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Position of Hyoid Bone in Different Classes of Skeletal Malocclusion Using Cone-Beam Computed Tomography

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Abstract

Background: The goal of this study was to evaluate and compare the position of the hyoid bone (HB) in different classes of malocclusion using cone-beam computed tomography (CBCT). Gender differences were investigated across the studied groups.

Methods and Materials: The study included 120 CBCTs acquired from equal groups of males and females and evenly distributed among the three classes of malocclusion. The age of the participants $\geq$ 18 years. Multiplanar reconstruction were generated in axial, sagittal, coronal, and 3D views using Ez3D-i software. Several measurements points including SNA, SNB, ANB, H-Me, H-EB, C3-Me, HC3-Me, H-PNS, HB-H, and H-V were measured following standardized definitions. The data was entered and analyzed using the SPSS. Significance was set a value of $P < 0.05$.

Results: Across gender-based differences were observed in HB positioning. Males demonstrated greater distances between the third cervical vertebra (C3) and HB (C3-HB, $p < 0.001$), as well as between C3 and the Menton point (C3-Me, $p < 0.001$), compared to females. The position of HB compared to the maxilla (H-PNS), its horizontal position (HB-H), and its vertical position (H-V) were all significantly different between males and females. No significance gender differences were found for H-Me, H-EB, and HC3-Me. Significant statistically differences were observed among skeletal Classes groups for H-Me, H-EB, C3-Me, HC3-Me, H-PNS, HB-H, and H-V ($p < 0.05$). Class III group demonstrated the greatest H-Me value, while Class II showed the lowest.

Conclusions: The study demonstrated significance difference in HB position among male and females and across skeletal Classes. Males showed significantly greater distances and positional differences involving the C3, Me point, and HB compared to females. Additionally, the position of HB varies across different skeletal classes. Class III group exhibited the most inferior and anterior HB position, whereas Class II showed the least.

Article Info

Keywords:
hyoid bone, malocclusion, CBCT, Menton point, cervical vertebra.

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1. INTRODUCTION

The hyoid bone (HB) is a diminutive, U shaped bone in the neck. Its position is affected by the morphology of adjacent tissues, including the jaw, tongue, and pharyngeal muscles [1–3]. The HB serves as an attachment site for several muscles and ligaments integral to essential activities such as deglutition, phonation, and breathing [4–6]. In orthodontic and surgical contexts, the relationship between the hyoid bone and surrounding skeletal landmarks is of particular interest [7]. Changes in the position and size of the HB have been associated with various complications, such as obstructive sleep apnea, backward jaw positioning, and misaligned teeth [3, 8, 9]. Skeletal malocclusions are primarily categorized into three types, and understanding the different ways in which the HB can be located in various skeletal patterns is important for diagnosing and planning orthodontic treatment [10–12].

Many research studies have looked at the link between

HB placement and skeletal malocclusion, with some suggesting a possible connection between adjusted HB positioning and specific types of malocclusions [13–17].
In a previous study by Zheng et al., significant differences were observed in the HB across skeletal classes, while most other airway volumes did not differ across sagittal and vertical skeletal patterns [14].
However, the existing literature is limited, and the findings are not always reliable, highlighting the need for further research in this area.
Furthermore, research has indicated sex-based differences in the positioning of the HB, with certain studies suggesting that males generally exhibit a more inferiorly located HB than females [17–21]. Most of the previous studies showed gender differences [2, 18, 21]. except the study of Sahin Sağlam and Uydas (2006) that showed no gender differences [22].
This study aimed to evaluate the position of the hyoid bone in different classes of skeletal malocclusion using cone-beam computed tomography (CBCT). The study also examined any gender-based disparities in HB position across each malocclusion class.

Materials and methods

Study Design and Ethical Approval:

The present retrospective cross-sectional observational study was approved by the Medical Ethics Committee of Faculty of Dentistry at Sana'a University granted ethics sanction to current study (Ref No.: 474; Date: 9/6/2024).

