BULLETIN OF STOMATOLOGY AND MAXILLOFACIAL SURGERY
Volume 21, Issue 5

DOI: 10.58240/1829006X-2025.21.5-207

ORIGINAL ARTICALE

EVALUATION OF HYOID BONE POSITION AND ORIENTATION TO THE CRANIAL BASE, MANDIBLE, AND THIRD CERVICAL VERTEBRA IN DIFFERENT ANTEROPOSTERIOR SKELETAL MALOCCLUSION: AN OBSERVATIONAL STUDY

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Received: *May 1, 2025;* ***Accepted:*** *June 10, 2025;* ***Published:*** *June 25,2025*

ABSTRACT

Background: The aim of this study was to evaluate the hyoid bone (HB) position and it's orientation to cranial base, mandible, and third cervical vertebra in different anteroposterior skeletal malocclusion.

Materials and Methods: This retrospective study included 90 lateral cephalometric radiographs of Yemeni patients distributed into 3 groups with different skeletal classes of malocclusion aged between 18-30 years. All radiographs were traced manually by a researcher. The recorded data was collected, tabulated and analyzed by statistical program SPSS.

Results: The S-N (Sella-Nasion) distance, was low in Class III (69.5 mm) and the Hy-D distance was slightly higher in Class III. For, angular measurements, the NSAr (Nasion-Sella-Articulare angle) was high in Class III (128.2°) and SNA (Sella-Nasion-A point angle), was about 78.6 in Class III. A statistically significant difference was found in the S-N length (p = 0.03), indicating a longer cranial base in males. In females, the S-N distance correlated strongly with C3-HY (r = 0.73), while in males, C-Xi had a high correlation with Hy-D (r = 0.82). Angular measurements also showed strong correlations, such as SNA being negatively correlated with ArGoMe (-0.91) in females and NSAr negatively correlated with SNA (-0.77) in males, indicating cranial base influence on mandibular position.

Conclusions: The positioning of HB in different classes of skeletal malocclusion is a critical consideration in orthodontic therapy. The findings indicate significant variations in HB position and its orientation to other structures, emphasizing the need for clinicians to account for these differences during treatment planning.

Keywords: Hyoid Bone, skeletal malocclusion, malocclusion, prognathic maxilla, retrognathic mandible

INTRODUCTION

In orthodontics, understanding skeletal problems linked to malocclusion is essential. Numerous investigations utilising cephalometric radiographs have confirmed a correlation between the anatomy of the cranial base and the interaction of the jaw base. The cranial basis delineates both the skull and the facial bones.[1] The nasomaxillary complex is associated with the anterior cranial base, while the mandible is associated with the posterior cranial base.[2] The shape and structure of the anterior cranial base therefore have a significant impact on the position of the maxilla. The sagittal misalignment of the jaws is intricately linked to alterations in the cranial base.[3] The length and orientation of condylar growth, along with the displacement of the mandibular body due to the sutural growth of the cranial base, influence mandibular posture.[4]

The angle formed between the sella-nasion-articular (NSAr) and sella-nasion (NSBa) points is frequently utilised to radiographically assess the cranial base angle, also known as the saddle angle.[5] At birth, this angle measures 142 degrees, but by the age of five, it has gradually diminished to 130 degrees. This angle is rather stable between the ages of 5 and 15. The alignment of the jaws is profoundly affected by the growth and development of the cranium.[6] A predisposition for class II malocclusion may arise if the angle between the fossae increases.[7]

In the last two decades, there has been significant research in the hyoid bone (HB) and its correlation with facial patterns.[8] Certain physiological activities, including phonation, deglutition, and respiration, rely on HB. It is an essential element of the diagnostic instrument utilised to assess the prognosis of orthodontic treatment and evaluate the probability of recurrence post-treatment.[9] Amayeri et al. found that large distance alteration was noticed between HB and the third cervical vertebra in Class III (C3M) cases than in Class I(C1M) and Class II (C2M) cases.[10] As a result, comprehending the relationship between HB and adjacent structures is crucial for elucidating the aetiology of malocclusion.

