that teeth are erupting as the face is growing and developing, but there is need of research that clarifies understanding of how tooth

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Class I (50: 25 males, 25 females)
1. ANB 0 – 5°
2. Frankfort Mandibular Plane Angle (FH-MP) 23 – 29°
3. Ricketts Total Facial Height (NaBa-PmXi) 57 – 63°

Class II Hyperdivergent (50: 25 males, 25 females)
1. ANB > 6°
2. Frankfort Mandibular Plane Angle (FH-MP) > 29°
3. Ricketts Total Facial Height (NaBa-PmXi) > 63°

Class II Hypodivergent (40: 17 males, 23 females)
1. ANB > 6°
2. Frankfort Mandibular Plane Angle (FH-MP) < 23°
3. Ricketts Total Facial Height (NaBa-PmXi) < 56°

Class III Hyperdivergent (29: 17 males, 12 females)
1. ANB < 0°
2. Frankfort Mandibular Plane Angle (FH-MP) > 29°
3. Ricketts Total Facial Height (NaBa-PmXi) > 63°

Class III Hypodivergent (49: 28 males, 21 females)
1. ANB < 0°
2. Frankfort Mandibular Plane Angle (FH-MP) < 23°
3. Ricketts Total Facial Height (NaBa-PmXi) < 56°

Fig. 1. Cephalometric grouping criteria used to assign subjects to the appropriate group. The numbers in parentheses are the total number of subjects obtained for each group.

eruption contributes to the development of different malocclusions leading to maxillo-mandibular discrepancies. This information is necessary to determine whether orthodontic treatment at the dentoalveolar level can affect the individual's skeletal growth pattern.

Bjork [1–3] began conducting and publishing his series of classic longitudinal studies in the 1950s, in which metallic implants placed in the maxillae and mandibles of children were used as stable reference points against which growth and developmental changes were quantified and described over time. He was clear in his belief that tooth position is determined by skeletal changes. Bjork [1] concluded that occlusal changes were a reflection of dental compensation in response to the maxillo-mandibular relationship. In 1969, 1972, and 1984 Bjork and Skieller [2–4] introduced methods for predicting mandibular growth based on observations from the implant studies. Tooth eruption was described as a compensatory mechanism in reaction to the direction of facial rotation, and malocclusions as a result of incomplete or interrupted compensatory mechanism [3]. However, as recent articles have shown, Bjork and Skieller's methods have poor predictability when applied to patient populations outside the implant studies [5,6]. This raises questions about the validity of Bjork and Skieller's concept of dentoskeletal patterns of development. In 1965, F.F. Schudy [7] used a simple model to demonstrate the importance of vertical growth of the posterior dentition when considering the overall craniofacial growth pattern. His study showed that a variation in molar height affects the horizontal and vertical positions of the mandible [7].

Some of the more recent dentoalveolar height studies focus on the vertically growing or hyperdivergent patient [8–11]. These studies sometimes group male and female patients together and do not always exclude subjects with previous orthodontic treatment or fail to take prolonged vertical growth into account in groups of subjects based on dental characteristics. The results of these studies vary. Some report greater dentoalveolar heights in hyperdivergent groups compared with Class I groups, whereas others report reduced dentoalveolar heights [8–10]. Isaacson et al. [12] investigated several characteristics of subjects with high angle, average angle, and low angle. Like their predecessors, the authors mainly focused on describing facial development and mandibular rotations from the perspective of skeletal characteristics [12]. However, they mention several times that the heights of the posterior alveolar processes seem to be related to the mandibular plane angle, affected by tooth position [12].

The purpose of the present study was to compare the posterior dentoalveolar heights of orthodontically untreated individuals, past their peak growth spurt, with different vertical and horizontal skeletal growth patterns. This study is unique because of its focus on orthodontically untreated individuals and categorization of subjects by both horizontal and vertical skeletal characteristics only. This allows a true comparison of the dental characteristics in different malocclusions. Behrents [13] found that prolonged vertical change in the dentoskeletal complex is a reality. Therefore, it would be difficult to find a sufficient study sample of untreated individuals who have truly completed their vertical craniofacial growth. Instead, the goal was to select subjects at least 2 years past their peak mandibular growth spurts, as determined by Cervical Vertebral Maturation Stage 5 (CVMS V) [14]. These subjects have an established horizontal and vertical skeletal growth pattern and are of an age that is generally accepted as suitable for comprehensive orthodontic treatment.

