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Correlation between Cranial Base, Mandible, and Hyoid Bone Position in Different Anteroposterior Skeletal Malocclusions: A Cephalometric Study

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Abstract

Background Development of malocclusion can be promptly recognized through an understanding of the optimal position of the bone structures in the orofacial system and their relationship to the cranial base and jaw base. The aim of this study was to assess the relationship between the cranial base, mandible, and hyoid bone in different anteroposterior skeletal malocclusions.

Materials and Methods This retrospective study evaluated 120 lateral cephalometric radiographs of individuals aged between 15 and 30 years. The subjects were classified using Burstone's analysis into three groups based on the N perpendicular to point A and N perpendicular to point B. The collected lateral cephalograms of the selected individuals were analyzed using Nemoceph v.12 software (Nemotec, Spain). The nasion-sella-articulare (NSAr), hyoidale angle (C3HyD), sella-articulare-hyoid angle (SArHy), and nasion-sella-hyoid (NSHy) angles were measured and compared among all the three groups.

Results In the present study, considering the various angles among the three study groups, a statistically significant difference was observed for the SArHy angle ($p < 0.05$). However, the saddle angle (NSAr) and hyoidale angle (C3HyD) showed no statistically significant difference between the three study groups. Post hoc Bonferroni test was applied to compare the differences between two groups. A statistically significant difference ($p < 0.05$) was observed between class I and class II and between class II and class III groups.

Conclusion Though the findings of the present study concluded that there is no variation in saddle angle among the three groups, the significant association of SArHy angle among class I, class II, and class III skeletal relationships, suggests an adaptation of the hyoid bone position in various skeletal patterns. We also suggest that the posterior positioning of the hyoid bone is related to skeletal class II malocclusion, whereas a forward positioning of the hyoid bone is related to skeletal class III malocclusion.

Keywords
- ► cranial base
- ► mandible
- ► hyoid bone
- ► saddle angle
- ► malocclusion

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Introduction

Understanding skeletal deformities that contribute to malocclusion is of paramount importance in the field of orthodontics and dentofacial orthopaedics. The clinical diagnosis has a considerable impact on the treatment and orthodontic mechanics used. It is therefore crucial to identify the factors contributing to the etiology of skeletal discrepancies.

Existing literature have established a correlation between the morphology of the cranial base and the relationship between the jaw base using cephalometric radiographs.[1] The cranial base establishes the limit of the skull and facial skeleton. The mandible is connected to the posterior cranial base, whereas the nasomaxillary complex is connected to the anterior cranial base. Therefore, the structure and form of the anterior cranial base have a significant role in determining the position of the maxilla.[2] However, in the relationship to the mandible, any alteration in the posterior cranial base will impact the glenoid fossa's displacement, which in turn will directly impact the mandibular position.[2] Therefore, there is a strong relationship between the alteration in the cranial base and the sagittal malposition of the jaws. The mandibular position depends on the length and direction of the condyle's growth as well as the displacement of the mandibular body caused by the sutural growth of the cranial base.[2]

Cranial base angle: The cranial base angle or saddle angle is measured radiographically as the angle between the sella-nasion-basion (NSBa) or sella-nasion-articulare (NSAr) points. At birth, the angle is approximately 142 degrees, but then it reduces to 130 degrees at age of 5 years.[3] The angle is comparatively stable between the ages of 5 and 15 years.[4] The development and growth of cranium directly affect the position of the jaws. This can be explained based on the fact that a decrease in the angle formed between the anterior and middle cranial fossae may result in an increase in class III tendency as the flexure of the cranial base decreases, whereas as the angle between the fossae increases, so would the class II tendency.[5] In a systematic review, Almeida et al reported that an obtuse angle at the cranial base predisposes to class II division I malocclusion. In contrast, an acute angle at the cranial base may cause the mandible to be positioned anteriorly and the subsequent progression to class III malocclusions.[6] Thus, understanding the correlation between the cranial base to the jaw base provides a key to understanding the development of malocclusion.

