Original Article

Cranial base measurements in different anteroposterior skeletal relationships using Bjork-Jarabak analysis

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ABSTRACT

Objectives: To assess the linear and angular cranial base measurements (Bjork polygon) in different anteroposterior (AP) skeletal relationships using Bjork-Jarabak analysis.

Materials and Methods: Pretreatment lateral cephalograms of 288 (146 women, 142 men, mean ages 21.24 $\pm$ 2.72 years and 22.94 $\pm$ 3.28 years, respectively) adult patients were divided into Class I, II, and III skeletal relationships according to their ANB angle. Linear and angular measurements of Bjork polygon were measured and compared among different skeletal relationships. Analysis of variance was performed to detect the differences among groups. Independent-sample *t*-test was used to detect differences between men and women.

Results: The Class II skeletal relationship has a significantly larger saddle angle than Class III does ($P < .05$), whereas Class III has a significantly larger gonial angle than Class II does ($P < .05$). The articular angle and sum of Bjork polygon angles were not significantly different among groups ($P > .05$). Anterior (N-S) and posterior (S-Ar) cranial base lengths were similar in the different AP skeletal relationships ($P > .05$). The ramal height and body of the mandible length were significantly larger in Class III compared with Class I and II ($P < .05$). Women had a significantly larger articular angle than men did ($P < .05$), although men had significantly larger linear measurements of Bjork polygon than women did ($P < .05$).

Conclusions: The Class III skeletal relationship has a smaller saddle angle and larger mandibular length and gonial angle. Men have a larger cranial base and mandibular linear measurements and a smaller articular angle compared with women. (*Angle Orthod.* 2022;92:613–618.)

KEY WORDS: Cephalometric; Bjork polygon; Cranial base measurements

INTRODUCTION

The understanding of facial growth and development is necessary for proper orthodontic diagnosis and treatment planning. Cranial base growth is linked to the overall growth of facial bones, especially the maxilla and mandible, either directly or indirectly.[1,2] The cranial base consists of anterior and posterior parts, where the maxilla is directly attached to the anterior part through growth sutures and the mandible is indirectly attached to the posterior part through the temporomandibular joint. Therefore, any change in the amount and/or direction of growth of the cranial base can have direct or indirect effects on the developing maxilla and mandible.[3]

Previous studies[4–6] found that cranial base angular and linear measurements tended to decrease gradually in skeletal anteroposterior (AP) relationships II, I, and III, respectively. Proff et al.[5] found that cranial base length and cranial base angle were reduced in subjects with Class III sagittal relationship compared with those with other skeletal relationships. In addition, Chin et al.[6] suggested that, when the cranial base angle increased, SNB angle decreased. However, other studies[7–9] could not detect such a correlation between sagittal skeletal relationships and cranial base measurements.

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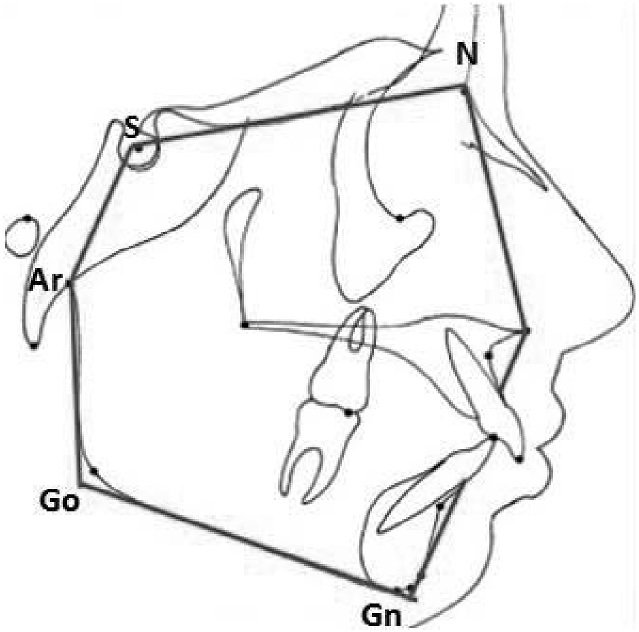

Figure 1. Bjork polygon linear and angular measurements.