2. Materials and methods

This study was carried out in the orthodontic department of the University of Illinois-Chicago (UIC) using lateral cephalometric radiographs obtained from the preexisting patient records in the orthodontic department, as well as from two private orthodontic

Table 1
Frequency of ethnicity for male individuals by group

Ethnicity group	Caucasian		Hispanic		Asian		African-American		Middle Eastern	
	n	%	n	%	n	%	n	%	n	%
Class I (control)	3	12.0	12	48.0	7	28.0	1	4.0	2	8.0
Class II Hyperdivergent	2	8.0	11	44.0	9	36.0	2	8.0	1	4.0
Class II Hypodivergent	12	70.6	1	5.9	0	0	4	23.5	0	0
Class III Hyperdivergent	5	29.4	8	47.1	1	5.9	2	11.8	1	5.9
Class III Hypodivergent	9	32.1	7	25.0	2	7.1	4	14.3	6	21.4

Table 2
Frequency of ethnicity for female individuals by group

Ethnicity group	Caucasian		Hispanic		Asian		African-American		Middle Eastern	
	n	%	n	%	n	%	n	%	n	%
Class I (control)	5	20.0	7	28.0	13	52.0	0	0	0	0
Class II Hyperdivergent	2	8.0	9	36.0	13	52.0	1	4.0	0	0
Class II Hypodivergent	13	56.5	4	17.4	1	4.3	4	17.4	1	4.3
Class III Hyperdivergent	7	58.3	4	33.3	1	8.3	0	0	0	0
Class III Hypodivergent	3	14.3	5	23.8	6	28.6	5	23.8	2	9.5

practices. The following inclusion and exclusion criteria were used for the initial sample:

As inclusion criteria:

- Full permanent dentition.
- All posterior teeth, including second molars, erupted and in occlusion.
- CVMS V (Baccetti et al. [14]).
- No previous orthodontic treatment.
- A ruler or specific resolution information for each image that can be used for accurate calibration.
- Subjects who meet the grouping criteria.

As exclusion criteria:

- Subjects not in full permanent dentition, whether due to missing teeth, or unerupted teeth.
- Any unerupted posterior teeth or posterior teeth not in occlusion.
- Subjects who have not reached CVMS V.
- Images in which cervical vertebrae 4 is not visible.
- Current or previous orthodontic treatment.
- The absence of a reliable method for calibrating the image.
- Craniofacial anomalies that may impact cephalometric tracings.
- Subjects who do not meet the grouping criteria.

One pretreatment lateral cephalometric image was taken for each subject at a time when the subject was orthodontically untreated.

The 265 subjects who met the inclusion and exclusion criteria were initially obtained from the available sample of approximately 8000 subjects at UIC, and 2000 subjects at the two private orthodontic offices. After cephalometric tracings were completed using Dolphin Imaging (Version 11.7.05.66; Dolphin Imaging Systems, Chatsworth, CA), a total of 47 subjects were eliminated, as they did not meet one or more of the grouping criteria. Using the skeletal landmarks, the subjects were evaluated by the grouping criteria, as defined in Figure 1.

The final sample age range was from 13 to 56 years and was diverse in ethnic backgrounds and representative of a practice in an urban setting, approximately 28% Caucasian, 31% Hispanic, 24% Asian, 11% African American, and 6% Middle Eastern (Tables 1 and 2).

Using a method similar to the one proposed by Arriola-Guillen and Flores-Mir [8], the dentoalveolar heights were measured as the perpendicular distance from both the buccal cusp tip of the premolars and the mesio-buccal cusp tip of the molars to the palatal plane for the maxillary teeth. Similarly, the perpendicular distances from the buccal cusp tip of the premolars and the mesio-buccal cusp tip of the molars to the mandibular plane were used for the mandibular teeth [8]. An example of the cephalometric tracing method can be seen in Figure 2. All radiographs were calibrated using either the Nasion bar ruler captured in the image or, if there was no ruler in the image, the specific image resolution and magnification. Composite average tracings were generated for each gender in each group and were used to create superimpositions as the visual representations of the comparison between the groups. Comparisons were made between the Class I groups and all other groups.

Before proceeding with the data collection for the entire sample, the reliability of the proposed method of cephalometric analysis was tested. Intrareliability was tested by comparing the tracings of the same 10 radiographs, traced at two different time points, approximately 1 week apart. Interreliability was tested by comparing the tracings of the same 10 radiographs completed by the principal investigator and an orthodontic faculty member at UIC. A total of 218 cephalometric radiographs, each from a different subject, were completely traced by the principal investigator, including the dentoaveolar heights measurements and analyzed for statistical significance.