Study Population:

The study population consisted of 120 patients aged > 18 years, 40 of each class of malocclusion (C1M, C2M, and C3M), who visited an imaging center in Sana'a city (Alwaleed Radiographic Center). To ensure patient confidentiality, only their sex and age were recorded, and the remaining demographic data were omitted. Confidentiality was maintained for all information that was gathered.

Patient Selection and Data Collection:

Only good quality CBCTs were included if there were no craniofacial deformities such as cleft lip and/or palate. They were excluded if CBCT had unclear HB and landmarks or existing orthodontic treatment. The participants were positioned in a standardized upright posture during the acquisition of CBCT images. The images were captured using a PaX-i3D green scanner (model PHT-60CFO; Vatech Co., Hwaseong, Korea), which has a viewing area of 15 × 15 cm, can adjust the tube voltage from 50 to 99 kV, the tube current from 4 to 16 mA, and produces small image cubes (voxels) that are 0.2 to 0.3 mm in size. The scanning duration was 15 s. The resulting data were exported in the Digital Imaging and Communications in Medicine (DICOM) multifile format and analyzed using the Ez3Di 2009 software (Ewoosoft Co., Ltd., Hwaseong, Korea).

Processing of the Data or Images:

The CBCT images were processed on a 64-bit Windows 10 operating system using Ez3D-i software. Image evaluation was conducted in a dimly lit room on a 17-inch HP Z Book display with a resolution of 1920 × 1080 pixels. This software's image enhancement tools were utilized to optimize image visualization through adjustments in brightness, sharpness, and contrast.

Construction of Multiplanar Windows:

Initially, multiplanar reconstructions were performed, generating views in the coronal, sagittal, axial, and 3D planes (Figure 1). The midline was identified on the 3D reconstruction and subsequently transferred to sagittal view. All anatomical landmarks and measurement parameters were then assessed within the sagittal plane (Table 1).

Points Identification:

The identified points were Point A (Subspinale) (A), Nasion (N), Point B (Supramentale) (B), and A point-Nasion-B point (ANB). The other landmarks identified were HB-Me, HB-EB, HB-C3, C3-Me, HB-C3-Me, HB-PNS, HB–H, HB-V (Figure 2).

Reliability of the Measurements

To ensure the accuracy and reproducibility of the measurements, both intra-examiner and inter-examiner reliability were assessed.
For intra-examiner reliability, a random subset of CBCT scans (approximately 20% of the total sample) was re-evaluated by the same examiner after a two-week interval to minimize the memory bias. All measurements were repeated under identical conditions using the same software and standardized landmark definitions.
For inter-examiner reliability, a second calibrated examiner independently performed measurements on the same subset of scans. Prior to data collection, both examiners underwent a calibration session to standardize landmark identification and measurement protocols.
Reliability was assessed using the Intraclass Correlation Coefficient (ICC) for continuous variables. ICC values were interpreted as follows: values less than 0.75 indicated moderate reliability, values between 0.75 and 0.90 indicated good reliability, and values greater than 0.90 indicated excellent reliability.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics for Windows, version 26.0 (IBM Corp Armonk NY, USA). Descriptive statistics, including means and standard deviations, were calculated for all continuous variables. The normality of data distribution was assessed using the Shapiro-Wilk test. Accordingly, independent t-tests