It was thought that cranial base angle or flexure angle (N-S-Ar) played an important role in the development of malocclusion. Flattening of this angle can result in more posterior positioning of the glenoid fossa and therefore a greater tendency toward backward positioning of the mandible. In contrast, reduction of the cranial base angle can result in more forward positioning of the glenoid fossa and a tendency toward a Class III skeletal relationship.

Bjork-Jarabak analysis can be a useful tool for understanding the relationship between cranial base growth and the developing maxilla and mandible.[2] It was proposed that, if the sum of Bjork polygon angles was greater than 400°, the mandible tended to have backward growth rotation, whereas if the sum was less than 392°, the mandible tended to have forward growth rotation.

The influence of cranial base angulation and linear measurements as a factor in the development of AP jaw relationships remains a matter of debate. Therefore, the aim of this study was to assess the linear and angular cranial base measurements in different AP skeletal relationships using Bjork-Jarabak analysis.

MATERIALS AND METHODS

This retrospective cross-sectional study was based on the pretreatment lateral cephalograms of 288 Caucasian adult orthodontic patients (146 women, 142 men; mean ages of 21.24 ± 2.72 and 22.94 ± 3.28 years, respectively) attending orthodontic clinics at the dental teaching clinics/Jordan University of Science and Technology. To access patient files, ethical approval was granted by the Institutional Research Board at Jordan University of Science and Technology. All subjects were Caucasians from the Jordanian population with an average maxillary to mandibular plane angle (MMPA) of 27° ± 5). Patients with a history of previous orthodontic treatment, orthognathic treatment, craniofacial anomalies, facial trauma, or detected asymmetries were excluded.

Lateral cephalograms were in centric occlusion using an Orthoslice 1000 C (Marne La Vallee Cedex 2, France) with a cephalostat at 64 KVp, 16 Ma, and 0.64-second exposure, according to the manufacturer's instructions.

Cephalometric Analysis

Lateral cephalograms were hand traced in a dark room under the same standardized technique. Magnification of radiographs was adjusted using the radiopaque ruler (calibration marker). Points and lines were marked with a 3H pencil. All measurements were performed by the same investigator (E.A.M.) to reduce interexaminer differences.

The measurements derived from Björk-Jarabak analysis (Figure 1) included linear and angular measurements of a Bjork polygon, as presented in Table 1. In addition, the ANB angle (angle formed between point A–Nasion–point B) was measured and used to classify AP skeletal relationships into three

Table 1. Cranial Base (Bjork Polygon) Linear and Angular Measurements Used in This Study

Measurement	Definition
Linear measurements	
Sella-Nasion (S-N)	Distance between point Nasion and point Sella. This represents the anterior cranial base length.
Sella-Articulare (S-Ar)	Distance between point Sella and point Articulare. This represents the posterior cranial base length.
Articulare-Gonion (Ar-Go)	Distance between point Articulare and point Gonion. This represents the ramal height.
Gonion-Gnathion (Go-Gn)	Distance between point Gonion and point Gnathion. This represents the body of mandible length.
Angular measurements	
Saddle angle (N-S-Ar)	Angle formed between Nasion-Sella-Articulare.
Articular angle (S-Ar-Go)	Angle formed between Sella-Articulare-Gonion.
Gonial angle (Ar-Go-Gn)	Angle formed between Articulare-Gonion-Gnathion.
Sum of Bjork polygon angles	Sum of saddle, articular, and gonial angles.