Investigators have discovered that changes in mandibular positioning correlate with adjustments in HB, which responds to variations in the anterior-posterior alignment of the head.[8,11] Recent decades have witnessed significant focus on investigating the impact of HB and its association with face traits. Previous research demonstrates a substantial correlation between the positional changes of HB and malocclusion. Therefore, the present study assessed and evaluated HB position and orientation to cranial base, mandible, and third cervical vertebra in different skeletal malocclusion.

2. MATERIAL AND METHODS

The present retrospective cross-sectional study was conducted carried out at Orthodontic Department, faculty of dentistry Sana'a University among a group of Yemeni adult population to analysis the relationship between HB position and Orientation to cranial base, mandible and cervical vertebra with different skeletal classes of malocclusion after obtaining an ethics approval from ethics from Institutional of the Medical Ethics Committee at the Faculty of Dentistry of Sana’a University with Ethical Approval Reference Number: OR: 06/ 09/ 2024.

Study Sample

A total of 90 subjects were classified into three groups and each containing 30 patients. The selected patterns were Class I (normal occlusion), Class II (retrognathism with a small mandible), and Class III (prognathism with a forward-positioned mandible). All radiographs were traced manually by a researcher. All subjects included in this study had been prescribed digital lateral Cephalometric image as a part of their diagnostics. The digital lateral cephalometric images were included if they were good quality radiographs permitting the identification of landmarks and taken from the same Machine. They were excluded if they were images with orthodontic treatment, severe long or short face, congenital anomalies like cleft lip and palate or had missing, supernumerary, prosthetic or implant placement. Variables like age and gender, and skeletal malocclusion were recorded.

Study Procedure

Digital lateral cephalograms were used to assess HB position. The radiographs were taken from Cephalometric machine Ex3Di-Vatech machine from Al-Weed X-ray center. The midsagittal plane was perpendicular to the floor and parallel to the film and the teeth are in maximum intercuspation in natural head position which means the standardized and reproducible position of the head in upright posture, with the eyes focused on a point in the distance at eye level, that indicates the visual axis is horizontal. The cephalometric radiograph was obtained at 85 KV and 10 mA per second. For stabilization of the head, the cephalometric machine’s ear-rods put in the external auditory meatus and forehead support put in the forehead. The radiograph was taken with the same criteria to have the high-quality detectors for this study.

Manual Tracing Procedure

After collecting of data, the researcher saved them as JPG files, then printing them through Laser printer. Tracing was done by a .0.5 mm HB lead pencil, Eraser, millimeter ruler, geometric protractor with half degree approximation for the recording of linear and angular measurements and 8“x 10“matte acetate papers of 0.003mm thickness. Matte acetate paper was placed over the hard copy of lateral cephalometric radiographs and calibration was done before printing. The radiographs were traced in daylight by the researcher. Tracing was done to 90 cases. Photos of traced x-rays are taken with Nikon Digital Camera D5100 that is made in Thailand. 10 cephalograms were selected randomly after month and were retraced and measured by the same researcher in order to check the reliability of the angular and linear measurements that were measured before by Mortazavi S et al, (2018).[12] The Manual tracings were done by the researcher to reduce the measurements variability. The five linear measurements (in mm) were analyzed in this study were Sella-Nasion (S-N), Capitulare-Xi (C-Xi), C3-Hy(C 3-Hy), Hyoidale-Pt. D (Hy-D), and AA’-PNS. The seven Angular Measurements (in degree) that is used in this study were Saddle angle (NSAr), Articulare angle (SArGo), Gonial angle (ArGoMe), SNA, SND, Hyoidale angle (C3 HyD), and Hyoid plane angle.

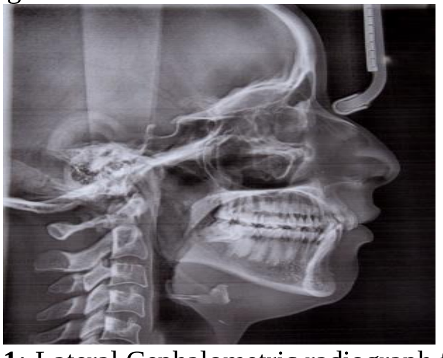

Figure 1: Lateral Cephalometric radiograph from the studied Sample Demonstrating proper head position and landmarks marked on tracing sheet for manual tracing

Statistical analysis

The data was collected and analyzed and coded before being input into the statistical software (SPSS) application. Data was analyzed using statistical software R version 4.4.0 and Microsoft Excel. Continuous variables given in Mean ± SD / Median form. Student's t test was used sexual dimorphism in linear and angular measurements of males and females. P-value less than or equal to 0.05 indicates statistical significance.