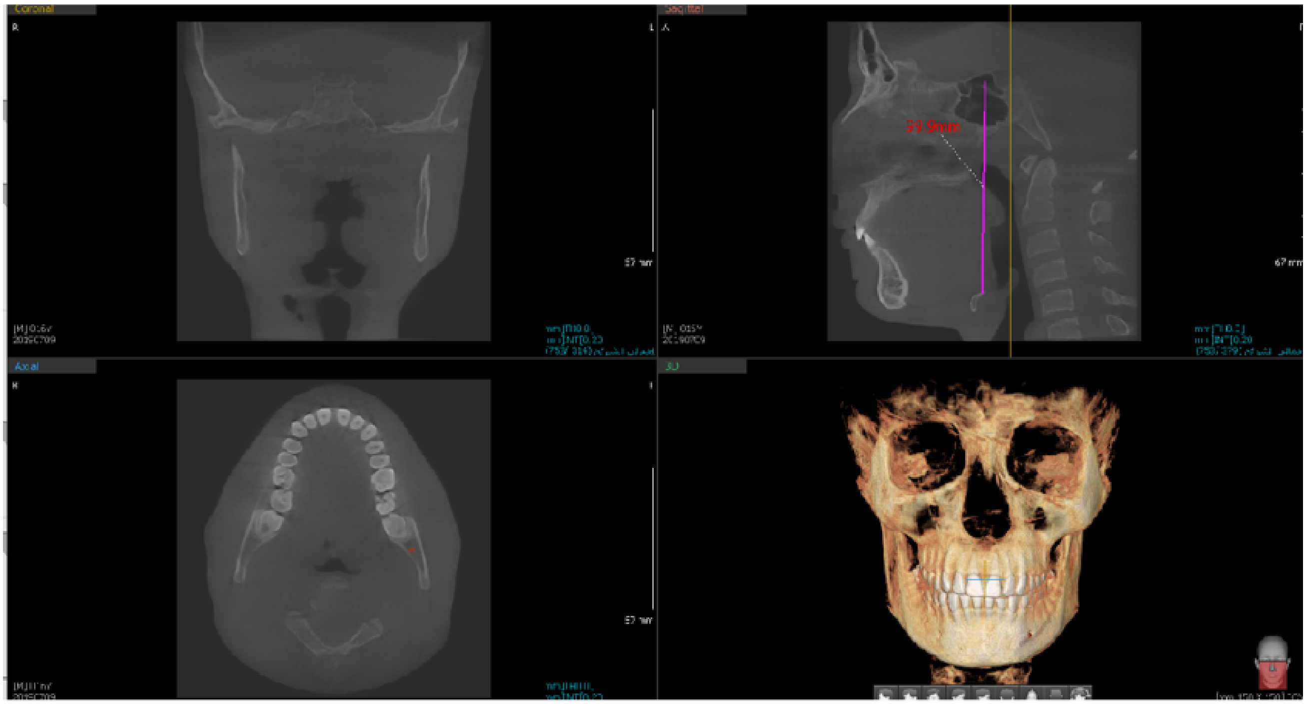

Figure 1. Construction of multiplanar windows of the CBCT

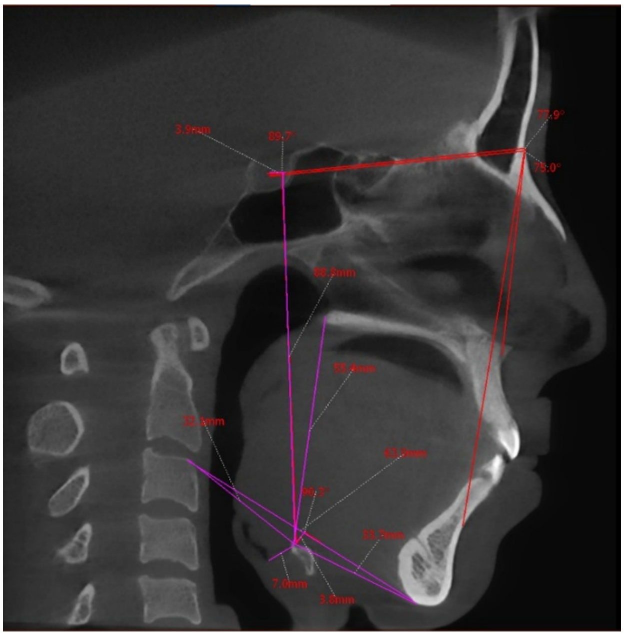

Figure 2. All Measurements and Landmarks

and One-way ANOVA were employed to compare normally distributed data between groups, while the Mann-Whitney U and Kruskal-Wallis tests were used for non-parametric comparisons. Statistical significance was set at P < 0.05.

2. RESULTS

The data contained measurements on 120 subjects, and the mean age of the participants was 23.12 years, with an SD of 7.56 years. Regarding sex distribution, the participants were evenly split, with 60 (50%) females and 60 (50%) males. The sample was evenly distributed across the three skeletal Classes, with 40 subjects (33.33%) in each class.