Table 2. Distribution of the Selected Sample According to the AP Skeletal Relationship

Skeletal Relationship	ANB, n (Mean ± SD)		
	Women	Men	Total No.
Class I	50 (2.82 ± 0.79)	44 (3.09 ± 0.84)	94 (2.95 ± 0.82)
Class II	49 (6.00 ± 1.20)	50 (6.08 ± 1.20)	99 (6.04 ± 1.19)
Class III	47 (−0.75 ± 1.75)	48 (−1.66 ± 1.59)	95 (−1.21 ± 1.26)
Total	146 (2.74 ± 2.03)	142 (2.54 ± 2.67)	288 (2.64 ± 2.36)

groups: Class I, II, or III (Class I: ANB angle between 2–4°, II: ANB angle >4°; and III: ANB angle <2°).

Sample Size Calculation

The G*power 3.1.9 program was used to calculate the sample size. A total sample size estimate of 255 subjects (85 subjects per group) was determined, assuming a small effect size difference (0.25) among groups at a conventional alpha level (0.05) and desired power (1 – β) of 0.90.

Error of the Method

Thirty lateral cephalograms were randomly selected and reanalyzed after a 1-month interval. The intraclass correlation coefficient (ICC) was used to measure intraexaminer reliability.

Statistical Analysis

Statistical Package for the Social Sciences (version 22.0; IBM Corp., Armonk, NY) was used for data analysis. Normal distribution was confirmed by Shapiro-Wilk tests and Q-Q normal plot. Descriptive statistics (means and standard deviations) were calculated for all of the measured variables. To assess the differences among groups, analysis of variance was used. Multiple pairwise comparisons were assessed using Bonferroni adjustment. Gender differences were detected using the independent-sample *t*-test. Statistical significance was predetermined as $P \leq .05$.

RESULTS

Error of the Method

A high correlation was found between the first and second measurements (ICC = 0.92).

Sample Characteristics

The distribution of the sample according to AP skeletal relationships is shown in Table 2. The age and gender distribution were similar among groups.

Cranial Base Measurement in Different AP Skeletal Relationships

Angular measurements

The means and standard deviations (SDs) of angular cranial base measurements (Bjork polygon angles) are shown in Table 3. Statistically significant differences among groups were found in the saddle and gonial angles ($P < .05$), whereas the articular angle and the sum of the Bjork polygon angles (saddle, articular, and gonial) were not significantly different between Class I, II, and III skeletal relationships ($P > .05$).

The saddle angle was found to be significantly larger in Class II compared with Class III skeletal relationships ($P < .05$), with a mean difference of 2.17°. However, there was no significant difference in saddle angle between Class I and Class II or between Class I and Class III groups. On the other hand, gonial angle was found to be highly significantly larger in the Class III compared with Class II skeletal relationships ($P < .001$), with a mean difference of 3.62°. No significant

Table 3. Means and Standard Deviations (SDs) of Cranial Base (Bjork Polygon) Measurements in Different AP Skeletal Relationships[a]

Cranial Base Measurements	Class I Mean (SD)	Class II Mean (SD)	Class III Mean (SD)	Difference Class I to Class II	Difference Class I to Class III	Difference Class II to Class III
Saddle angle, °	124.12 (5.08)	125.56 (5.23)	123.39 (5.39)	−1.44	0.73	2.17*
Articular angle, °	146.65 (7.03)	146.17 (7.07)	145.07 (6.90)	0.48	1.56	1.10
Gonial angle, °	126.45 (6.72)	124.63 (6.13)	128.24 (5.76)	1.82	−1.80	−3.62***
Bjork sum angles	397.21 (7.65)	396.35 (7.00)	396.71 (6.52)	0.86	0.51	−0.35
NS, mm	71.42 (3.56)	71.48 (3.23)	71.64 (3.86)	−0.06	−0.223	−0.16
S-Ar, mm	35.98 (4.02)	36.15 (3.27)	35.51 (3.97)	−0.17	0.47	0.64
Ar-Go, mm	46.32 (5.13)	45.34 (5.35)	48.22 (5.08)	0.98	−1.90*	−2.87***
Go-Gn, mm	76.64 (5.20)	76.46 (5.27)	80.26 (4.98)	0.19	−3.61***	−3.80***

[a] Results are based on an analysis of variance test.
* $P < .05$; ** $P < .01$; *** $P < .001$.

differences were detected in gonial angle between Class I and III or between the Class I and II groups.