2.1. Statistical analysis

Data were analyzed to test if there were any statistically significant mean differences between the groups of different malocclusions in terms of their maxillary and mandibular premolar and molar dentoalveolar heights. All data analysis was performed using IBM SPSS Statistics for Windows, Version 22.0 (IBM Corp, Armonk, NY) statistical software.

Intraclass correlation coefficient was used to test the intra- and interreliability of the examiners. The intraclass correlation

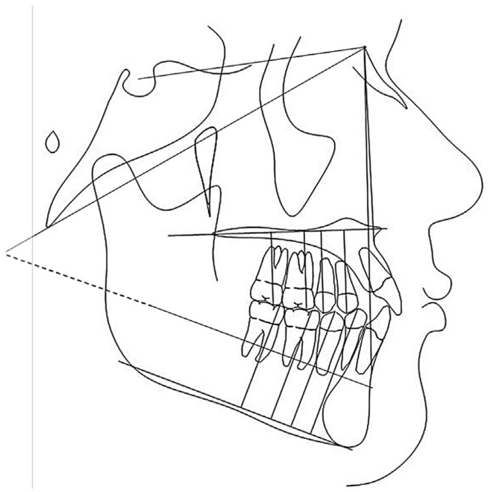

Fig. 2. Example of a completed cephalometric tracing, showing the planes used for grouping criteria, and the method used for measuring the dentoalveolar heights of maxillary and mandibular premolars and molars.

Table 3
Comparison of Class I normodivergent to Class II and Class III groups by gender

Variables	Class I	Class II				Class III			
		Hyper		Hypo		Hyper		Hypo	
		Mean difference[b]	*P*	Mean difference[b]	*P*	Mean difference[b]	*P*	Mean difference[b]	*P*
U4-PP	Male	+1.32	0.276	−3.22[a]	<0.001	−0.06	1.000	−2.25[a]	0.003
	Female	+2.20[a]	0.005	−1.75[a]	0.015	+0.78	1.000	−1.52[a]	0.049
US-PP	Male	+0.68	0.992	−3.04[a]	<0.001	−0.01	1.000	−1.59[a]	0.027
	Female	+1.53	0.056	−1.77[a]	0.010	+0.56	1.000	−0.98	0.304
U6-PP	Male	+0.29	1.000	−2.59[a]	0.001	+0.26	1.000	−0.85	0.481
	Female	+1.26	0.143	−1.43[a]	0.043	+0.87	0.801	−0.28	1.000
U7-PP	Male	−0.17	1.000	−2.20[a]	0.010	+0.56	1.000	+0.34	1.000
	Female	+0.50	1.000	−1.07	0.244	+1.08	0.560	+0.69	0.818
L4-MP	Male	+0.60	1.000	−2.27[a]	0.017	−2.02[a]	0.042	−1.54	0.092
	Female	+1.11	0.663	−2.17	0.055	−1.07	1.000	−1.76	0.180
LS-MP	Male	+0.22	1.000	−1.61	0.111	−2.36[a]	0.004	−1.35	0.137
	Female	+1.00	0.733	−1.31	0.452	−1.28	0.696	−1.28	0.514
L6-MP	Male	+0.04	1.000	−1.04	0.495	−2.71[a]	0.001	−1.01	0.367
	Female	+0.54	1.000	−0.60	1.000	−1.39	0.584	−1.00	0.932
L7-MP	Male	−0.90	0.350	−0.46	1.000	−4.28[a]	<0.001	−1.07	0.322
	Female	−0.26	1.000	0.00	1.000	−2.96[a]	0.009	−0.96	0.897

Differences are in mm.
[a] Denotes a statistically significant mean difference.
[b] A (−) value indicates that the Class I group has a higher mean value. A (+) value indicates that the Class II or Class III group has a higher mean value.

coefficient for all variables was >0.90, showing good support for the reliability of the method. The distribution of the raw data was investigated using the Shapiro-Wilk test for normality. This test indicated that the variables investigated were normally distributed; therefore, parametric tests were performed to test the mean differences in vertical dento-alveolar heights of posterior teeth (molars and premolars) in established occlusion between Class II hypo- and hyperdivergent, and Class III hypo- and hyperdivergent to the Class I normodivergent in male and female patients for the variables U4-PP, U5-PP, U6-PP, U7-PP, L4-MP, L5-MP, L6-MP, and L7-MP.