3. RESULTS

The dataset comprises measurements from 90 subjects. The participants were equally categorized into the three skeletal classes. Each class contained 30 participants, ensuring an even distribution. The gender distribution is evenly split, with 45 (50%) females and 45 (50%) males.

Table 1 presents the mean and standard deviation (SD) of various linear measurements. The S-N (Sella-Nasion) distance, was highest in C2M (71.7 mm) and lowest in C3M (69.5 mm), suggesting cranial base length variations among skeletal classes. The Hy-D (Hyoid-Mandible distance) was slightly higher in Class III, indicating a possible anterior shift of HB. The C3-HY (Hyoid-Third Cervical Vertebra distance) was lowest in C2M, which may imply a retracted hyoid position in retrognathic individuals.

Table 1. Comparison of Linear Measurements parameters in skeletal groups

Parameters	C1M	C2M	C3M
	Mean±SD	Mean±SD	Mean±SD
S-N	70.9±3.17	71.7±3.54	69.5±4.5
C-Xi	35.3±3.44	34.9±4.15	35.2±4.23
Hy-D	42.2±5.2	42.1±5.1	43.6±7.87
C3-HY	38.1±9.13	35.8±3.99	37.3±5.68
AA'-PNS	32.4±5.03	35.5±8.36	32.6±3.82

In **Table 2,** Angular measurements were compared among skeletal classes. The NSAr (Nasion-Sella-Articulare angle) was highest in C2M (129.4°), suggesting an increased cranial base flexion in these individuals. The SNA (Sella-Nasion-A point angle), an indicator of maxillary positioning, was highest in C2M, confirming a more pronounced maxilla. The SND (Sella-Nasion-D point angle) was highest in C3M, reflecting a more forward-positioned mandible.

Table 2. Comparison of Angular Measurement parameters in skeletal groups

Parameters	C1M	C2M	C3M
	Mean±SD	Mean±SD	Mean±SD
NSAr	125.9±5.81	129.4±5.97	128.2±10.69
SArGo	143.9±7.41	142.9±7.5	140±6.75
ArGoMe	127.4±6.48	126.2±6.81	131±10.75
SNA	79.8±3.21	81.8±4.54	78.6±4.49
SND	74.8±4.3	72.7±3.66	77.4±5.22
C3HyD	158.4±12.58	155.5±16.66	158.8±12.58
Hyoid Plane Angle	92.7±7.27	93±5.1	90.2±4.82

The Principal Component Analysis accounted for 45.56% of variance in linear measurements while PC2 adds another 23.78% and together they explain 69.34% of the variance **(Table 3)**. The analysis indicates that PC1 and PC2 stand out as the primary components for capturing dataset patterns. PC1 leads all components with the maximum eigenvalue of 2.28 which establishes its key importance whereas PC2 retains significance in data analysis with its eigenvalue of 1.19. The variables S-N, CXi, and C3-HY show the highest loadings on PC1 which demonstrates their primary impact on this principal component **(Figure 2)**. In angular measurements, the PCA analysis demonstrates that PC1 stands out as the primary component by explaining 51.96% of the variance while PC2 accounts for 20.6% and PC3 accounts for 15.57%. The combination of these three components explains 88.13% of the variance which shows they provide an effective summary of the dataset. PC1 (3.64), PC2 (1.44), and PC3 (1.09) show their importance in explaining the dataset structure because their eigenvalues are above 1 whereas PC4 through PC7 have eigenvalues below 1 which makes their contribution to total variance minimal. PC1 demonstrates the most substantial representation from the variables SArGo and SNA because they show the highest factor loadings on this principal component. **(Figure 3).**