Linear measurements

The means and SDs of the linear measurements of Bjork polygon angles (sides) in different AP skeletal relationships are shown in Table 3.

The anterior and posterior cranial base lengths were not significantly different among groups ($P > .05$). However, ramal height and the length of the body of the mandible were significantly different among groups ($P < .05$) and both were significantly larger in Class III than in Class I and Class II groups. The ramal height was larger in Class III compared with Class I ($P < .05$) and Class II ($P < .001$), with a mean difference of 1.90 mm and 2.87 mm, respectively. The length of the body of the mandible was highly significantly larger in Class III compared with Class I and Class II ($P < .001$), with a mean difference of 3.61 and 3.80 mm, respectively.

Gender Differences

Means and SDs of cranial base measurements in men and women and the differences between them are shown in Table 4. Women were found to have a significantly larger articular angle than men ($P < .05$), with a mean difference of 1.85°. On the other hand, gender differences were not detected in the saddle and gonial angles.

Men showed significantly ($P < .05$) larger anterior (N-S) and posterior (S-Ar) cranial base lengths compared with women, with mean differences of 2.79° and 2.81°, respectively. Ramal height (Ar-Go) and body of the mandible length (G0-Gn) were also significantly ($P < .05$) larger in men compared with women, with mean differences of 3.47° and 2.49°, respectively.

Table 4. Means and Standard Deviations (SDs) of Cranial Base (Bjork Polygon) Measurements in Men and Women and the Differences Between Them[a]

Cranial Base Measurements	Men Means (SD)	Women Means (SD)	Difference Between Men and Women
Saddle angle, °	124.80 (5.14)	123.96 (5.43)	0.84
Articular angle, °	145.11 (7.28)	146.96 (6.70)	−1.85*
Gonial angle, °	126.75 (6.23)	126.08 (6.51)	0.67
Bjork sum angles	396.85 (7.21)	396.66 (6.92)	0.19
NS, mm	72.92 (3.38)	70.13 (3.15)	2.79*
S-Ar, mm	37.30 (3.77)	34.49 (3.20)	2.81*
Ar-Go, mm	48.36 (5.66)	44.89 (4.33)	3.47**
Go-Gn, mm	79.02 (5.68)	76.53 (4.87)	2.49*

[a] Results are based on an independent-sample *t* test.
* $P < .05$; ** $P < .01$.

DISCUSSION

AP growth and positioning of the cranial base are highly associated with the midface and position of the mandible. This can play an important role in jaw growth and directly influence the skeletal pattern.[10,11]

All measurements in this study were performed on lateral cephalograms, which have been extensively used to provide guidelines for diagnosis and treatment planning. Bjork-Jarabak analysis was used in this study, because it was shown to be very useful when assessing facial characteristics through only a few measurements.[12,13]

Nanda[14] suggested that most of the growth changes of the facial tissues would predominantly take place before the age of 18 years. Accordingly, only adult patients (>18 years) were included in this study to ensure that most of the growth changes had been attained.

Anterior cranial base length (N-S) is the linear distance between points N and S, while the posterior cranial base length is controversial, defined as either S-Ba or S-Ar linear distances. Björk[15] suggested that S-Ar was more easily visualized, whereas Varjanne and Koski[16] considered that S-Ar is too distant and suggested the use of Ba to measure the skull base angle. Many studies supported that the two points (Ba) and (Ar) were highly correlated and the differences between them were negligible.[17,18] Accordingly, S-Ar was used in this study, because the Bjork polygon was used in which (S-Ar-Go) is the articular angle of the polygon, to assess linear and angular cranial base measurements.

