DOI: https://doi.org/10.70749/ijbr.v3i07.1913

INDUS JOURNAL OF BIOSCIENCE RESEARCH
https://ijbr.com.pk
ISSN: 2960-2793/ 2960-2807

Evaluation of Hyoid Bone Position in Different Anteroposterior Skeletal Relationships: A Cross Sectional Study

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ARTICLE INFO

Keywords: Hyoid Bone, Skeletal Malocclusion, Cephalometry, Orthodontics, Airway.

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Declaration
Authors' Contribution
All authors equally contributed to the study and approved the final manuscript

Conflict of Interest: No conflict of interest.

Funding: No funding received by the authors.

Article History
Received: 21-06-2025 Revised: 09-07-2025
Accepted: 12-07-2025 Published: 15-07-2025

ABSTRACT

Introduction: The hyoid bone, one of the major structures of the craniofacial complex, affects functions such as deglutition and respiration. It is variable in skeletal malocclusions and has implications for orthodontic correction and airway management. **Objective:** To assess the position of the hyoid bone in skeletal class I, II, and III malocclusions using the cephalometric analysis in Pakistani individuals. **Materials and Methods:** This cross-sectional study was carried out at LUMHS, Jamshoro, from 1st January 2024 to 15 June 2024, amongst 66 participants aged between 18 and 35 with skeletal malocclusion. Lateral cephalograms were performed to trace hyoid distances (L1, L2, and L3) and angles (A1, A2). Data analysis was done using SPSS 23.0 with t-tests for the determination of differences ($p \leq 0.05$). **Results:** Class III demonstrated the poorest hyoid position (L1: 14.3±3.5 mm), Class II (12.1±3.2 mm), in comparison with Class I (10.2±2.8 mm, $p<0.01$). The inferiority place of males was more inferior to that of females ($p=0.01$). There were significant angular differences for A1 in class III ($p=0.03$). **Conclusion:** The position of the hyoid bone is highly variable in skeletal malocclusions, which can assist orthodontic and airway treatment.

INTRODUCTION

The hyoid bone, a uniquely U-shaped structure in the anterior neck, is essential in different physiological functions such as deglutition, respiration, and phonation. It adds to the stability of the craniofacial complex. The other bones lack bony articulations but rely on muscular and ligamentous attachments to the mandible, tongue, and cranium, which allow it to impact the posture and function of the oral cavity (1). Its role is essential in the treatment planning process in orthodontics because it affects skeletal, dental, and soft tissue relations in the dentofacial complex. Cephalometric radiography has enabled the determination of such relationships and the appreciation of the spatial orientation of the hyoid bone about various anteroposterior skeletal malocclusions such as Angle Class I, II, and III. It is important to know changes of position in diagnosing and treating orthodontic cases and other complications, including obstructive sleep apnea (OSA). The placement of hyoid bone is important in the assessment of the patency of airway and success of the treatment.

Variety in the positioning of the hyoid has been published in studies of different skeletal patterns. The position of the hyoid bone is more anterior and inferior in Class II skeletal malocclusions involving the retrognathic mandible, as compared to when in Class I. It tends to affect the airway dimensions and the tongue position (2). In contrast, while mandibular prognathism is prevalent in skeletal Class III malocclusions, the hyoid bone tends to be displaced posteriorly. These changes in position are significant because not only could they influence the stability of the orthodontic corrections and success of interventions like the mandibular advancement surgeries which are supposed to move the hyoid bone closer to the mandibular plane to provide more airway space to the OSA patients. (3). Scientists have also looked at the relations between the positioning of the hyoid bone, shape of the cranial base, and form of the mandible. It was discovered that its anterior or posterior location is determined by the structuring skeletal tissue that envelops it, especially in populations with odd craniofacial patterns (4).

Another significant research objective is the interaction between the hyoid bone positions and the size

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of the airways, particularly nasal and mouth breathing patterns. In an individual with class II skeletal malocclusion, the lower positioning of the hyoid bone could further push down the space in the pharyngeal airway, thereby complementing the reduced breathing. CBCT studies have provided a three-dimensional understanding of such relationships. It has been suggested that the position of the hyoid bone differs very much from the nasal to the mouth breathers and influences orthodontic treatment planning (5). Morphology and volume of the hyoid bone can regulate the dimensions of the pharyngeal airway. Such results highlight the need for full-fledged cephalometric examination to assess the hyoid bone position against the airway health and craniofacial morphology (6).