Independent *t*-tests were performed to test the mean differences between male and female subjects within each group, for each variable. One-way analysis of variance with Bonferroni post hoc analysis and independent *t*-tests were performed to test the mean differences among the malocclusion groups for each gender. Statistical significance for all tests was set at 0.05.

3. Results

All variables tested in both the Class I normodivergent group and the Class III hypodivergent group showed mean significant differences in dentoalveolar heights between male and female subjects. For the Class II hyperdivergent group, Class II hypodivergent group, and Class III hyperdivergent group, there were at least two variables in each group that showed mean significant differences. Because most of the variables showed statistically significant mean differences between male and female subjects, all groups were separated by gender for the rest of the statistical comparisons.

There were several statistically significant differences between Class I groups and all other groups. The greatest differences were found between the male Class I and hypodivergent Class II groups, and between the male Class I and hyperdivergent Class III groups (Table 3). For the male Class I and hypodivergent Class II groups, the greatest differences occurred in the maxilla, with the hypodivergent Class II dentoalveolar heights ranging from 2.20 mm to 3.22 mm less than those of the Class I group (Table 3). Between the male Class I and hyperdivergent Class III groups, the greatest differences were in the mandible, with the hyperdivergent Class III dentoalveolar heights ranging from 2.02 mm to 4.28 mm less than in the Class I group (Table 3). There were almost no significant differences between Class I and hyperdivergent Class II groups, for

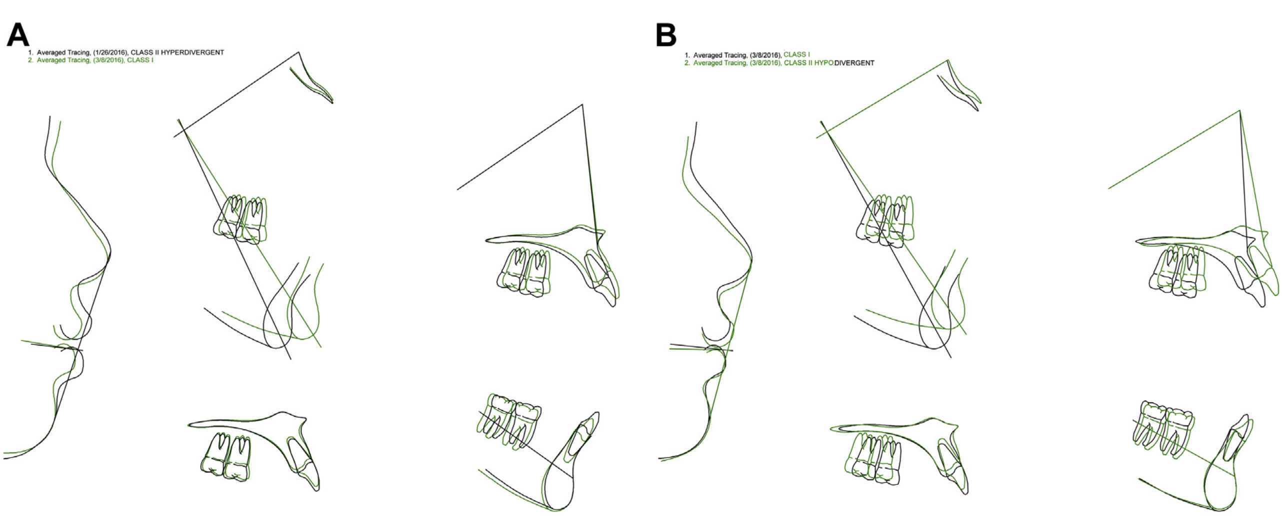

Fig. 3. Comparison of composite average tracings of Class I normodivergent with Class II hyperdivergent (A) and hypodivergent (B).