Distribution of sample according to different variables

The ANB angle mean value was 2.52 ± 2.89. The SNA angle showed a mean of 80.32 ± 4.89, and the SNB angle had a mean of 77.8 ± 5.31. For H-Me, the mean was 43.56 ± 6.8, H-EB had a mean of 9.33 ± 2.65. C3-H had a mean of 34.47 ± 4.67, while C3-Me had a mean of 75.65 ± 7.86. The mean HC3-Me was 7 ± 4.15, the mean H-PNS was 55.54 ± 5.94, and the mean HB-H was 6.16 ± 2.48 (Table 1).

Comparison of different variables according to gender

No significant differences were observed for ANB, H-Me, H-EB, and HC3-Me, and several variables showed statistically significant differences between the sexes. Males had significantly higher SNA, SNB, C3-H, C3-Me, H-PNS, HB-H, and H-V values than females **(Table 2, Figure 3).**

Comparison of different variables according to skeletal Classes

According to the results of this study, H-Me, H-EB, C3-Me, HC3-Me, H-PNS, HB-H, and H-V showed statistically significant differences across classes. For example, H-Me was largest in C3M (46.51 ± 6.56) and smallest in C2M (40.2 ± 7.06). C3-H showed no significant differ-

Table[1]: Distribution of subjects according to different variables

Variable	Mean ± SD	Median (Min, Max)
ANB	2.52 ± 2.89	2.5 (-7.1, 7.7)
SNA	80.32 ± 4.89	80.25 (61.9, 94.2)
SNB	77.8 ± 5.31	77.45 (54.2, 92.4)
H-Me	43.56 ± 6.8	43.2 (25.7, 57)
H-EB	9.33 ± 2.65	9.25 (3.1, 16.2)
C3-H	34.47 ± 4.67	33.9 (24.7, 47.7)
C3-Me	75.65 ± 7.86	75.2 (49.8, 96.1)
HC3-Me	7 ± 4.15	6.55 (1.2, 19.9)
H-PNS	55.54 ± 5.94	54.7 (44.3, 70.4)
HB-H	6.16 ± 2.48	5.7 (2, 12.6)
H-V	94.34 ± 6.98	94.15 (80.6, 110.6)

Table[2]: Comparison of different variables according to gender

Variable	Gender		p-value
	Female	Male	
ANB	2.73 ± 2.38 2.45 (-3.7, 7.7)	2.31 ± 3.33 2.5 (-7.1, 7)	0.8071MW
SNA	79.33 ± 4.52 79.5 (61.9, 92.3)	81.31 ± 5.07 81.95 (71.9, 94.2)	0.0247MW*
SNB	76.6 ± 5.6 76.35 (54.2, 92.4)	79 ± 4.77 79.2 (67.4, 88.7)	0.0059MW*
H-Me	42.93 ± 7.21 44.2 (29.8, 57)	44.2 ± 6.36 42.65 (25.7, 56.5)	0.3071t
H-EB	9.05 ± 2.84 9 (3.1, 14.9)	9.61 ± 2.44 9.3 (5.5, 16.2)	0.2725MW
C3-H	32.37 ± 3.73 32.15 (24.7, 47.7)	36.57 ± 4.59 37.05 (27, 45.8)	< 0.001MW*
C3-Me	73.07 ± 6.94 73.1 (49.8, 88.1)	78.23 ± 7.93 77.55 (55.4, 96.1)	< 0.001t*
HC3-Me	6.5 ± 4.3 5.05 (1.4, 19.9)	7.51 ± 3.97 7.2 (1.2, 17.5)	0.0635MW
H-PNS	53.2 ± 4.98 53.15 (44.3, 66.3)	57.88 ± 5.93 58 (47.4, 70.4)	< 0.001t*
HB-H	5.64 ± 2.24 5.05 (2.1, 10.1)	6.67 ± 2.62 6.7 (2, 12.6)	0.0286MW*
H-V	90.52 ± 4.84 90.85 (80.6, 102)	98.16 ± 6.72 98.1 (81.1, 110.6)	< 0.001MW*

ences across the skeletal Classes (p-value >.05) (**Table 3**, **Figure 4**).