The hyoid bone and its relation to facial patterns and probable influence has garnered a great deal of attention during the last two decades.[7] The hyoid bone is an anatomical structure that relates the position of the head to the neck. The hyoid bone is attached to the cranial base and the mandible with various muscular attachments. This bone is crucial for carrying out some physiological functions such as breathing, speaking, and swallowing. Researchers have demonstrated that changes in the mandibular position are related to the changes in the hyoid bone and that the position of the hyoid bone responds to changes in the anteroposterior position of the head.[7,8] Previous studies which examined the location of the hyoid bone after 3 years of chin cup therapy revealed a backward and inferior displacement of the hyoid bone. Within the context of skeletal class I malocclusion, an alteration in the position of the hyoid bone in relation to the mandible have also been described.[9,10] This may be due to the musculature and ligamentous attachments of the hyoid bone, thereby acting as a functional interface between the cranium, cervical spine, and mandible. Thus, any alterations in the hyoid bone may provide significant functional ramifications. The findings of these studies suggest that the positional alteration of the hyoid bone is closely related to malocclusion.

Thus, the aim of this study was to assess the correlation between the cranial base, mandible, and hyoid bone positional changes in different anteroposterior skeletal malocclusions.

Materials and Methods

This retrospective study included lateral cephalograms of 120 individuals. The subjects were classified using Burstone's analysis into three groups (skeletal class I, skeletal class II, and skeletal class III) based on the values, N⊥A (Male = 0 ± 3.7 mm, Female = –2 ± 3.7 mm) and N⊥B (Male = –5.3 ± 6.7 mm, Female = –6.9 ± 4.3 mm). The sample size was calculated using G*Power software (version 3.1) with a level of significance (alpha error) of 5%, 80% power, and an effect size of 0.7 for the three groups. The total sample determined is 120, that is, 40 in each group.

All the records for the study were selected from patients who reported to the department of orthodontics seeking orthodontic treatment during the years 2020 to 2022. The data were collected from the archives of the Department of Orthodontics at AB Shetty Memorial Institute of Dental Sciences in Mangalore, Karnataka, India, following the Institutional Ethical approval (ABSM/EC/67/2021).

The following cephalometric landmarks were used (►**Fig. 1**)[11]:

Nasion (N): The deepest point on the frontonasal suture.
Sella (S): The midpoint of the shadow of the pituitary fossa (sella turcica).
Articulare (Ar): An intersection point of the posterior margin of the mandible and the basilar border of the occipital bone.
Point D: A lateral cephalogram shows this location as the center of the mandibular symphysis.
Hyoidale (Hy): The most superior, anterior point on the body of the hyoid bone.
C3: The point at the most inferior anterior position on the third cervical vertebra.

Angular Measurements Taken in the Study (►Fig. 1)

(1) Saddle angle (NSAr): Lines connecting nasion to sella and sella to articulare form this angle. It represents the cranial base flexure. (2) Hyoidale angle (C3HyD): A line connecting C3 to hyoidale and from hyoidale to point D forms an angle. One can read the hyoidale angle as the superior angle formed by the two planes. (3) SArHy angle: A line joining sella and