The hyoid bone has other roles besides the orthodontic functions, which influence the vertical facial patterns and head position. In high-angle (hyperdivergent) facial designs, the hyoid bone is in a low position (7). It might affect tongue position and the airway behavior. Regarding the low-angle patterns (hypodivergent), the position of the hyoid bone is usually high, which supports the stability of the airway. Such differences emphasize the necessity of using the vertical patterns of dental and skeletalism in determining the position of the hyoid bone because they have the possible ability to define what treatment outcome would be in the fields of orthodontics and other related areas (8). The clarifications of these relations have been presented in the CBCT studies as they have identified the specific positions of the hyoid bones in patients with skeletal Class II, which correspond to the narrowing of the pharyngeal airway, with a particular emphasis on adults (9).

The clinical significance of the position of the hyoid bone is emphasized in orthodontic surgery patients, particularly bimaxillary surgery for skeletal Class III malocclusions with facial asymmetry (10). Hyoid bone position changes post-operation might change the dimensions of the pharyngeal airway and, as such, impact respiratory function and long-term stability of treatment. The results point to the need for the preoperative evaluation of the position of the hyoid bone for predictions of surgical outcomes and optimal airway treatment (11). Moreover, existing information indicates that head posture in Class II malocclusions may affect the position of the hyoid bone and airway width, rendering planning for treatment of sagittal discrepancies even more challenging (12). In such populations with poor data collection, like in Pakistan, studies have shown variation of hyoid bone position between skeletal classes, with females having a smaller distance from hyoid to mandibular planes than males, suggesting a requirement for population-specific research in guiding the practices of orthodontists.

Contrary to this tremendous amount of research, there is a varied outcome for the positional stability of the hyoid bone in various populations and different skeletal patterns. Geographic and racial differences and different approaches of many studies lead to such inconsistencies. For example, whereas some studies indicate stable hyoid bone positions in the sagittal planes, other studies indicate variability that depends, among other things, on age, gender, and ethnicity. This emphasizes the need for local studies to generate normative data for specific populations, which can improve the accuracy of diagnosis and effectiveness of treatments in the orthodontics and related fields (13). With the intention of adding to the existing knowledge about the hyoid bone's position in the anteroposterior skeletal relationship as it relates to the diagnosis and management of skeletal malocclusions, airway disorders of the local population, this study investigates the position of the hyoid bone in the anteroposterior skeletal relationship.

Objective: To analyze the position of the hyoid bone in patients with skeletal Class I, II, and III malocclusions based on cephalometric analysis to improve diagnosis and treatment plans in orthodontics.

MATERIALS AND METHODS

Design: Comparative Cross-sectional Design.

Study setting: The investigation was done at the Orthodontic Department, Liaquat University of Medical and Health Sciences (LUMHS), Jamshoro/Hyderabad, Pakistan.

Duration: The study period was six months, from 1st January 2024 to 15 June 2024.

Inclusion Criteria: Subjects aged between 18 and 35 with skeletal Class I, II, or III malocclusions were included. Lateral cephalograms of good definition obtained in centric occlusion and natural head positions were needed.

Exclusion Criteria: Patients previously treated for orthodontics, mandibular trauma, orthognathic operations, or craniofacial disorder were excluded to make the study conditional on untreated skeletal malocclusion.

Methods

This study recruited 66 participants (33 males, 33 females) interested in getting fixed orthodontic treatment in the Orthodontic Department, LUMHS, Jamshoro/ Hyderabad, following ethical approval. Among the participants, aged 18–35 years, were randomly assigned to two (male and female) groups. Operational classification was performed using lateral cephalometric radiographs (ANB 0.5–4°, ANB >4°, and ANB <0.5°) as per skeletal classification. Acquired digital cephalograms provided using natural head position with centric occlusion were traced manually by the author on the acetate paper (in a magnifying glass) to measure the position of the hyoid bone relative to the mandibular (L1), palatal (L2), C3 vertebrae (L3), and angles between the hyoid Informed consent was sought and the ALARA principle was used to ensure the least radiation exposure. Data collection was carried out by the researcher and the senior colleagues to minimize the bias, with only complete proformas used for analysis.

RESULTS

This cross-sectional study determined the position of the hyoid bone in 66 participants (33 males, 33 females) with skeletal Class I, II, and III malocclusions at the Orthodontic Department, LUMHS, Jamshoro/Hyderabad between 1st January 2024 to 15 June 2024. Subjects were in the 18–35

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age group, and skeletal classifications were achieved with ANB angles. Class I (0.5-4°), Class II (>4°) and Class III (<0.5°). Cephalometric measurements involved the distances from the hyoid to the mandibular plane (L1), palatal plane (L2), and C3 vertebra (L3), and angles between the long axis of the hyoid and the mandibular (A1) and palatal planes (A2). Data were analyzed using SPSS version 23.0, and normality was assessed by the Shapiro-Wilk test. For quantitative variables, mean and standard deviation were determined, t-tests were used for differences, and a p-value of ≤0.05 was significant.