Table 3. Factor Analysis of Linear and Angular Measurements

Linear Measurements					
Variable	**PC1**	**PC2**	**PC3**	**PC4**	**PC5**
S-N	0.5062	0.0735	0.4922	-0.6801	0.1835
CXi	0.5336	-0.2705	-0.2988	0.3314	0.6656
C3-HY	0.5373	0.051	0.3865	0.5477	-0.5092
HyD	0.3963	0.4478	-0.6911	-0.2443	-0.3243
AA-PNS	-0.1153	0.8475	0.2038	0.2608	0.3985
Eigen Value	2.28	1.19	0.71	0.49	0.33
% explained	45.56	23.78	14.22	9.79	6.65

Angular Measurements							
Variable	**PC1**	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**	**PC7**
NSAr	-0.438	-0.2225	-0.2723	0.4953	-0.0403	-0.1843	0.6353
SArGo	0.4654	-0.1946	0.077	-0.4626	0.3325	-0.1176	0.6334
ArGoMe	-0.2934	0.6588	-0.0957	-0.1878	0.1704	0.5589	0.3067
SNA	0.4448	-0.2622	0.0694	0.5104	0.0671	0.6792	0.0479
SND	0.3491	0.4473	-0.3421	0.3925	0.5129	-0.3577	-0.1264
C3HyD	-0.0223	0.288	0.8709	0.2978	0.0188	-0.2008	0.1694
Hyoid Plane Angle	-0.4304	-0.3562	0.1745	-0.046	0.7687	0.1015	-0.2326
Eigen Value	3.64	1.44	1.09	0.54	0.18	0.07	0.04
% explained	51.96	20.6	15.57	7.72	2.57	1.07	0.52