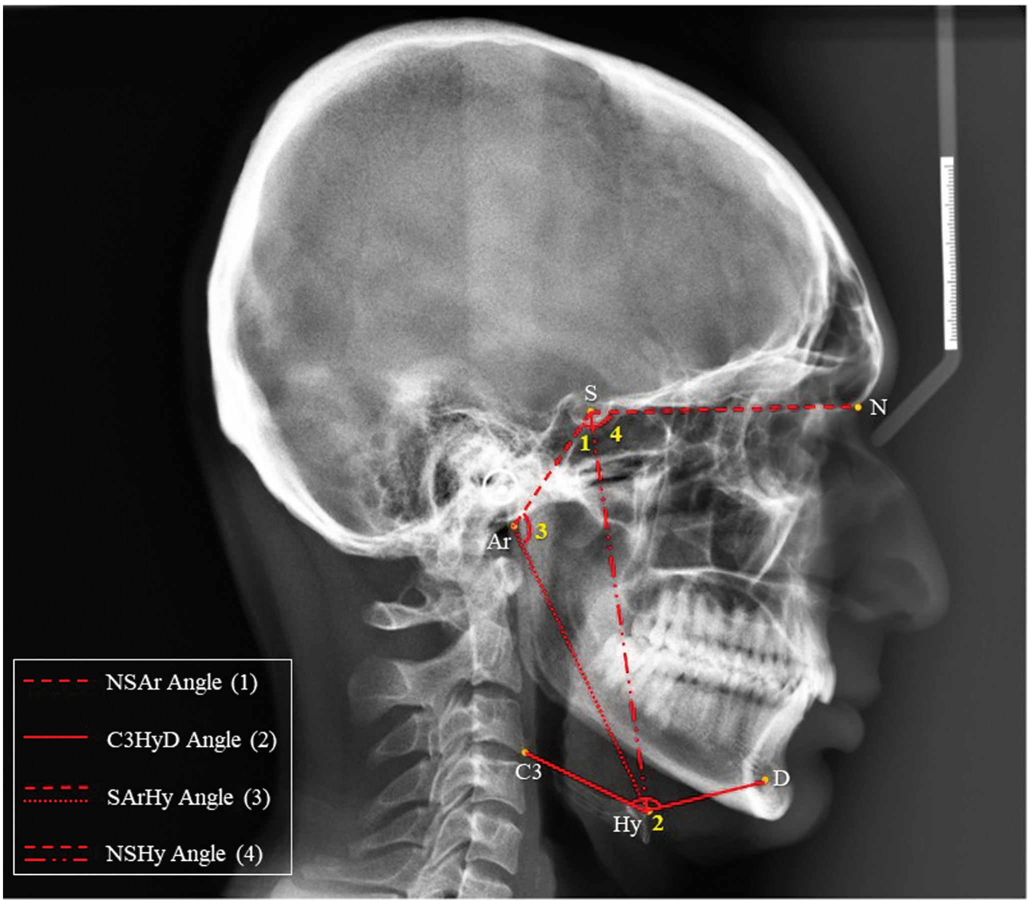

Fig. 1 Lateral cephalogram illustrating nasion-sella-articulare (NSAr), hyoidale angle (C3HyD), sella-articulare-hyoid angle (SArHy), and nasion-sella-hyoid (NSHy) angles.

articulare and a line joining articulare and hyoidale form this angle. (4) NSHy angle: A line joining nasion to sella and sella to hyoidale forms this angle.

Statistical Analysis

Descriptive statistics of quantitative variables were analyzed by using mean and standard deviation. Descriptive statistics of qualitative variables were summarized by using counts/percentages. Each of the parameters under the different study groups was analyzed by using analysis of variance (ANOVA). If ANOVA was significant, a post hoc test was conducted. Carl–Pearson correlation was used to find the correlation between the different parameters in the study. A p-value of < 0.05 was considered to be statistically significant. SPSS software (Version 22) was used to analyze the collected data.

Results

Comparison of NSAr, C3HyD, SArHy, and NSHy Angle between the Three Groups

1. Saddle angle (NSAr)

The saddle angle is formed by the line joining nasion to sella and the line joining sella to articulare. It represents the flexure of the basicranium. In class I, the mean saddle angle was 122.76 degrees ± 5.40 and 122.43 degrees ± 5.68. However, there was no statistical difference observed among the three study groups ($p > 0.05$) (►**Table 1** and ►**Fig. 2**).

2. Hyoidale angle (C3hyD)

The hyoidale angle is formed by the line joining C3 to hyoidale and the line joining hyoidale to point D. In the skeletal class I group, the mean hyoidale angle was 166.87 degrees ± 17.87, while in class II and class III it was 162.69 degrees ± 15.05 and 165.90 degrees ± 15.25, respectively. In this study, among the three groups, class II showed decreased hyoidale angular measurement, followed by class III and class I. No significant difference was found between the class I, class II, and class III groups ($p > 0.05$) (►**Table 1** and ►**Fig. 2**).

3. SArHy angle

The SArHy angle is formed by the line joining sella to articulare and the line joining articulare to hyoidale. Class I had a mean SArHy angle of 128.12 degrees ± 6.75, whereas the mean angular measurement of the SArHy angle was 133.89 degrees ± 5.79 and 129.74 degrees ± 6.50 in class II and class III, respectively. Class II showed the highest SArHy angular measurement, followed by class III and class I. A statistically significant difference was observed for the SArHy angle when compared between the three

Table 1 Comparison of NSAr, C3HyD, SArHy, and NSHy angle between the three groups

Variable	Group	*N*	Mean	Standard deviation	Minimum	Maximum	*p*-Value
NSAr	Class I	40	122.76	4.96	115.00	140.00	0.948
	Class II	40	122.76	5.40	110.00	133.00	
	Class III	40	122.43	5.68	109.00	139.00	
C3HyD	Class I	40	166.87	17.87	116.50	197.00	0.481
	Class II	40	162.69	15.05	131.00	205.00	
	Class III	40	165.90	15.25	132.50	202.00	
SArHy	Class I	40	128.12	6.75	113.50	145.00	**0.001**[a]
	Class II	40	133.89	5.79	123.00	150.00	
	Class III	40	129.74	6.50	121.00	147.00	
NSHy	Class I	40	89.03	8.23	81.00	135.00	0.061
	Class II	40	90.25	4.42	79.00	99.00	
	Class III	40	87.21	3.21	76.50	93.50	

Abbreviations: C3HyD, hyoidale angle; NSAr, nasion-sella-articulare; NSHy, nasion-sella-hyoid; SArHy, sella-articulare-hyoid angle.