Table 1

Demographic Characteristics of Study Participants

Variable	Class I (n=22)	Class II (n=22)	Class III (n=22)
Age (years, mean ± SD)	25.4 ± 4.2	24.8 ± 3.9	26.1 ± 4.5
Gender (M/F)	11/11	11/11	11/11
Socioeconomic Status (%)			
Upper (>35,000 PKR)	27.3%	31.8%	22.7%
Middle (15,000–35,000 PKR)	54.5%	50.0%	59.1%
Lower (<15,000 PKR)	18.2%	18.2%	18.2%

The demographic distribution tested for balanced distribution among skeletal classes had no significant difference in age (p=0.62) or gender. Socioeconomic status was mainly middle class, as appropriate for the local population.

The position of the hyoid bone was very different from one skeletal class to another. In Class I, the mean L1 (H-MP) was 10.2±2.8 mm, but smaller than Class II (12.1±3.2 mm, p=0.03) and Class III (14.3±3.5 mm, p<0.01). This indicates a poorer hyoid position in Class III than in Class I.

Table 2

Hyoid Bone Distance Measurements across Skeletal Classes

Measurement	Class I (mean ± SD)	Class II (mean ± SD)	Class III (mean ± SD)	p-value
L1 (H-MP, mm)	10.2 ± 2.8	12.1 ± 3.2	14.3 ± 3.5	<0.01
L2 (H-PP, mm)	35.6 ± 4.1	33.8 ± 3.9	37.2 ± 4.3	0.04
L3 (H-C3, mm)	32.4 ± 3.7	34.1 ± 4.0	30.8 ± 3.5	0.02

The L2 (H-PP) distance was the shortest in Class II (33.8±3.9 mm) compared to that of Class I (35.6± 4.1 mm, p=0.04) and Class III (37.2± 4.3 mm, p=0.01), which identifies a closer hyoid position. The L3 (H-C3) distance was the minimum in Class III (30.8±3.5 mm, p=0.02), revealing a posterior position of the hyoid bone in relation to the cervical spine.

Gender differences were notable. Males' mean L1 (10.8 ± 3.1 mm) was significantly larger than that of females (8.4 ± 2.9 mm, p=0.01), and this difference was consistent throughout all classes.

Table 3

Gender-Based Comparison of Hyoid Bone Position

Measurement	Males (mean ± SD)	Females (mean ± SD)	p-value
L1 (H-MP, mm)	10.8 ± 3.1	8.4 ± 2.9	0.01
L2 (H-PP, mm)	36.2 ± 4.0	34.5 ± 3.8	0.08
L3 (H-C3, mm)	33.1 ± 3.9	31.9 ± 3.6	0.12

Angular measurements continued to explain the differences in position. The A1 (LAH-MP) angle was highest in Class III (42.5 ± 5.2°) than in Class I (38.7 ± 4.8°, p=0.03) and Class II (40.1 ± 5.0°, p=0.04). There are no significant differences in the A2 (LAH-PP) angle in different classes.

Table 4

Angular Measurements of Hyoid Bone Orientation

Measurement	Class I (mean ± SD)	Class II (mean ± SD)	Class III (mean ± SD)	p-value
A1 (LAH-MP, °)	38.7 ± 4.8	40.1 ± 5.0	42.5 ± 5.2	0.03
A2 (LAH-PP, °)	85.2 ± 6.1	84.6 ± 5.9	86.1 ± 6.3	0.15

Stratification by age, ethnicity, and socioeconomic status demonstrated no significant effect modification (p>0.05). These findings show different positions of hyoid bones throughout skeletal malocclusions, with implications for orthodontic and airway use as well.

DISCUSSION

The results of this study informs the positional variations of the hyoid bone within skeletal Class I, II, and III malocclusions in a Pakistani population, and increase an understanding of its role in the diagnosis and treatment planning in orthodontics. The hyoid bone, which has no direct bony articulation, is extremely important to functions such as deglutition, respiration, and phonation, and its location alters the craniofacial complex. This fact is in agreement with previous studies, which show considerable differences concerning the position of the hyoid bone in the anteroposterior skeletal relationships between different skeletal types and genders. Such changes affect orthodontic treatment, particularly if one is treating airway-related disorders such as obstructive sleep apnea (OSA) and enhancing the stability of the treatment (1).