3. DISCUSSION

The present study provided a comprehensive three-dimensional evaluation of the HB position in relation to skeletal malocclusion patterns and sex using CBCT. The findings clearly demonstrate that the HB position is not static; rather, it is a dynamic anatomical entity influenced by sagittal skeletal relationships, craniofacial morphology, and functional demands, particularly those related to airway maintenance. In addition, the study showed the presence of marked sexual dimorphism in several hyoid-related parameters and emphasized the multifactorial nature of HB positioning.

The results of the present study revealed significant

Table[3]: Comparison of different variables according to skeletal Classes

Variables	Skeletal Class			p-value
	C1M	C2M	C3M	
H-Me	43.99 ± 5.25 44.5 (33.2, 54.1)	40.2 ± 7.06 40.3 (25.7, 52.4)	46.51 ± 6.56 46.65 (33.9, 57)	< 0.001A*
H-EB	8.89 ± 1.91 9.15 (5.1, 14.7)	10.21 ± 3.19 9.8 (4.3, 16.1)	8.88 ± 2.52 8.3 (3.1, 16.2)	0.0339A*
C3-H	34.42 ± 5.11 33.85 (24.7, 47.7)	35.4 ± 4.57 35.25 (27.2, 45.8)	33.59 ± 4.23 32.55 (27.1, 43.5)	0.1758K
C3-Me	75.71 ± 6.13 75.2 (63.9, 88.8)	72.92 ± 9.4 71.65 (49.8, 94.7)	78.33 ± 6.9 77.8 (64.2, 96.1)	0.0077A*
HC3-Me	7.55 ± 4.38 6.9 (1.5, 19.7)	7.81 ± 4.09 7.2 (2.8, 17.5)	5.66 ± 3.73 4.6 (1.2, 19.9)	0.0231K*
H-PNS	56.86 ± 5.33 56 (48.5, 70.4)	56.34 ± 6.57 55.1 (45.5, 69.9)	53.42 ± 5.38 52.95 (44.3, 64)	0.0188A*
HB-H	6.95 ± 2.7 7.15 (2.8, 12.6)	5.62 ± 2.46 5.05 (2, 11.6)	5.9 ± 2.11 5.75 (2.7, 10.3)	0.0399A*
H-V	96.24 ± 5.84 95.95 (86.9, 108.1)	94.75 ± 7.27 94.85 (80.8, 110.6)	92.03 ± 7.24 90.6 (80.6, 105.2)	0.0225A*

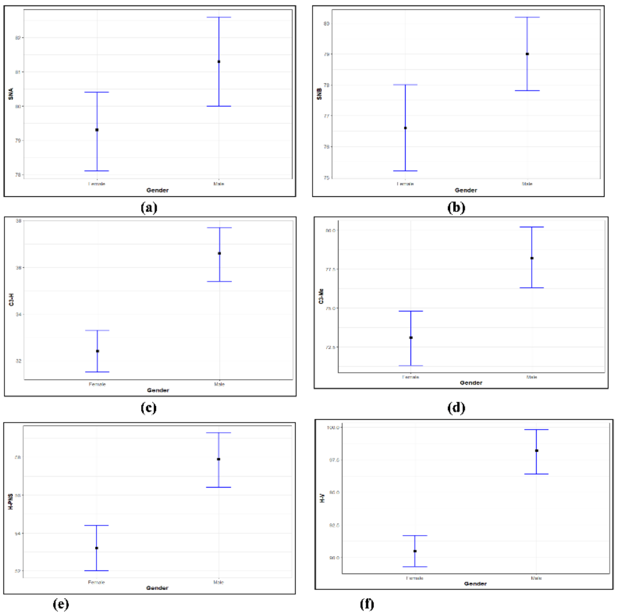

Figure 3. Mean Plot over Gender (a) SNA, (b) SNB, (c) HB-C3, (d) C3-Me, (e) HB-PNS, (f) HB-V

variations in HB position among skeletal malocclusion classes. Specifically, Class III subjects exhibited a more anterior and inferior positioning of the hyoid bone, whereas Class II subjects demonstrated a relatively posterior and superior position. These findings can be interpreted as biomechanical adaptations of the suprahyoid and infrahyoid muscles in response to mandibular positional discrepancies.