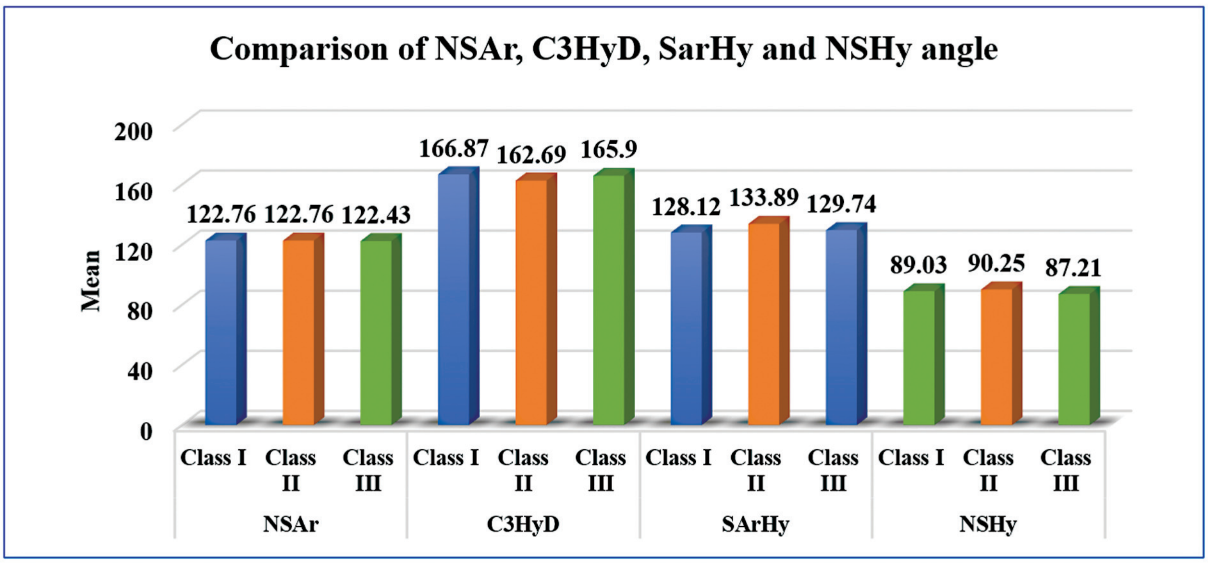

Fig. 2 Comparison of nasion-sella-articulare (NSAr), hyoidale angle (C3HyD), sella-articulare-hyoid angle (SArHy), and nasion-sella-hyoid (NSHy) angles among different malocclusion groups.

groups ($p < 0.05$) (►**Table 1** and ►**Fig. 2**). A post hoc Bonferroni was applied to check the difference between the two groups. A statistically significant difference ($p < 0.05$) was observed between class I and class II, and between class II and class III; however, a nonsignificant difference was observed between class I and class III ($p > 0.05$) (►**Table 2**).

4. NSHy angle

The NSHy angle is formed by the line joining nasion to sella and the line joining sella to hyoidale. The mean angular measurement in class I was observed to be 89.03 degrees ±8.23, whereas the mean measurement was 90.25 degrees ±4.42 and 87.21 degrees ± 3.21 in class II and class III, respectively. In this study, the highest measurement was seen in the class II group followed by class I and class III. However, no statistically significant difference was found among the three groups ($p > 0.05$) (►**Table 1** and ►**Fig. 2**).

Discussion

The present study investigated the influence of the cranial base and positional alteration of the mandible and hyoid bone on different skeletal relationships and vice versa. In the present study, the sample was divided into three groups based on Burstone's analysis into skeletal class I, II, and III, respectively.

