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Cephalometric Evaluation of Age-dependent Craniofacial Skeletal Changes in Iranian Population with Class II Malocclusion: A Cross-sectional Study

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Abstract

Background: Class II malocclusion is one of the most prevalent occlusion discrepancies. Knowledge of growth changes in craniofacial components can help clinicians plan orthodontic treatment, determine the proper timing to initiate the treatment, and predict the treatment outcome, especially in growth modification protocols. This study evaluates craniofacial skeleton changes in class II malocclusion subjects compared to class I malocclusion.

Methods: In this cross-sectional study, cephalograms of 858 individuals aged between 7 and 23 were investigated. The samples were divided into the class I group (ANB angle 0–4) and class II group (ANB angle ≥ 4 degrees), including 426 and 432 cephalograms, respectively, and each group was divided into seven subgroups considering age. Cephalometric analysis was performed using OnyxCeph software, and statistical analyses of variance, mean, paired *t* test, and independent samples *t* test were performed using SPSS software.

Results: The results showed no significant differences between class I and class II groups in variables related to the cranial base and vertical facial height. In class II groups, the SNA angle was significantly greater. The total mandibular height (Co-Gn), facial angle (Npog-FH), and SNB angle were significantly greater in class I compared to the class II group.

Conclusion: Protrusion of the maxilla affects the formation of class II malocclusion, but an underdeveloped mandible is the main component of Class II malocclusion formation. With increasing age, especially after puberty, the mandible may become more retruded in class II patients.

Keywords: Malocclusion, Angle class I, Angle class II, Cephalometry, Cranial base

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Introduction

Class II malocclusion is a common type found in 20-80 percent of the world population according several studies and 24.7% (20.8–28.7) of the Iranian population (1). Malocclusion may affect speech, function, temporomandibular joint, emotional and social well-being, and increased susceptibility to periodontal disease and trauma (2). Multifactorial etiology consists of malocclusions such as hereditary factors, oral habits, diet, and environmental and ethnic components (1).

Skeletal class II patterns are often the result of discrepancies in size, form, or position of the jaws relative to each other (3). Perception of craniofacial growth and development is necessary for diagnosing and treating orthodontic patients (4). The cranial base angulation and length can also affect the relationship between the nasomaxillary complex and the mandible and the overall craniofacial pattern in subjects with different malocclusions (5). It has been reported that the growth changes of the cranial base, nasomaxillary complex, and mandible often occur simultaneously and are dependent (6).

Being aware of the magnitude and direction of craniofacial growth changes in subjects with class II malocclusion may be considered a prerequisite for planning orthodontic treatment or orthognathic surgery, determining the best time to start the treatment, and evaluating treatment outcomes, particularly in growth modification protocols. The characteristics of class II malocclusion were initially represented in 1899 by Edward Angle; he reported that this type of malocclusion resulted from the posterior positioned or short, underdeveloped mandible (7). While some of the

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published literature reported no significant differences in the maxilla's dentoalveolar and skeletal position in class II malocclusion versus the control group (8,9), Antonini et al reported that maxillary protrusion is the main component of class II malocclusion (10). In many of these published papers, it has been suggested that the mandible is significantly shorter or more retruded in subjects with class II malocclusion (8,11); however, Bishara et al found no differences in mandibular growth in individuals with class II malocclusion vs. those with normal occlusion (12). Ardani et al announced that mandibular length deficiency with normal maxilla is the most frequent skeletal Class II malocclusion (13). Considering controversy in previous studies and the influence of factors such as race, ethnicity, and sample size on the results of the studies done in this field in Iran, this study aimed to evaluate craniofacial growth changes in Iranian subjects with class II malocclusion in comparison to the control group (class I).

Material and Methods

The samples of this cross-sectional study were selected out of 1458 lateral cephalometric radiographs of subjects referred to a private radiology center for three years after the initial analysis; 858 cephalograms of subjects with class I and II malocclusions were included. This article used images prepared by an orthodontist due to orthodontic problems, and no radiographs were taken for this study alone. The age range was 7-23 years. None of the subjects had a history of orthodontic treatment. Subjects with congenital craniofacial abnormalities and cephalograms with an FH-SN angle of more than 8° were excluded. The samples were divided into two groups according to the ANB angle: class I group (ANB angle 0 – 4 degrees) and class II group (ANB angle ≥ 4 degrees), including 426 and 432 cephalograms, respectively. All cephalograms were taken in natural head position (NHP) using a PM (Planmeca EC) with 1.1 magnification and CR system (Agfa. CR30, Germany).