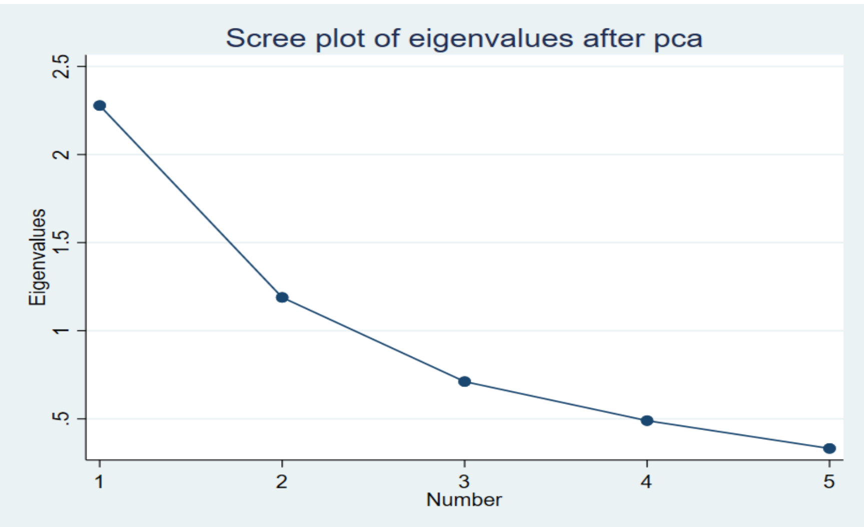

Figure 2. Scree Plot – Linear measurements

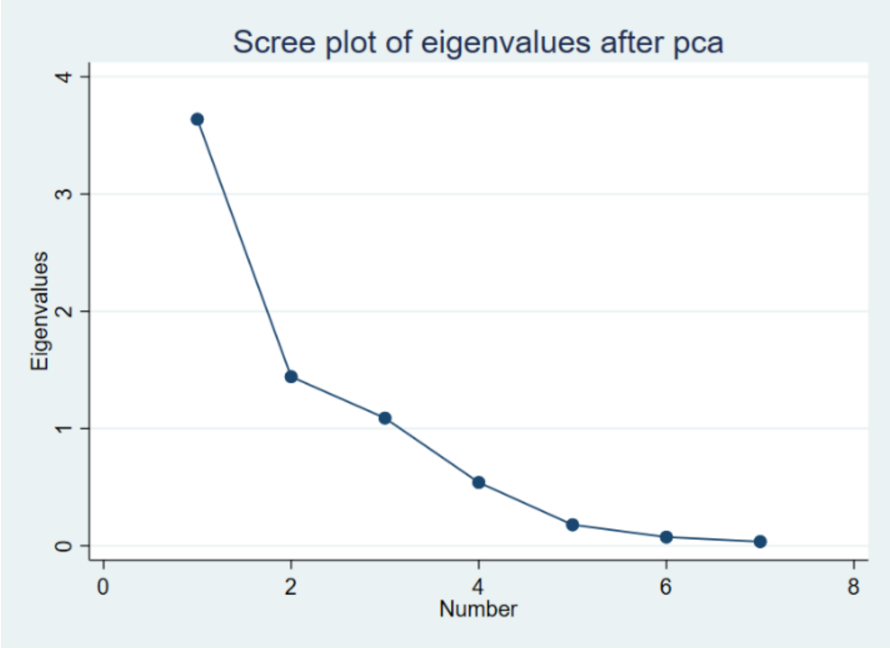

Figure 3.Scree plot – Angular Measurements

Table 4. Correlation matrix for linear measurements – female (95% CI)

	S-N	C-Xi	C3-HY	Hy-D	AA'-PNS
S-N	**1.00**				
C-Xi	**0.23**	**1.00**			
C3-HY	**0.73***	**0.67***	**1.00**		
Hy-D	**0.27**	**0.06**	**0.64***	**1.00**	
AA'-PNS	**-0.65***	**-0.73***	**-0.55***	**0.29**	**1.00**

***Statistically Significant**

Table 5. Correlation matrix for linear measurements – male (95% CI)

	S-N	C-Xi	C3-HY	Hy-D	AA'-PNS
S-N	**1.00**				
C-Xi	**0.44***	**1.00**			
C3-HY	**0.45***	**0.43***	**1.00**		
Hy-D	**0.47***	**0.82***	**0.21**	**1.00**	
AA'-PNS	**0.51***	**0.06**	**0.55***	**-0.06**	**1.00**

***Statistically Significant**

Table 6. Correlation matrix for linear measurements – total (95% CI)

	S-N	C-Xi	C3-HY	Hy-D	AA'-PNS
S-N	**1.00**				
C-Xi	**0.42***	**1.00**			
C3-HY	**0.55***	**0.53***	**1.00**		
Hy-D	**0.32***	**0.37***	**0.31***	**1.00**	
AA'-PNS	**-0.05**	**-0.33***	**-0.03**	**0.17**	**1.00**

***Statistically Significant**

Correlation matrix shows correlations between different linear and angular measurements for males, females, and the total sample. In females, the S-N distance correlated strongly with C3-HY (r = 0.73), while in males, C-Xi had a high correlation with Hy-D (r = 0.82). The total sample showed moderate correlations, suggesting that certain skeletal parameters are interrelated **(Tables 4–6)**.

Table 7. Correlation matrix for angular measurements – female

	NSAr	SArGo	ArGoMe	SNA	SND	C3HyD	Hyoid Plane Angle
NSAr	1.00						
SArGo	-0.52*	1.00					
ArGoMe	-0.39	-0.49	1.00				
SNA	0.69*	0.09	-0.91*	1.00			
SND	-0.60*	-0.26	0.59*	-0.55*	1.00		
C3HyD	0.31	-0.76*	0.16	0.17	0.56*	1.00	
Hyoid Plane Angle	0.69*	0.23	-0.92*	0.94*	-0.79*	-0.13	1.00

Table 8. Correlation matrix for angular measurements – male

	NSAr	SArGo	ArGoMe	SNA	SND	C3HyD	Hyoid Plane Angle
NSAr	1.00						
SArGo	-0.85*	1.00					
ArGoMe	0.65*	-0.89*	1.00				
SNA	-0.77*	0.86*	-0.79*	1.00			
SND	-0.39*	0.46*	-0.26	0.68*	1.00		
C3HyD	-0.43*	0.10	0.18	-0.07	-0.32	1.00	
Hyoid Plane Angle	0.81*	-0.85*	0.71*	-0.94*	-0.81*	0.10	1.00

Table 9. Correlation matrix for angular measurements – total (95% CI)

	NSAr	SArGo	ArGoMe	SNA	SND	C3HyD	Hyoid Plane Angle
NSAr	1.00						
SArGo	-0.81*	1.00					
ArGoMe	0.23	-0.63*	1.00				
SNA	-0.52*	0.70*	-0.75*	1.00			
SND	-0.50*	0.37*	0.05	0.47*	1.00		
C3HyD	-023	-0.11	0.17	-0.01	-0.10	1.00	
Hyoid Plane Angle	0.72*	-0.56*	0.13	-0.55*	-0.78*	0.05	1.00

Angular measurements also showed strong correlations, such as SNA being negatively correlated with ArGoMe (-0.91) in females and NSAr negatively correlated with SNA (-0.77) in males, indicating cranial base influence on mandibular position **(Tables 7–9)**.