In the present study, the saddle angle was found to be smaller in a Class III compared with Class II skeletal relationship. This was in agreement with findings reported by previous studies.[5,6,19–22] On the other hand, Thiesen et al.[23] reported that the saddle angle was not different among different skeletal relationships. However, the sample in the study by Thiesen et al.[23] included growing subjects with an age range between 8 and 17 years old, so the result might not have reflected the adult size after growth completion.

No significant difference in saddle angle was found between Class I and Class II or between the Class I and Class III groups. This was in agreement with previous studies.[23–26] The only difference was between the Class II and Class III skeletal relationships, indicating more forward positioning of the posterior cranial base and, thus indirectly, more forward positioning of the mandible, which is a more common finding in Class III.

In the current study, the articular angle was similar among the different AP skeletal relationships. This was in agreement with Hegde et al.[27] Rodriguez-Cardenas et al.,[28] on the other hand, found that articular angle was increased in the Class I skeletal relationship compared with other skeletal relationships. The differences between the current results and the previous studies could have been related to the nature of the samples and included age groups. Also, Rodriguez-Cardenas et al.[28] used cone-beam computed tomography (CBCT)–synthesized lateral cephalograms, which could be different from the lateral cephalograms used in the current study.

Gonial angle was larger in Class III compared with the Class II skeletal relationship. This was supported by the findings of Gasgoos et al.,[29] who found that the gonial angle was larger in the Class III group. Those authors suggested that the increase in the gonial angle resulted from the increase in the effective length of the mandible (Ar-Gn).

The sum of the Bjork polygon angles was similar among the groups in the present study. This was also found by Rodriguez-Cardenas et al.,[28] who reported that sum of the Bjork polygon angles showed no significant differences among the three sagittal classes. This finding can also be explained by the fact that the current sample included only those patients with average MMPA. This angle is affected by growth rotation of the mandible, which is linked to the sum of Bjork polygon angles.

The similarity of the anterior and posterior cranial base lengths in the studied groups coincided with the findings of previous studies[5,9,19,22,30] and contradicted that reported by Chang et al.[31] and Gong et al.,[32] who found that anterior and total cranial base lengths were smaller in Class III than in the Class I and II groups. The differences might have been related to the sample included and the age range studied. For example, Chang et al.[31] studied a sample of Chinese patients whose craniofacial features might be different when compared with a Caucasian population.

In the present study, ramal height (Ar-Go) was smaller in the Class II skeletal relationship compared with the Class I and Class III groups, whereas it was similar between Class I and Class III subjects. This was in agreement with Dong et al.,[33] who found that patients with a Class II skeletal relationship tended to have smaller ramal height (Co-Go) when compared with Class I subjects.

Mandibular body length was larger in the Class III compared with Class II skeletal relationship in the present study. This was supported by the findings of a previous study.[5] Gasgoos et al.[29] also found that subjects with a Class III skeletal relationship had a larger mandibular body length (Go-Pog) and larger effective mandibular length (Ar-Gn) than Class II subjects.

The body length of the mandible was larger in the Class III group. This agreed with the findings of previous studies that reported a longer mandible in Class III cases.[29,34,35]

No differences were found in angular measurements between men and women except for articular angle. This was supported by previous findings of Rodriguez-Cardenas et al.,[28] who reported that the articular angle was increased in female patients. In the present study, linear measurements were found to be significantly greater in male patients compared with female patients. These findings were supported by previous studies.[36–38] In addition, this was in agreement with Valiathan et al.,[39] who found that male patients had longer anterior and posterior cranial base lengths, ramal heights, and mandibular body lengths. They also found that females tended to have larger articular angles than males did.