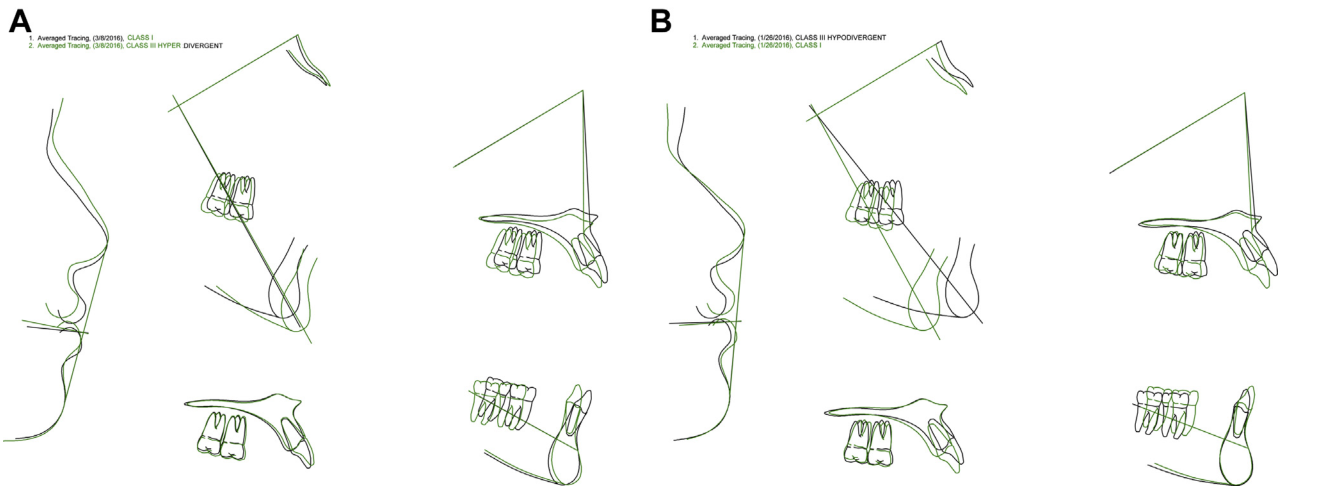

Fig. 4. Comparison of composite average tracings of Class I normodivergent with Class III hyperdivergent (A) and hypodivergent (B).

male and female subjects, with the fewest differences occurring between Class I and hypodivergent Class III groups. These findings are also demonstrated with the superimpositions shown in Figures 3 and 4. In the overall superimposition, the tracings were superimposed on the sella-nasion line and registered at sella.

The next set of comparisons, between the hyperdivergent Class II and Class III groups and between hypodivergent Class II and Class III groups, isolated the horizontal component of growth in groups with similar vertical growth. Among the male hyperdivergent groups, all the mandibular variables had statistically significant differences, with the Class III group ranging from 2.58 mm to 3.38 mm less than the Class II group (Tables 4 and 5). Between the hypodivergent groups, there were fewer variables with statistically significant differences. In the male subjects, both the U6-PP and U7-PP variables had statistically significant differences. In both cases, the Class II group was significantly shorter, with a difference of 1.75 mm for U6-PP and 2.54 mm for U7-PP (Tables 6 and 7).

The final set of comparisons, between hyperdivergent and hypodivergent Class II groups and between hyperdivergent and hypodivergent Class III groups, isolated the vertical differences between the groups by comparing them with those of similar horizontal growth, but much different vertical growth. For both male and female subjects, hypodivergent Class II groups had significantly shorter dentoalveolar heights for all the maxillary variables (Tables 8 and 9) compared with hyperdivergent Class II groups. The comparisons between hyperdivergent and hypodivergent Class III groups also showed significant differences. For both male and female subjects, the hypodivergent groups had significantly shorter maxillary dentoalveolar heights, mainly on the bicuspids, ranging from 22.31 mm to 26.54 mm. The hyperdivergent groups had significantly shorter mandibular dentoalveolar heights, mainly on the molars, ranging from 25.30 mm to 32.34 mm (Tables 10 and 11).

4. Discussion

Orthodontic treatment is very often, if not always, planned based on skeletal and dental problems, but with regard to its execution, the greatest changes occur at the dentoalveolar level. It is therefore beneficial to conduct studies that attempt to establish the deepest correlation between the dentition and the craniofacial complex, while understanding its role within the context of skeletal growth. Some authors have hypothesized that the posterior dentition may play an important role in skeletal growth pattern [8,10,15,16]. The focus of this study was to investigate the association between the amount of posterior tooth eruption and the development of different malocclusions leading to maxillomandibular discrepancies. This information could be extremely relevant to establish the capabilities of orthodontic treatment, executed only at dentoalveolar level, to actually affect the individual's skeletal growth pattern.