To evaluate the craniofacial changes with age, according to previous studies, each group was divided into seven subgroups: (A) 7-9 year olds, (B) 9-11 year olds, (C) 11-13 year olds, (D) 13-15 year olds, (E) 15-17 year olds, (F) 17-19 year olds, (G) 19-23 year olds.

Cephalometric analysis

All cephalograms were traced and analyzed using OnyxCeph software (version 2.6.22, Germany). OnyxCeph is an orthodontic software that can help clinicians diagnose and analyze lateral and posterior-anterior (PA) cephalograms and photographs. First, a new analysis is defined for the software and then marked for anatomical points of each cephalogram. Software measured angles and lines according to the defined analysis (Figure 1). The cephalometric analysis included measurements of lines and angles of the cranial base (Figure 2A), maxilla (Figure 2B), mandible (Figure 2C), and vertical skeletal measurements (Figure 2D). All cephalograms were traced by one observer (AN).

Statistical analysis

Descriptive statistics of craniofacial measurements, including mean and standard deviation, were determined for each subgroup within the control and class II groups using SPSS version 22. The Kolmogorov-Smirnov test showed normal distribution for all cephalometric variables ($P > 0.05$). Therefore, we used *t* test for parametric statistics with independent samples so that significant differences in the angular and linear distances between class I and class II malocclusion in each age subgroup would be evaluated. *P* value = 0.01 was

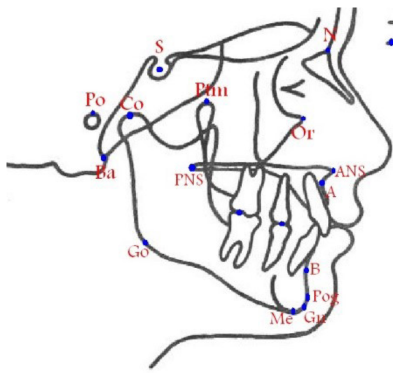

Figure 1. Schematic diagram of anatomical points used; Cephalometric landmarks and planes: nasion (N), sella (S), porion (Po), basion (Ba), pogonion (Pog), gnathion (Gn), orbit (Or), gonion (Go), condyle (Co), menton (Me), point B (the deepest point on the outer contour of the mandible) (B), point A, (the deepest midline points on the anterior outer contour of the maxillary alveolar process) (A), anterior nasal spine (ANS), posterior nasal spine (PNS), pterygomaxillary (Ptm)

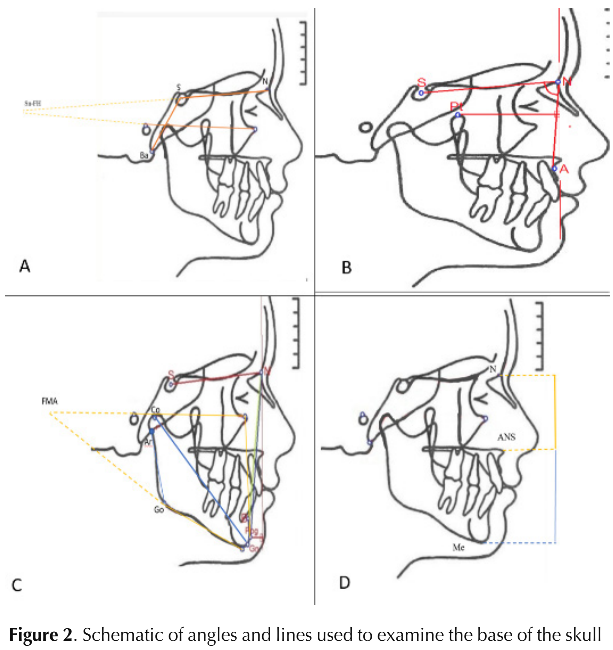

Figure 2. Schematic of angles and lines used to examine the base of the skull (A), maxilla (B), and mandible (C) and Vertical skeletal measurements (D)

considered a threshold for significance.

Intra-examiner error

One hundred cephalograms were randomly selected and retraced after at least two weeks of first tracing by the same observer, and both measurements were analyzed using a paired *t* test.