CONCLUSIONS

- The Class II skeletal relationship has a larger saddle angle compared with Class III.
- The Class III skeletal relationship has a larger gonial angle compared with Class II.
- The Class III skeletal relationship has a larger ramal height and body of the mandible length compared with Class I and Class II.
- Articular angle, anterior (N-S), and posterior (S-Ar) cranial base lengths are not different among different skeletal relationships.
- Females tend to have a larger articular angle than males do.
- Males have a longer cranial base length (anterior and posterior) and longer ramal height and body length of the mandible than females do.

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REFERENCES

1. Björk A. Prediction of mandibular growth rotation. *Am J Orthod*. 1969;55:585–599.
2. Jarabak JR, Fizzel JA. *Technique and Treatment With Light Wire Appliances*. 2nd ed. St Louis, Mo: CV Mosby; 1972.
3. Björk A, Skieller V. Normal and abnormal growth of the mandible: a synthesis of longitudinal cephalometric implant studies over a period of 25 years. *Eur J Orthod*. 1983;5:1–46.
4. Dibbets JM. Morphological associations between the Angle classes. *Eur J Orthod*. 1996;18:111–118.
5. Proff P, Will F, Bokan I, Fanghänel J, Gedrange T. Cranial base features in skeletal Class III patients. *Angle Orthod*. 2008;78:433–439.
6. Chin A, Perry S, Liao C, Yang Y. The relationship between the cranial base and jaw base in a Chinese population. *Head Face Med*. 2014;101:31–39.