Table 4
Mean differences between female hyperdivergent Class II and Class III groups

Groups	Class III		Class II		Mean difference[b]	*P*
Variables	Mean	SD	Mean	SD		
U4-PP	25.13	2.38	26.55	2.83	−1.42	0.275
U5-PP	23.85	2.17	24.82	2.67	−0.97	0.661
U6-PP	23.05	1.99	23.44	2.65	−0.39	1.000
U7-PP	20.89	1.70	20.30	2.76	+0.59	1.000
L4-MP	33.72	1.99	35.91	3.59	−2.18	0.163
L5-MP	31.29	1.86	33.58	3.33	−2.28	0.106
L6-MP	29.23	2.13	31.17	3.12	−1.93	0.219
L7-MP	25.30	2.44	27.98	2.61	−2.69[a]	0.020

Mean differences are in mm.
[a] Denotes a statistically significant mean difference.
[b] A (−) value indicates that the Class II group has a higher mean value. A (+) value indicates that the Class III group has a higher mean value.

Table 5
Mean differences between male hyperdivergent Class II and Class III groups

Groups	Class III		Class II		Mean difference[b]	*P*
Variables	Mean	SD	Mean	SD		
U4-PP	26.54	2.22	27.92	3.17	−1.38	0.338
U5-PP	25.50	1.95	26.19	2.89	−0.69	1.000
U6-PP	24.77	1.67	24.80	2.88	−0.03	1.000
U7-PP	22.78	1.51	22.05	2.88	+0.72	1.000
L4-MP	35.45	2.70	38.07	3.01	−2.62[a]	0.005
L5-MP	33.03	2.28	35.62	2.61	−2.58[a]	0.001
L6-MP	30.65	2.00	33.40	2.57	−2.75[a]	<0.001
L7-MP	26.60	1.77	29.99	2.14	−3.38[a]	<0.001

Mean differences are in mm.
[a] Denotes a statistically significant mean difference.
[b] A (−) value indicates that the Class II group has a higher mean value. A (+) value indicates that the Class III group has a higher mean value.

Table 6
Mean differences between female hypodivergent Class II and Class III groups

Groups	Class III		Class II		Mean difference[b]	*P*
Variables	Mean	SD	Mean	SD		
U4-PP	22.84	2.10	22.61	2.36	+0.23	1.000
U5-PP	22.31	1.93	21.53	2.29	+0.78	0.595
U6-PP	21.90	1.79	20.75	2.29	+1.15	0.170
U7-PP	20.49	1.61	18.73	2.51	+1.76[a]	0.021
L4-MP	33.04	2.58	32.63	3.46	+0.41	1.000
L5-MP	31.30	2.54	31.26	3.57	+0.04	1.000
L6-MP	29.66	2.52	30.03	3.65	−0.37	1.000
L7-MP	27.29	2.70	28.25	3.53	−0.96	0.925

Mean differences are in mm.
[a] Denotes a statistically significant mean difference.
[b] A (−) value indicates that the Class II group has a higher mean value. A (+) value indicates that the Class III group has a higher mean value.

Table 8
Mean differences between female hyperdivergent and hypodivergent Class II groups

Groups	Hyper		Hypo		Mean difference[b]	*P*
Variables	Mean	SD	Mean	SD		
U4-PP	26.55	2.83	22.61	2.36	+3.94[a]	<0.001
U5-PP	24.82	2.67	21.53	2.89	+3.30[a]	<0.001
U6-PP	23.44	2.63	20.75	2.29	+2.69[a]	<0.001
U7-PP	20.3	2.76	18.73	2.51	+1.57[a]	0.046
L4-MP	35.91	3.59	32.63	3.46	+3.28[a]	0.002
L5-MP	33.58	3.33	31.26	3.57	+2.31[a]	0.025
L6-MP	31.17	3.12	30.03	3.65	+1.14[a]	0.249
L7-MP	27.98	2.61	28.25	3.53	−0.27	0.769

Mean differences are in mm.
[a] Denotes a statistically significant mean difference.
[b] A (−) value indicates that the hypo group has a higher mean value. A (+) value indicates that the hyper group has a higher mean value.

Comparing skeletal growth patterns and dentoalveolar heights, this study revealed two strong trends: no matter how they were compared, hypodivergent Class II subjects always had shorter maxillary posterior dentoalveolar heights and hyperdivergent Class III subjects always had shorter mandibular posterior dentoalveolar heights. Using multiple sets of comparisons elicited these two trends. The first set of comparisons was to use the Class I mesiofacial group as a control and compare it with all other groups.