Results

Intra-examiner error was calculated; the differences between the two measurements of studied variables on the first and second readings were insignificant ($P > 0.05$). Descriptive statistics for the cephalometric measurements in the class II and class I subjects are given in Tables 1 to 4 and the most critical findings in each component are as follows:

Cranial base

The results of this study showed that the dimension of SN increases due to growth in both groups. However, there is no significant difference in cranial base parameters (SN, Ba-S-N, SN-FH) in subjects with class II malocclusion

Table 1. Comparison of cranial base measurements in class II and class II in different age groups

Age variable	Groups/*P* value	7-9 (n = 51)	9-11 (n = 92)	11-13 (n = 176)	13-15 (n = 176)	15-17 (n = 122)	17-19 (n = 64)	19-23 (n = 64)
SN (mm)	Class 1	56.76 ± 2.53	57.65 ± 2.76	58.72 ± 2.99	59.56 ± 2.04	60.49 ± 2.92	61.09 ± 3.35	60.24 ± 2.96
	Class 2	56.66 ± 3.11	57.19 ± 4.50	58.91 ± 3.20	59.97 ± 2.78	60.34 ± 2.96	60.40 ± 3.68	60.45 ± 2.87
	P value	0.89	0.589	0.680	0.274	0.784	0.433	0.622
Sn-FH	Class 1	4.78 ± 2.85	6.36 ± 3.56	5.57 ± 3.06	5.42 ± 3.71	5.30 ± 2.90	4.53 ± 3.40	5.43 ± 3.60
	Class 2	7.41 ± 4.24	5.79 ± 3.68	5.74 ± 3.34	5.93 ± 3.46	4.94 ± 2.95	4.91 ± 3.54	5.53 ± 3.20
	P value	012*	0.472	0.726	0.365	5.30 ± 2.90	0.667	0.835

Table 2. Comparison of maxilla measurements in class II and class II in different age groups

Age variable	Groups/*P* value	7-9 (n = 51)	9-11 (n = 92)	11-13 (n = 176)	13-15 (n = 176)	15-17 (n = 122)	17-19 (n = 64)	19-23 (n = 64)
Pt to N Prep.	Class 1	39.49 ± 2.31	39.83 ± 2.83	41.53 ± 3.52	41.53 ± 3.52	43.84 ± 3.20	43.92 ± 3.60	87.88 ± 4.33
	Class 2	39.35 ± 2.50	40.07 ± 3.69	41.77 ± 3.26	41.77 ± 3.26	44.21 ± 3.39	64.66 ± 4.28	43.74 ± 3.11
	P value	0.837	0.745	0.635	0.635	0.541	0.974	0.324
SNA	Class 1	79.99 ± 3.95	78.64 ± 3.55	79.53 ± 3.71	79.01 ± 3.84	79.17 ± 3.35	79.83 ± 3.74	79.74 ± 4.09
	Class 2	80.72 ± 3.48	81.59 ± 3.61	80.75 ± 3.58	80.99 ± 3.46	81.64 ± 4.25	81.67 ± 3.04	81.57 ± 3.74
	P value	0.446	0.000*	0.029 *	0.001*	0.000*	0.036*	0.002*

* *P* value < 0.05 (significant).

Table 3. Comparison of mandible measurements in class II and class II in different age groups

Age variable	Groups/*P* value	7-9 (n = 51)	9-11 (n = 92)	11-13 (n = 176)	13-15 (n = 176)	15-17 (n = 122)	17-19 (n = 64)	19-23 (n = 64)
SNB	Class 1	77.90 ± 4.01	76.56 ± 3.83	77.37 ± 3.61	77.02 ± 3.87	77.47 ± 3.22	78.20 ± 3.85	77.93 ± 4.08
	Class 2	73.97 ± 3.40	75.15 ± 3.58	74.97 ± 3.51	75.06 ± 3.62	75.65 ± 428	76.00 ± 3.03	75.32 ± 3.60
	P value	0.000*	0.078	0.000*	0.001*	0.009*	0.014*	0.000*
Co-Gn	Class 1	83.31 ± 9.52	86.27 ± 10.17	89.04 ± 10.01	91.55 ± 10.30	97.24 ± 8.13	98.15 ± 9.02	98.38 ± 10.11
	Class 2	74.12 ± 8.12	76.11 ± 10.07	80.10 ± 10.56	81.52 ± 10.75	83.14 ± 11.97	84.09 ± 12.69	84.32 ± 12.48
	P value	0.001*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
ramus height	Class 1	41.61 ± 3.86	44.07 ± 3.62	45.17 ± 4.53	47.05 ± 3.82	50.11 ± 3.74	50.73 ± 5.04	51.19 ± 5.05
	Class 2	39.72 ± 3.52	42.15 ± 4.09	44.40 ± 3.73	46.95 ± 3.72	47.95 ± 4.25	50.24 ± 4.50	49.24 ± 3.96
	P value	0.074	0.027	0.217	0.872	0.004*	0.684	0.004*
Facial angle (N Pog-FH),	Class 1	82.47 ± 3.96	82.99 ± 3.87	82.87 ± 3.67	82.70 ± 4.03	83.09 ± 3.76	82.64 ± 3.84	83.53 ± 3.96
	Class 2	81.13 ± 4.71	80.95 ± 4.36	80.70 ± 4.23	81.36 ± 3.96	80.14 ± 4.42	81.04 ± 3.97	81.34 ± 4.09
	P value	0.278	0.027	0.001*	0.032*	0.000*	0.107	0.000*
Pog to N Prep	Class 1	5.63 ± 4.45	6.62 ± 4.76	8.29 ± 5.08	8.76 ± 4.91	9.36 ± 5.44	8.87 ± 5.75	7.63 ± 4.71
	Class 2	8.31 ± 5.90	8.18 ± 5.53	9.18 ± 5.26	11.88 ± 6.47	14.09 ± 5.61	11.59 ± 6.68	11.47 ± 6.07
	P value	0.73	0.162	0.258	0.001*	0.000*	0.088	0.000*