Our results revealed no variation in the saddle angle (NSAr) among the three groups (►**Table 1**) which was in accordance with the observations of Dhopatkar et al, Rothstein and Phan, and Polat and Kaya who also failed to find a positive impact of the cranial base angle in class I, class II, and

Table 2 Post hoc comparison of SArHy angle between two groups

Variable	Group	Group	Mean difference (I-J)	Standard error	Significance	Lower bound	Upper bound
SArHy	Section I	Class II	−5.76	1.42	**0.001**[a]	−9.22	−2.32
		Class III	−1.62	1.42	0.77	−5.07	1.83
	Section II	Class III	4.15	1.42	**0.01**[a]	0.70	7.60

Abbreviation: SArHy, sella-articulare-hyoid angle.
[a]Statistically significant ($p < 0.05$).

class III malocclusions, respectively.[12–14] This could be due to the reality that the temporomandibular joint is situated at the lateral borders of the cranial base which is spatially isolated from the mid-sagittal plane that provides the basis for cephalometric analysis and also depends on the length and direction of the condyle's growth as well as the displacement of the mandibular body. Therefore, changes in the cranial base angle may or may not always directly influence the alteration in the mandibular articulation due to the virtue of remoteness by the mandible in this region.[12] However, few studies evaluating the cranial growth pattern have observed variations in the saddle angle and cranial base angle among class I, class II, and class III malocclusions.[15,16]

Considering the hyoidale angle (C3HyD), the mean average in our study was highest among class I, followed by class III and class II. However, no significant difference was noted among all the three groups (►**Table 1**). In all the three groups, the hyoid bone was discovered to be centrally situated between the third cervical vertebra and the symphysis, with less variation in the anteroposterior location. Hence, there were not many changes observed in the angulations in all the three groups which was in agreement with the studies conducted by Amayeri et al and Bibby and Preston.[11,17]

The SArHy angle was assessed between skeletal class I, class II, and class III groups and was noticed to be statistically significant ($p < 0.05$). Class II showed the highest mean average followed by class III and class I (►**Table 1**). This indicates the adaptation of hyoid bone position in various skeletal malocclusions. When post hoc comparison was carried out a noteworthy difference was seen between class I and lass II malocclusions and among class II and class III malocclusions ($p < 0.05$). However, no significant differences were noted between class I and class III relationships ($p > 0.05$) (►**Table 2**). These findings were in accordance with the results of a similar study conducted by Chauhan et al, wherein differences in the angular inclination of the hyoid bone were noted between class I and class II malocclusions and between class II and class III malocclusions but no statistical differences were noted between class I and class III.[18] When observing at the angle SArHy, it is evident that if the angle increases it shows that the hyoid bone is posteriorly positioned with relation to the mandible and cranial base and anterior if the angle decreases. The current study is in agreement with the study of Mortazavi et al and Bilal, the hyoid bone is anteriorly located in cases of skeletal class I and class III and posteriorly in cases of skeletal class II. This may be due to the reduced size or backwardly positioned mandible in skeletal class II individuals or the inverse in class I and class III subjects.[8,19]

The present study evaluated the NSHy angle which signifies the hyoid bone position in relation to the cranial base. The class II group had the highest mean values, followed by the class I and class II groups. However, no statistically significant differences were noted between the three groups ($p > 0.05$) (►**Table 1**). This indicates a minor alteration in the hyoid bone position in different skeletal relationships. Similar findings were observed in a study conducted by Amayeri et al wherein it was observed that the hyoid bone was positioned backward in class II malocclusions and forward in class III malocclusions.[11]

Clinical Significance of NSAr, C3HyD, SArHy, and NSHy Angles

Anteroposterior relationships of the maxilla and mandible are key diagnostic skeletal relationships in orthodontics and maxillofacial surgery. Our findings suggest that an altered mandibular growth pattern could be related to changes in the hyoid bone, which in turn responds to variations in the cranial base morphology of each individual. Eventually, when an orthognathic surgery or functional appliance therapy is carried out on a patient, the hyoid bone is not noticed, despite its crucial role in numerous physiologic functions. Thereby, the various aforementioned angles play a pivotal diagnostic role in the planning of treatment strategies in different orthodontic procedures of various malocclusions.

Limitation and Future Prospect

Lastly, since conclusions cannot be drawn from a single study, further research in terms of longitudinal studies needs to be conducted to overcome the gender bias and also demonstrate the influence of cranial base angulations on mandible and hyoid bone position on skeletal relationships.