These observations are in strong agreement with the

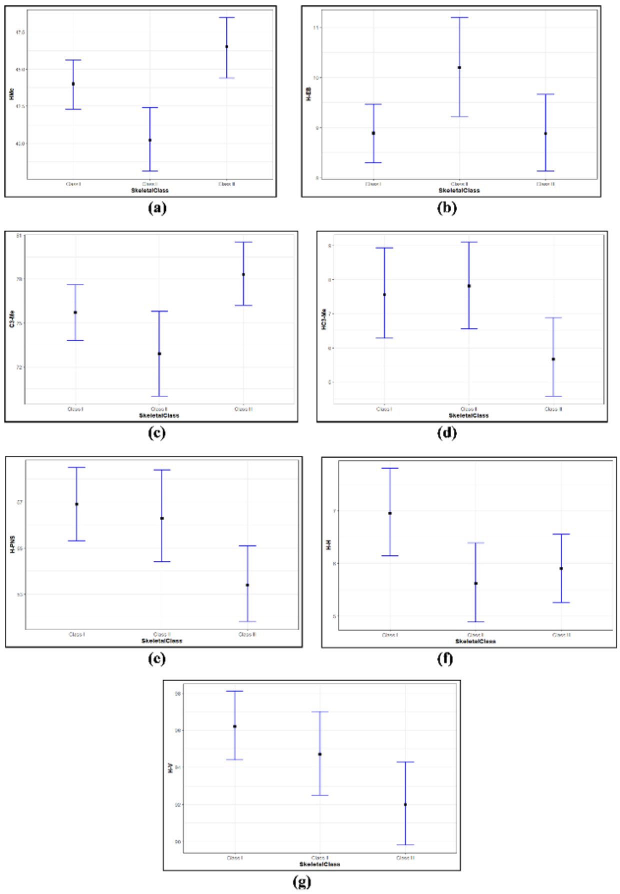

Figure 4. Mean Plot according to skeletal classes (a) H-EB, (b) C3-Me, (c) HC3-Me, (d) H-PNS, (e) HB-H, (f) H-V

findings of Shokri et al. [23], who reported significant interclass differences in hyoid-related parameters

(H–Me, H–PNS, and C3–Me) along with corresponding variations in airway dimensions. Their study demonstrated that Class III individuals tended to present with larger airway volumes and a more anteriorly positioned hyoid bone, whereas Class II subjects exhibited reduced airway space and posterior displacement of the HB.

Similarly, Singh et al. [24] reported that Class II skeletal patterns are associated with the posterior positioning of the hyoid bone and reduced oropharyngeal airway volume. This supports the interpretation that posterior HB displacement in Class II individuals may represent a compensatory mechanism that could predispose them to compromised airway function.

Importantly, the findings of the present study are further reinforced by the work of Mohamed et al. [25], who demonstrated that hyoid bone position is significantly influenced by the skeletal class, age, and breathing mode. Their results indicated that skeletal Class II subjects exhibit altered anteroposterior and vertical HB positioning, and that parameters such as C3–Me and H–EB are significantly associated with functional breathing patterns, particularly, mouth breathing. This adds a critical functional dimension to the current findings, suggesting that HB displacement is not only structurally determined but also functionally modulated by the diaphragm.

In contrast, Arikan et al. [26] reported that hyoid bone changes in Class III patients were primarily horizontal, with no significant vertical displacement. Although partially consistent, the present study identified both horizontal and vertical differences among skeletal classes. This discrepancy may be attributed to methodological differences, including a smaller sample size, limited measurement variables, and the absence of a comprehensive three-dimensional CBCT analysis in their study.