**P* value < 0.05 (significant).

Table 4. Comparison of vertical skeletal measurements in class II and class II in different age groups

Age variable	Groups/*P* value	7-9 (n=51)	9-11 (n=92)	11-13 (n=176)	13-15 (n=176)	15-17 (n=122)	17-19 (n=64)	19-23 (n=64)
N-ANS facial height	Class 1	40.47±2.66	42.88±2.51	44.04±2.83	45.05±2.50	46.11±2.94	45.7476±3.59	45.91±3.66
	Class 2	40.59±2.54	41.83±3.24	44.15±2.51	45.68±2.70	45.61±2.50	45.65±2.66	46.17±3.23
	P value	0.879	0.109	0.780	0.120	0.342	0.908	0.611
ANS-Me	Class 1	52.93±5.978	54.41±3.50	56.17±4.60	57.64±4.53	60.06±5.06	61.44±4.88	61.91±6.59
	Class 2	54.03±3.80	55.07±5.57	57.06±4.74	59.64±5.37	61.23±5.88	61.53±5.02	62.72±5.23
	P value	0.423	0.542	0.212	0.011*	0.250	0.937	0.305
UAFH/LAFH	Class 1	76.98±6.50	79.00±6.21	78.77±6.41	78.55±6.35	77.22±6.94	74.76±6.47	74.63±7.75
	Class 2	75.37±6.15	76.31±5.51	77.77±6.35	77.08±6.82	75.09±7.63	74.55±6.16	73.98±6.68
	P value	0.368	0.034	0.308	0.152	0.119	0.895	0.541

*P value < 0.05 (significant).

compared to the control group (Table 1).

Maxilla

"Pt to Na Perpendicular" is a variable that indicates anterior-posteriorly maxilla growth; an increase in the value of this variable was found in both groups during growth till the age of 15. There was no statistically significant difference between class I and class II groups in anterior-posteriorly growth of the maxilla in any age subgroup ($P > 0.05$).

The SNA angle showed no significant differences between different age groups; it seemed to remain constant during growth. However, this angle was significantly greater in the class II group compared to class I in all age subgroups (Table 2) ($P < 0.05$).

Mandible

The SNB angle in class II malocclusion was smaller than in class I, reaching statistical significance in all groups except for 9-10-year-olds. Findings also showed that the effective length of the mandible (Co-Gn) and the ramus height increase with age; also, the effective length of the mandible in all age ranges was significantly smaller in the class II group compared with the class I group ($P < 0.01$), and ramus height in subject with the class I was more considerable than those in class II group, reaching statistical significance in age groups 9-10, 15-16, and 19-23 ($P < 0.05$).

Facial angle (NPog-FH), which shows the chine's position, was significantly smaller in class II malocclusion in all age subgroups except for 7-8 and 17-18 -year-old groups.

The dimension of "Pog to Na perpendicular" increased in both groups' growth until the age of 15. This variant in class II was significantly larger than in class I in older age groups (Table 3).

Vertical skeletal variables

Findings indicated that lower anterior facial height (ANS-Me) in class II subjects was larger than in class I and this difference was statistically significant only in the 13-14-year-old group. There were no significant differences in most vertical skeletal variables (N-ANS, ANS-Me, UAFH/LAFH, N-Me) in subjects with class II malocclusion compared to those with class I (Table 4).