DISCUSSION

The present study was undertaken to evaluate the position of HB and its orientation to cranial base, mandible and third cervical vertebra in different anteroposterior skeletal malocclusions. Out of 90 participants, for linear measurements, the S-N distance, was highest in C2M and lowest in C3M. The Hy-D was slightly higher in C3M, indicating a possible anterior shift of HB. The C3-HY was lowest in C2M, which may imply a retracted hyoid position in retrognathic individuals. When angular measurements were compared among skeletal classes, the NSAr was highest in C2M, suggesting an increased cranial base flexion in these individuals. The SNA was highest in C2M, confirming a more pronounced maxilla. For angular measurements, our study suggested an increased cranial base flexion in the included patients. Our study found no statistically significant differences in linear and angular measurement across groups, indicating class alone not strongly influence these parameters. Thus, our null hypothesis that there is no agreement of presence of correlation between cranial bases, mandible and third cervical vertebra with HB position and orientation in different anteroposterior skeletal malocclusion in cephalometric x-rays was rejected.

A statistically significant difference was found in the S-N length, indicating a longer cranial base in males. The C3-HY distance was significantly higher in females, suggesting a gender-related difference in HB positioning. This suggests that the oropharyngeal dimension is smaller in females than in males, as the HB is relatively positioned closer to the third cervical vertebra in females.

Our results are consistent with other studies. Breh R et al, 2017 that found anterior cranial base was shortest in skeletal C3M and longest in skeletal C2M.[13] Bhullar et al., in a similar 2020 study observed that the anteroposterior position of HB does not change with different growth patterns in skeletal C1M subjects.[14] Soheilifar et al., studied 50 cephalographs and observed that there is no statistically significant difference between HB position in skeletal C1M and skeletal C2M patients. Thus, as HB position is similar in skeletal C1M and C2M patients, the skeletal pattern must not be considered as the only determinant of the position of HB.[15] This is consistent with our findings on non-parametric comparisons of linear and angular measurements across skeletal classes which showed that no statistically significant differences were observed across groups, indicating that skeletal class alone does not strongly influence these parameters.

The anteroposterior position of the HB is the consequence of the activity of the suprahyoid muscles, which is associated with the clockwise and anticlockwise rotations of the mandible. HB is in an anterior and upward position during an anterior rotation. In the posterior, it is situated more retro-inferior. It is evident that the mandibular rotation has a significantly greater influence on the sagittal HB position than the classes.[16]

From our current study, PCA was performed to minimize data dimensions and identify which components best illustrate the data's variability. The analysis indicates that PC1 and PC2 stand out as the primary components for capturing dataset patterns. The result was that variables S-N, CXi, and C3-HY show the highest loadings on PC1 which demonstrates their primary impact on this principal component. The variables SArGo and SNA show the highest factor loadings on this principal component. PCA performed in similar studies has yielded agreeable findings.

Another study by Bedoya A et al., The anteroposterior position of the HB is the consequence of the activity of the suprahyoid muscles, which is associated with the clockwise and anticlockwise rotations of the mandible. HB is in an anterior and upward position during an anterior rotation. In the posterior, it is situated more retro-inferior. It is evident that the mandibular rotation has a significantly greater influence on the sagittal HB position than the classes.[17] Accordingly, Bibby and Preston discovered significant variability in the impact of HB position on head position, even with slight movements.[18] In this study, the variable that measures the position of HB was very stable and behaved independently; i.e. it was not related to any other variable.