7. Rothstein T, Phan XL. Dental and facial skeletal characteristics and growth of females and males with Class II Division 1 malocclusion between the ages of 10 and 14 (revisited). Part II. Anteroposterior and vertical circumpubertal growth. *Am J Orthod Dentofacial Orthop*. 2001;120:542–555.
8. Wilhelm BM, Beck FM, Lidral AC, Vig KW: A comparison of cranial base growth in Class I and Class II skeletal patterns. *Am J Orthod Dentofac Orthop*. 2001;119:401–405.
9. Dhopatkar A, Bhatia S, Rock P. An investigation into the relationship between the cranial base angle and malocclusion. *Angle Orthod*. 2002;72:456–463.
10. Moyers RE. *Ortodontia*. 4th ed. Rio de Janeiro: Guanabara Koogan; 1991.
11. Santos-Pinto A, Martins JCR, Uetanabaro T, Sakima T, Mendes AJD. Influência do grau de deflexão da base craniana no relacionamento ântero-posterior dos maxilares. *Ortodontia*. 1983;16:5–9.
12. West KS, McNamara JA Jr. Changes in the craniofacial complex from adolescence to midadulthood: a cephalometric study. *Am J Orthod Dentofacial Orthop*. 1999;115:521–532.
13. Pecora NG, Baccetti T, McNamara JA Jr. The aging craniofacial complex: a longitudinal cephalometric study from late adolescence to late adulthood. *Am J Orthod Dentofacial Orthop*. 2008;134:496–505.
14. Nanda SK. Growth patterns in subjects with long and short faces. *Am J Orthod Dentofacial Orthop*. 1990;98:247–258.
15. Björk A. Cranial base development. *Am J Orthod*. 1955;41: 198–255.
16. Varjanne I, Koski K. Cranial base, sagittal jaw relationship and occlusion: a radiological: craniometric appraisal. *Proc Finn Dent Soc*. 1982;78:179–183.
17. Björk A. Cranial base development: a follow-up X-ray study of the individual variation in growth occurring between the ages of 12 and 20 years and its relation to brain case and face development. *Am J Orthod*. 1955;41:198–225.
18. Bhatia SN, Leighton BC. *A Manual of Facial Growth: A Computer Analysis of Longitudinal Cephalometric Growth Data*. Oxford, UK: Oxford University Press; 1994.
19. Kamak H, Catalbas B, Senel B. Cranial base features between sagittal skeletal malocclusions in Anatolian Turkish adults: is there a difference? *J Orthod Res*. 2013;1:52–56.
20. Klocke A, Nanda RS, Kahl-Nieke B. Role of cranial base flexure in developing sagittal jaw discrepancies. *Am J Orthod Dentofacial Orthop*. 2002;122:386–391.
21. Hussein FA, Al-Khalifa HN, Salama AE. A cephalometric appraisal of cranial base configuration in a sample of Egyptian patients with skeletal Class III malocclusion. *Egypt Dent J*. 2012;58:2941–2949.
22. Awad AM, Gaballah SM, Gomaa NE. Relationship between cranial base and jaw base in different skeletal patterns. *Orthod Waves*. 2018;77:125–133.
23. Thiesen G, Pletsch G, Zastrow MD, et al. Comparative analysis of the anterior and posterior length and deflection angle of the cranial base, in individuals with facial pattern I, II and III. *Dental Press J Orthod*. 2013;18:69–75.
24. Ildwein M, Bacon W, Turlot JC, Kuntz M. Spécificités et discriminants majeurs dans une population de Classe II division 1 [Specifications and major discriminants in a Class II division 1 population]. *Rev Orthop Dento Faciale*. 1986;20: 197–208.
25. Varrela J. Longitudinal assessment of Class II occlusal and skeletal development in the deciduous dentition. *Eur J Orthod*. 1993;15:345.
26. Varrela J. Early developmental traits in Class II malocclusion. *Acta Odontol Scand*. 1998;56:375–377.
27. Hegde S, Revankar A, Patil A. Evaluating condylar position in different skeletal malocclusion patterns: a cephalometric study. *APOS Trends Orthod*. 2015:5(3):111.
28. Rodriguez-Cardenas YA, Arriola-Guillen LE, Flores-Mir C. Björk-Jarabak cephalometric analysis on CBCT synthesized cephalograms with different dentofacial sagittal skeletal patterns. *Dental Press J Orthod*. 2014;19(6):46–53.
29. Gasgoos SS, Al-Saleem NR, Awni KM. Cephalometric features of skeletal Class I, II and III (a comparative study). *Al–Rafidain Dent J*. 2007;7:122–130.
30. Polat Ö, Kaya B. Changes in cranial base morphology in different malocclusions. *Orthod Craniofac Res*. 2007;10: 216–221.
31. Chang HP, Hsieh SH, Tseng YC, Chou TM. Cranial-base morphology in children with Class III malocclusion. *Kaohsiung J Med Sci*. 2005;21:159–165.
32. Gong A, Li J, Wang Z, et al. Cranial base characteristics in anteroposterior malocclusions: A meta-analysis. *Angle Orthod*. 2016;86:668–680.
33. Dong Q, Shi H, Jia Q, Tian Y, Zhi K, Zhang L. Analysis of three-dimensional morphological differences in the mandible between skeletal Class I and Class II with CBCT fixed-point measurement method. *Scanning*. 2021;2021:9996857.
34. Battagel MJ. The etiological factors in Class III malocclusion. *Eur J Orthod*. 1993;15:347–370.
35. Chang HP, Kinoshita Z, Zawamoto T. Craniofacial pattern in Class III deciduous dentition. *Angle Orthod*. 1992;62:139–144.
36. Alexander AEZ, McNamara JA, Franchi L, Baccetti T. Semi longitudinal cephalometric study of craniofacial growth in untreated Class III malocclusion. *Am J Orthod Dentofacial Orthop*. 2009;135:701–714.
37. Zeng XL, Forsberg CM, Aronson SL. Craniofacial morphology in Chinese and Swedish children with Angle Class I and Class II occlusal relations. *Australian Orthod J*. 1998;15: 168–176.
38. Johannsdottir B, Thordarson A, Magnusson TE. Craniofacial morphology in 6-year-old Icelandic children. *Eur J Orthod*. 1999;21:283–290.
39. Valiathan M, Valiathan A, Ravinder V. Jarabak cephalometric analysis reborn. *J Indian Orthod Soc*. 2001;35:66–76.