Discussion

Class II malocclusion may result from numerous combinations of skeletal and dental components. To the best of our knowledge, understanding different aspects of craniofacial components' growth changes is of primary importance in orthodontic treatment planning and controlling treatment outcomes in growing patients. A few studies with this sample size have investigated growth changes of untreated class II subjects in Iran; therefore, this research was planned to compare craniofacial growth changes in class II malocclusion versus normal occlusion in the Iranian population. The age range of our samples was between 7 and 23 years due to small numbers of cephalograms below this range and also because, in some literature, it has been suggested that growth, especially in the vertical direction, stops at the early twenties (5,14).

Obaidi (15) and Matthews et al (16) found no differences between males and females in terms of characteristics of craniofacial components. Also, de Almeida and colleagues' systematic review pointed out that no significant difference was found in the angular measurements between sexual dimorphism (17).

Concerning available cephalograms and the above-said studies' results, males and females were not evaluated separately in the current study.

The current study found an increase in SN in both groups, which agrees with Afrand and colleagues' study; they reported that, in general, the length of the SN, due to the backward and downward rotation of sella turcica and forward motion of the nasion, increases through growing (18).

Our study also revealed that cranial flexure is stable over age. Also, de Almeida and colleagues' systematic review concluded that the skull base angle is relatively stable between the ages of 5 and 15 (17).

Our findings, in line with Barbosa and colleagues' findings, indicated that the anterior cranial base's growth changes are more evident in the anteroposterior direction, and angles are almost stable (9).

Although, in our study, the cranial base angle was more obtuse in class II malocclusion, no significant differences were found between the two study groups regarding craniofacial growth patterns ($P > 0.05$), similar to Wu et al study (19) and different with Gong et al (20) and Obaidi (15). Although there was no difference in SN length between the two groups in our study, Monirifard et al expressed a significant difference. However, as in our study, there were no significant differences in other cranial base angles (Ba-S-N, SN-FH) (21). Also, in the study by Wu et al, the SN's length was longer in class II div. 1 patients than in class I significantly (19).

In the systematic review by de Almeida and colleagues, due to the division into two groups (1 and 2), the results were as follows: N-S-Ba was larger in class II div. 1 malocclusion than in class I malocclusion and did not differ between class II div. 2 and class I malocclusions (17). Awad et al found a significant difference in the cranial base angle (NSBa) between all three malocclusion groups (22).

Gong et al, in their meta-analysis, reported that class II patients had a significantly larger NSBa angle. Moreover, the angle and length of the cranial base were significantly greater among class II patients than in class I. (20).

According to Currie and colleagues' systematic review, the change in cranial base angle (N-S-Ba) through age was inconclusive because some studies reported a decrease in cranial base angle, and some have reported non-significant differences (23).

Differences in these findings may partly be attributed to different races and criteria for the classification of patients in each group of malocclusions (i.e., ANB > 2 degrees was defined as class II malocclusion in their study; in comparison, we classified class II malocclusion by ANB angle ≥ 4 degrees).

In our study, the linear dimension describing maxillary length (i.e., the distance between point PT to the actual perpendicular from the nasion point) exhibited a gradual increase with age in both groups. However, the relationship between the maxilla and the cranial base (SNA angle) was almost constant and showed little change during growth. Some previous studies have also met these findings (10,24). Considering the increase in SN and constancy of SNA with age, increasing the maxillary length through aging seems to imply the harmonious development of the anterior cranial base and maxilla in the anteroposterior direction during growth. In the current study, we found no significant differences in the maxillary length in any age subgroups between class 1 and class II malocclusion, which agrees with the study of Antonini et al (10) and Wu et al (19). Our findings also revealed that the SNA angle in class II was greater than in the class I group in all age ranges, and it can be explained by a maxillary protrusion in these patients. Since only the samples in the 7-8-year-old subgroup had no differences between class I and II in the SNA angle, this may indicate that the maxilla is more protruded in the age range of 8-9 years. A significant difference between class I and II in terms of the SNA in Yoon and Chung's study (25) was reported, in contrast with Barbosa et al (9) and Ramezanzadeh and Sabzevari (26) studies that insignificantly difference was seen. Our findings for this parameter in the primary and mixed dentition period contrast with Antonini and colleagues' findings (10).

This inconsistency can be explained by differences in the type of study, sample size, patient selection criteria, and, most essential, differences in race.