Lastly, in our study correlation analysis shows that in females, the S-N distance correlated strongly with C3-HY, while in males, C-Xi had a high correlation with Hy-D. The total sample showed moderate correlations, suggesting that certain skeletal parameters are interrelated. Angular measurements also showed strong correlations, such as SNA being negatively correlated with ArGoMe in females and NSAr negatively correlated with SNA in males, indicating cranial base influence on mandibular position. Various studies have reported strong correlations with respect to HB positions and its orientations.

Deljo et al. (2012)[19] aimed to ascertain the position of HB in relation to the cranial base, mandible, and cervical region of the vertebrae. The position of HB is variable and contingent upon the maxillo-mandibular anterior-posterior relationships. The lengths of the HB and its greater horns vary in relation to sagittal malocclusion. The flat position of HB is highly correlated with the cranial base and maxillary bones. A positive correlation was identified concerning the cervical vertebra, while a dependence was established in relation to the steep mandibular plane. The flat position of HB is strongly correlated with the cranial base and maxillary bones. In patients from group II, the longest HB length was observed. A correlation between the length of the anterior cranial base and the length of the maxilla was also identified.[19] performed a correlation analysis and discovered that the hyoidale angle was also correlated with the angle. SNA exhibited a notable correlation in C1M normal subjects, whereas in C2M division 1 samples, it was statistically insignificant. An elevation in saddle angle (NSAr) and articulare angle (SArGo) results in a retrognathic mandibular configuration. The correlation of these angular measurements with the hyoidale angle revealed a statistically insignificant negative correlation in C1M normal subjects and C2M division 1 samples.[20] The gonial angle (ArGoMe) exhibited no significant correlation with the hyoidale angle in both classes. These findings reinforce the notion that skeletal malrelationship induces a shift in HB position, specifically indicating that sagittal malformation plays a highly significant role in the anteroposterior positioning of HB.

The low level correlation between saddle angle and hyoidale angle may be attributed to the fact that a large saddle angle is compensated for by a change in articulare angle and ramus length. In addition to influencing the anteroposterior positioning of the mandible, the articulare angle also influences the closing and opening of the bite. The articulare angle in C2M division 1 is increased by the distal mandibular position, which is compensated for by the deep overbite, resulting in a relatively minimal change in articulare angle.

A positive correlation was observed between the length of the mandible (measured from the points of GonMen) and the distance between the third cervical vertebra and HB, as described by Trenouth and Timms in 1999.[21] Ingervall et al. discovered a positive correlation (although not always statistically significant) between the anteroposterior distance between the retruded contact and intercuspal positions of the mandible and the vertical movement of HB between these positions.[22]

The mean value of C3-H for females was 3.57 ± 0.43, while for males it was 3.58 ± 0.43, as observed by Raghav et al. in their study. Consequently, they verified a statistically significant correlation between the Gonial angle of males and females.[23] Similarly, Jose et al. confirmed that a positive correlation was observed between the lower airway and the horizontal distance from the HB to the retrognathion in the C1M skeletal pattern with an average growth pattern. Nevertheless, no correlation was observed between the horizontal and vertical positions of HB in the C2M and C3M skeletal patterns and the normal growth pattern.[24]

The present study has a few limitations. The study population was restricted to a single institution. With larger cohorts, these findings can be broadened. Then all patients included in the study were from Yemen; hence, generalizing the results to individuals of other ethnicities would require further investigation. As the present study was a single-center study, the results may not be generalized to different ethnic groups. Next, severity of malocclusion in the participants was not classified, and patients with severe skeletal malocclusions may present with more severe compensatory characteristics, which may influence conclusions. Lastly, a limitation of current study was that the absence of functional assessment of HB during functions such as swallowing, speech and breathing which can be incorporated in future research.

5. CONCLUSION

The placement of HB in different types of skeletal malocclusion is a vital factor in orthodontic treatment. Our research reveals considerable discrepancies in the position and orientation of HB relative to other anatomical features among various skeletal classes, underscoring the necessity for clinicians to consider these variances in treatment planning. Moreover, considering the possible hazards of sleep apnoea and airway blockage, a thorough assessment of the patient's airway status is necessary before any surgical procedure to reduce the risk of problems.

DECLARATIONS

Ethical approval and consent to participate

Not Applicable

Availability of data and material

All data generated or analyzed during this study are included in the published article.

Competing interest

The authors declare that there are no competing interests.

Acknowledgments

None

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