The hyoid bone occupies a central position within the craniofacial complex and acts as a key anchoring structure connecting the mandible, tongue, and cervical region. Consequently, its position reflects a delicate balance between skeletal morphology and functional requirements, particularly airway patency.

Although airway volume was not directly assessed in the present study, the observed positional patterns were consistent with the functional interpretations reported in the literature. Shokri et al. [23] demonstrated significant correlations between hyoid parameters (e.g., H–EB and H–PNS) and airway morphology, suggesting that the anterior positioning of the HB is associated with increased airway volume.

Similarly, Singh et al. [24] reported reduced oropharyngeal airway volume in Class II individuals, accompanied by posterior hyoid positioning. The present findings—particularly the posterior positioning in Class II and anterior displacement in Class III—strongly support the concept that the HB position acts as a compensatory mechanism aimed at preserving airway patency under varying skeletal conditions.

Furthermore, Mohamed et al. [25] provided additional evidence linking HB position to functional respiratory patterns. Their study demonstrated that mouth breathing significantly affects hyoid positioning, with specific parameters (C3–Me and H–EB) serving as predictors of the breathing mode. This highlights the importance of considering functional factors, such as respiration, when interpreting the HB position and supports the notion that airway function plays a critical role in shaping craniofacial adaptations.

A significant finding of this study was the presence of clear gender-based differences in several hyoid-related measurements. Males exhibited significantly larger linear dimensions (including C3–H, H–PNS, H–V, and HB–H) and a more inferiorly positioned hyoid bone than females.

These findings are consistent with those of Singh et al. [24], who observed larger airway volumes and lower hyoid positions in males. Similarly, previous CBCT-based investigations have shown that men tend to exhibit a more inferior and posterior HB position, likely due to differences in craniofacial size, airway volume, and muscular attachments.

However, certain parameters, such as H–Me, did not demonstrate statistically significant gender differences in the present study. This finding contrasts slightly with previous reports suggesting higher values in males, but it may indicate that some anatomical relationships remain relatively stable across genders to preserve essential physiological functions such as respiration and swallowing.

An important observation in the present study was the lack of significant differences in certain measurements, such as C3–H, among the different skeletal classes. This suggests that the spatial relationship between the hyoid bone and cervical vertebrae remains relatively stable despite sagittal skeletal variation.

This stability may reflect neuromuscular regulatory mechanisms responsible for maintaining airway patency and head posture. Even in the presence of significant mandibular discrepancies, the cervical anchorage of the hyoid bone appears to be preserved within a functional range, thereby ensuring biomechanical equilibrium.

Similarly, the consistency of H–Me values across skeletal classes, as reported by Shokri et al. [23], supports the notion that certain craniofacial relationships are conserved and may serve as reliable reference parameters for clinical assessment.

While the present findings are largely consistent with those of previous studies, certain discrepancies can be attributed to methodological differences among studies. These include imaging techniques and patient positioning. The use of upright CBCT in the present study, compared to supine imaging in studies such as Shokri et al. [23], may have influenced hyoid position due to gravitational and muscular factors. Variations in defining anatomical landmarks (e.g., H, EB, C3) can contribute to inter-study variability. Ethnic and genetic differences, particularly in the Yemeni population, may affect craniofacial morphology and limit direct comparisons with other populations. Furthermore, differences in grouping methods (e.g., ANB angle versus combined skeletal indicators) may influence study outcomes.

The findings of this study have important clinical implications for orthodontic diagnosis and orthognathic surgery planning, where the potential effects on the hyoid bone and airway patency should be considered. In addition, the posterior positioning of the hyoid bone in Class II individuals may indicate a predisposition to airway compromise, ensuring the importance of incorporating airway evaluation into treatment planning.

4. CONCLUSION

The study demonstrated that the HB position was significantly influenced by sagittal skeletal relationships, with anterior–inferior displacement in Class III and posterior–superior positioning in Class II individuals. Significant gender differences were observed, with males exhibited larger linear dimensions and a more inferiorly positioned HB.

5. LIMITATIONS:

The single-center Yemeni sample limits generalizability, the lack of malocclusion severity classification, and the absence of direct airway volumetric analysis restricted functional interpretation.

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