On the whole, our findings implied that the difference between class I occlusion and class II malocclusion regarding the relationship of the maxilla to the cranial base is not considered significant. Another variable, Pt.N perpendicular, shows no significant difference between classes I and II. Thus, we suspected that protrusion of the maxilla has a low effect on class II malocclusion formation.

Our findings revealed that the SNB angle was smaller in class II malocclusion in all age ranges, and it was similar to those of Ardani et al (13) and García-Díaz et al (27). In a study by Yoon and Chung (25), SNB showed no significant difference between classes I and II. Wu et al reported that there was no significant difference in terms of SNB between class II division 1 subjects and class I subjects (19). Barbosa et al (9) found no significant differences between class I and class II division 2.

In the current study, the length of the mandible (Co-Gn) was significantly smaller in the class II group compared to that in the class I group in all age ranges, and it was in line with previous studies (24,25,28,29). But there were no significant differences in mandibular length growth change between class I and II groups. Also, the growth difference in SNA and SNB between the two groups was not significant.

This study's findings showed that the maximum growth in the effective length of the mandible in class I and class II occur in the age range of 9-12 years, while the top growth of the cranial base occurs between the ages of 11-14 years. The growth of the skull base appears to stop at the age of 15; in contrast, the mandible continues growth. There was a difference observed in the mean effective length of the mandible between the two age groups of 15-17 years and above 18 years, while no difference was observed between the two age groups in terms of anterior cranial base (SN) in the control and class II groups, which is consistent with the theory of growth pattern with cranio-caudal slope.

Stahl et al compared growth changes in class II and class I malocclusion at six consecutive developmental intervals according to the six stages of cervical vertebral maturation (CS1-CS6) through a longitudinal study. Their findings showed that the average total mandibular length (Co-Gn) was shorter in class II malocclusion compared to class I during the observation period, except for two study groups at the initial stages (30).

According to our findings, the ramus height increased with age; however, it was smaller in subjects in class II than those in the class I group, which was found in previous studies (10,24). Nonetheless, Yoon and Chung (25) and Jacob and Buschang (29) reported no significant difference in ramus height between the two groups.

An increase in ramus height and posterior facial height (S-Go) with age in both class II and I could cause increasing in lower facial height despite small changes in FMA angle during growth. The difference in lower facial height is insignificant between the two groups in the study by Yoon and Chung (25), similar to ours.

In the current study, the distance between the Pog point to the perpendicular of the nasion point was significantly different between class I and II subjects older than 15 years of age. This finding implied retruded position of the chin in class II malocclusion versus class I, which was in agreement with that of Ramezanzadeh and Sabzevari (26) and Loredana (31). Because of similar results to Ramezanzadeh and Sabzevari's study that has been done in Iran, this controversy may be attributed to the different races.

Considering that values for the SNB, facial angle, ramus height, and CO-GN length are smaller in class II malocclusion than in class I, it seems that the low growth of the mandible has an essential role in the creation of class II malocclusion. An increase in Pog-Na perpendicular length in class II older age groups suggests that the retruded growth of the mandible was more prominent in adolescents.

Conclusion

Patterns of cranial base growth changes in individuals with untreated class II malocclusion are like subjects with normal occlusion. Although protrusion of the maxilla affects the formation of class II malocclusion, an underdeveloped mandible is the main component of class II malocclusion formation. It seems that with increasing age, especially after puberty, the mandible may become more retruded in class II patients compared to class I subjects. Hence, it appears that growth modification protocols with more effect on mandibular growth could be more appropriate compared to those which restrict maxillary growth. However, in many cases, the appropriate treatment plan should be based on a thorough clinical and cephalometric evaluation of each patient. Our findings also indicated that the class II malocclusion pattern does not tend to self-correct with growth, which is associated with worsening the deficiency in mandibular dimensions and/or maxillary protrusion. Also, these growth differences between the two groups are more predominant in the anteroposterior direction than the vertical dimension of craniofacial components

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Conceptualization: Najmeh Anbiaee, Roozbeh Rashed.
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Software: Roozbeh Rashed, Ali Bagherpour.
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Writing–review & editing: Fereshteh Goudarzi, Najmeh Anbiaee.

Competing Interests
The authors declare that they have no conflict of interest.

Ethical Approval
This is an observational study, and only the samples that were radiographed at the discretion of the orthodontist were used, and no patient was exposed due to this study. This study was approved by the Ethics Committee of Mashhad University of Medical Sciences (Ethics No. ethical code: IR.MUMS.REC.1390.112).

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