Conclusion

The present study was an attempt to assess the correlation between the cranial base, mandible, and hyoid bone positional changes in different anteroposterior skeletal malocclusions in which the following inferences were drawn after the statistical analysis: (1) the saddle angle (NSAr) showed no variation among the three groups, that is, the skeletal class I, class II, and class III; (2) SArHy angle showed a significant difference among skeletal class I, class II, and class III groups, which suggests an adaptation of the hyoid bone position in various skeletal relationships and correlation between the cranial base, mandible, and the hyoid bone; (3) skeletal class II had the highest NSHy angle values, followed by skeletal class I and class III relationships, this denotes that a posterior of the hyoid bone is associated with the skeletal class II individuals, whereas a forward positioning of the hyoid bone is associated with skeletal class III relationships.

Ethical Approval

The study was approved by the Institutional Ethics and Research committee, AB Shetty Memorial Institute of Dental Sciences, Constituent college of NITTE (Deemed to be University), Mangalore (protocol number: ABSM/EC/67/2021, date: 09.01.2021).

Authors' Contributions

All authors contributed at different stages of the project, read and approved the final manuscript.

Conflict of Interest

None declared.

References

1 Elgadir Ahmed AA, Abuaffan AH. Correlation between cranial base morphology and skeletal maloclusion in a sample of Sudanese orthodontic patients. J Dent Probl Solut 2020;7(02):90–95

2 Ferros I, Mora MJ, Obeso IF, Jimenez P, Martinez-Insua A. Relationship between the cranial base and the mandible in artificially deformed skulls. Orthod Craniofac Res 2016;19(04):222–233

3 Monirifard M, Sadeghian S, Afshari Z, Rafiei E, Sichani AV. Relationship between cephalometric cranial base and anterior-posterior features in an Iranian population. Dent Res J (Isfahan) 2020;17(01):60–65

4 Dileep S, Khader MA, Ali H, Paul K D, Narayan M, Jayan A. Cranial base parameters in adults with skeletal class I and class II skeletal pattern. J Orthod Sci 2022;11:41

5 Plachiyska KT, Krasteva S, Zlatev S, Krasteva S. Cephalometric evaluation of the cranial base in the Bulgarian population. Scr Sci Med Dent 2017;3(01):41–46

6 Almeida KCM, Raveli TB, Vieira CIV, Santos-Pinto AD, Raveli DB. Influence of the cranial base flexion on Class I, II and III malocclusions: a systematic review. Dental Press J Orthod 2017;22(05):56–66

7 Jose NP, Shetty S, Mogra S, Shetty VS, Rangarajan S, Mary L. Evaluation of hyoid bone position and its correlation with pharyngeal airway space in different types of skeletal malocclusion. Contemp Clin Dent 2014;5(02):187–189

8 Mortazavi S, Asghari-Moghaddam H, Dehghani M, et al. Hyoid bone position in different facial skeletal patterns. J Clin Exp Dent 2018;10(04):e346–e351

9 Firwana A, Wang H, Sun L, Wang J, Zhang WB. Relationship of the airway size to the mandible distance in Chinese skeletal Class I and Class II adults with normal vertical facial pattern. Indian J Dent Res 2019;30(03):368–374

10 Noorani MK, Adarsh K, Mishra K, Seth KG, Kalburgi MN, Sharan S. Comparative evaluation of different measurements of hyoid bone in different malocclusion in North Indian population. J Adv Med Dent Scie Res 2020;8(11):123–126

11 Amayeri M, Saleh F, Saleh M. The position of hyoid bone in different facial patterns: a lateral cephalometric study. Eur Sci J 2014;10(15):19–34

12 Dhopatkar A, Bhatia S, Rock P. An investigation into the relationship between the cranial base angle and malocclusion. Angle Orthod 2002;72(05):456–463

13 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(05):542–555

14 Polat OO, Kaya B. Changes in cranial base morphology in different malocclusions. Orthod Craniofac Res 2007;10(04):216–221

15 Klocke A, Nanda RS, Kahl-Nieke B. Role of cranial base flexure in developing sagittal jaw discrepancies. Am J Orthod Dentofacial Orthop 2002;122(04):386–391

16 Nie X. Cranial base in craniofacial development: developmental features, influence on facial growth, anomaly, and molecular basis. Acta Odontol Scand 2005;63(03):127–135

17 Bibby RE, Preston CB. The hyoid triangle. Am J Orthod 1981;80(01):92–97

18 Chauhan R, Bagga DK, Agrawal P, Kalra H, Kumar P, Singh A. Radiographic evaluation of the hyoid bone position and pharyngeal airway depth in anteroposterior dysplasia. Int J Clin Pediatr Dent 2019;12(02):101–106

19 Bilal R. Position of the hyoid bone in anteroposterior skeletal patterns. J Healthc Eng 2021;2021:7130457