The comparison between Class II hypodivergent groups and Class I was consistent with similar comparisons in the literature showing statistically significant shorter mean maxillary dentoalveolar heights with hypodivergent Class II individuals when compared with Class I subjects.[10,11] Arriola-Guillen and Flores-Mir [8] found that Class II and Class III hyperdivergent subjects had significantly greater maxillary molar heights when compared with Class I subjects, whereas the Class II hyperdivergent subjects also had significantly greater mandibular molar heights compared with Class I subjects. A review of the mean-difference columns in Table 1 from the present study reveals the same general trend among those groups, but virtually no statistically significant mean differences. This nonstatistical significance might have been expressed with regard to the large "standard deviations values" derived from linear measurements of different individuals, suggesting that proportional analyses should be considered [17–19].

Quite different from the results of Arriola-Guillen and Flores-Mir [8], the present study found statistically significant shorter mean mandibular posterior dentoalveolar heights on hyperdivergent Class III subjects when compared with the Class I group, regardless of gender. It is important to note that even though there were statistically significant differences between male and female subjects for most of the tested variables, the genders were grouped together in the Arriola-Guillen and Flores-Mir [8] study, which could contribute to some of the discrepancy in findings between the studies. Furthermore, the grouping criteria and cephalometric parameters differ between the two studies, which could also contribute to the disparate results.

The finding of gender dimorphism is not a novel one. There are many studies in the existing literature that support the finding of gender-specific differences in numerous areas of study, including research of dentoalveolar heights. Behrents [13], for example, states findings of gender dimorphism in long-term facial skeletal changes. Zafar-ul-Islam et al. [15] stressed the importance of grouping by gender, Janson et al. [11] demonstrated gender differences, and other studies restrict their samples to one gender only [9,16]. Gender dimorphism was also expressed in this study in terms of the magnitude of the differences in dentoalveolar heights. This finding represents the differences in growth between male and female subjects. Female individuals generally mature earlier and complete their growth earlier, whereas puberty and its associated growth in male individuals tends to start later and can last for much longer [20]. Studies that do not take gender dimorphism into consideration while discussing results may be missing the key factor in dentoalveolar characteristics among malocclusions.

Clinical orthodontists would likely agree that small vertical changes during orthodontic treatment can have significant effects on treatment time and treatment outcomes. The smallest statistically significant mean dentoalveolar height difference in this study was 1.11 mm and the largest was 4.55 mm.

Based on the findings of this study, there are greater posterior mandibular dentoalveolar heights with Class II individuals when compared with the Class III subjects within the hyperdivergent

Table 7
Mean differences between male hypodivergent Class II and Class III groups

Groups	Class III		Class II		Mean difference[b]	*P*
Variables	Mean	SD	Mean	SD		
U4-PP	24.35	2.03	23.38	2.48	+0.98	0.540
U5-PP	23.92	1.81	22.46	2.38	+1.46	0.090
U6-PP	23.66	1.73	21.92	2.47	+1.75[a]	0.033
U7-PP	22.56	1.78	20.02	2.80	+2.54[a]	0.002
L4-MP	35.93	2.25	35.20	3.65	+0.73	1.000
L5-MP	34.05	2.07	33.79	3.53	+0.26	1.000
L6-MP	32.34	1.89	32.32	3.51	+0.02	1.000
L7-MP	29.81	1.92	30.42	3.42	−0.61	1.000

Mean differences are in mm.
[a] Denotes a statistically significant mean difference.
[b] A (−) value indicates that the Class II group has a higher mean value. A (+) value indicates that the Class III group has a higher mean value.

Table 9
Mean differences between male hyperdivergent and hypodivergent Class II groups

Groups	Hyper		Hypo		Mean difference[b]	*P*
Variables	Mean	SD	Mean	SD		
U4-PP	27.92	3.17	23.38	2.48	+4.55[a]	<0.001
U5-PP	26.19	2.89	22.46	2.38	+3.73[a]	<0.001
U6-PP	24.80	2.88	21.92	2.47	+2.88[a]	0.002
U7-PP	22.05	2.88	20.02	2.80	+2.03[a]	0.029
L4-MP	38.07	3.01	35.20	3.65	+2.86[a]	0.008
L5-MP	35.62	2.61	33.79	3.53	+1.83	0.600
L6-MP	33.40	2.57	32.32	3.51	+1.08	0.255
L7-MP	29.99	2.14	30.42	3.42	−0.44	0.611

Mean differences are in mm.
[a] Denotes a statistically significant mean difference.
[b] A (−) value indicates that the hypo group has a higher mean value. A (+) value indicates that the hyper group has a higher mean value.

Table 10
Mean differences between female hyperdivergent and hypodivergent Class III groups

Groups	Hyper		Hypo		Mean difference[b]	P
Variables	Mean	SD	Mean	SD		
U4-PP	25.13	2.38	22.84	2.10	+2.30[a]	0.007
U5-PP	23.85	2.17	22.31	1.93	+1.54[a]	0.043
U6-PP	23.05	1.99	21.90	1.79	+1.15[a]	0.099
U7-PP	20.89	1.70	20.49	1.61	+0.39[a]	0.509
L4-MP	33.72	1.99	33.04	2.58	+0.68	0.435
L5-MP	31.29	1.86	31.30	2.54	−0.01	0.997
L6-MP	29.23	2.13	29.66	2.52	−0.43	0.627
L7-MP	25.30	2.44	27.29	2.70	−2.00[a]	0.043

Mean differences are in mm.
[a] Denotes a statistically significant mean difference.
[b] A (−) value indicates that the hypo group has a higher mean value. A (+) value indicates that the hyper group has a higher mean value.

sample; with the hypodivergent groups, on the other hand, there was a great tendency for smaller maxillary dentoalveolar heights with Class II when compared with Class III.

This suggests that a better treatment approach regarding posterior vertical control on Class II patients would be to intrude mandibular molars on vertically growing patients and to extrude maxillary molars on horizontally growing patients, repositioning the mandible to facilitate the skeletal sagittal correction. The opposite movement is needed for Class III sagittal correction, in which the extrusion of the posterior mandibular segment of vertical growers and intrusion of the posterior maxillary segment on horizontal ones should easily correct the skeletal condition and rotate the mandible.

It would be of great interest to design a longitudinal study starting at a younger age with similar grouping criteria, to observe growth of the buccal segments over time and, possibly, using a different type of analysis that accesses proportional measurements instead of linear averages, thus avoiding bias related to different cranial configuration sizes.

5. Conclusions

Once most of the variables showed statistically significant mean differences between male and female individuals, we could assume that gender is an important factor to be considered when describing dentoaveolar heights.

In the present study, the comparisons among different groups of skeletal discrepancies showed several significant findings with respect to the dentoalveolar heights of the posterior region, such as the following:

Table 11
Mean differences between male hyperdivergent and hypodivergent Class III groups

Groups	Hyper		Hypo		Mean difference[b]	P
Variables	Mean	SD	Mean	SD		
U4-PP	26.54	2.22	24.35	2.03	+2.19[a]	0.002
U5-PP	25.50	1.95	23.92	1.81	+1.58[a]	0.009
U6-PP	24.77	1.67	23.66	1.73	+1.11[a]	0.041
U7-PP	22.78	1.51	22.56	1.78	+0.22	0.679
L4-MP	35.45	2.70	35.93	2.25	−0.48	0.519
L5-MP	33.03	2.28	34.05	2.07	−1.02	0.133
L6-MP	30.65	2.00	32.34	1.89	−1.70[a]	0.007
L7-MP	26.60	1.77	29.81	1.92	−3.21[a]	<0.001

Mean differences are in mm.
[a] Denotes a statistically significant mean difference.
[b] A (−) value indicates that the hypo group has a higher mean value. A (+) value indicates that the hyper group has a higher mean value.

- Male Class I compared with hypodivergent Class II groups, the greatest differences occurred in the maxilla, with the hypodivergent Class II dentoalveolar heights ranging from 2.20 mm to 3.22 mm less than those of the Class I group.
- Male Class I compared with hyperdivergent Class III groups, the greatest differences were in the mandible, with the hyperdivergent Class III dentoalveolar heights ranging from 2.02 mm to 4.28 mm less than in the Class I group.
- Among the male hyperdivergent groups, all the mandibular variables had statistically significant differences, with the Class III group ranging from 2.58 mm to 3.38 mm less than the Class II group.

The strongest trends seem to be in the short mandibular dentoalveolar heights of Class III hyperdivergent subjects and the short maxillary dentoalveolar heights of Class II hypodivergent subjects.

Based on our results, orthodontists may have a better knowledge about the influences of the dentoaveolar heights on the development of different malocclusions, therefore making better decisions regarding vertical control of upper and lower buccal segments during their treatment plans.

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