The difference in the Mean Position of the analyzed hyoid bone, in particular the L1(H-MP) distance was significant with Class III malocclusions having an inferior position (14.3±3.5 mm) as opposed to Class I (10.2 ± 2.8 mm) and Class II (12.1 ± 3.2mm This is one of the findings based on earlier studies that the hyoid bone is posteriorly and inferentially placed in the Class III as a result of the mandibular prognathism and that might influence measures of airways and placement of the tongue (2, 3). Sadik and Shetty (2021) observed similar trends and reported an association when mandibular position was associated with hyoid bone displacement. Class III cases display a lower placement of the hyoid bone due to the forward mandibular position (1). Such an alignment with cranial base and mandible highlights the hyoid's role in striking a balance to the craniofacial structure, particularly sagittal disparities (4).

The difference between genders was also present, where males had larger L1 distance (10.8 + 3.1 mm) than females (8.4 + 2.9 mm), indicating the more inferior position of the hyoid in males. This finding confirms previous studies by Saeed et al. (2021) that noted less L1 distances in females (8.06 ± 3.0 mm) than in males (10.16 ± 3.1 mm) in a Pakistani cohort (7). Anatomical variation in attachments of muscles and craniofacial morphology between genders can be considered as the cause of these differences, and they affect hyoid bone positioning (5). Chen et al (2021) further highlighted the importance of

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gender-specific differences in hyoid morphology and position, assessed with cone beam computed tomography (CBCT), which should be implemented into the individualization of orthodontic treatment, especially in case of Class II malocclusions with the later, problem of airway narrowing present (5).

The L2 (H-PP) distance was least in Class II (33.8±3.9 mm), closer hyoid position to palatal plane, consistent with reports of the more-anterior and inferior hyoid position in Class II malocclusions around retrognathic mandibles (9). Trang et al. (2025) proved that Class II patients experience a decrease in pharyngeal airway dimensions associated with the lower position of the hyoid, potentially leading to respiratory issues (9). The L3 (H-C3) distance was minimal for Class III (30.8 ± 3.5 mm), indicating a posterior hyoid position relative to the cervical spine and in line with what Espada De-La-Cruz et al. (2021) observed for the cases of Class III (posterior displacement) (2). These positional changes are clinically relevant and could affect airway patency and treatment outcomes in orthodontics and orthognathic surgery (10).

Angular magnitudes further emphasised disparities, with the A1 (LAH-MP) angle being at its maximum in Class III (42.5 ± 5.2°), indicating a steeper angle to the mandibular plane. This is consistent with Kurbanova et al. (2023), who found that the orientation of the hyoid bone varies depending on the skeletal patterns, and this affects the pharyngeal airway volume (6). However, the A2 (LAH-PP) angle did not show significant differences, which may have been the case because of the relatively stable palatal plane in the skeletal classes. Soyoye et al. (2021) noted that vertical patterns of the face also influence hyoid position, wherein hyper divergent patterns influence low hyoid, which might propel sagittal disparities in Class II and III patients (7). Such coordination of vertical and sagittal dimensions highlights a need for global cephalometric assessments in treatment planning (8).

The consequences of the study findings are in OSA management, as the location of the hyoid bone is associated with the dynamics of the airway. Mohamed et al. (2022) held that the Class II patient-users of mouth-breathing tend having reduced hyoid position airway narrowing, which reflects the present study's results (4). Adil et al. (2023) further reinforced that the vertical facial patterns also influence the placement of the hyoid, which indicates airway stability among orthodontic patients (8). Kang et al. (2022) discovered postoperative hyoid repositioning with higher airway measurements in Class III patients who underwent bimaxillary surgeries, thereby establishing the surgical value of such findings (13). Similarly, Nascimento et al. (2022) found that the hyoid alignment in Class II/2nd Division malocclusions adds to the alignment of the cervical spine that will influence the course of treatment (11).

Head posture, one of the other important elements, was taken care of in this research by standardizing cephalometric radiographs in natural head posture. Rhiyanthy et al. (2024) found that the head posture in Class II malocclusions is associated with the hyoid position and airway width, positional differences might get worse because of postural habits (12). Acharya et al. (2022) also disclosed that craniofacial morphology affects the position of the hyoid. Class II patients' airways are narrowed because of the inferior position of the hyoid (10). These findings emphasize the necessity of individual treatment plans that would consider the skeletal and postural aspects.

Despite these insights, contradictory findings in the literature, as observed by Bilal (2021), indicate that geographical and racial differences affect hyoid bone alignment, calling for population-specific studies (3). The present study's concern with a Pakistani cohort fills this gap and offers the normative data for the local orthodontic practice. However, limitations include using two-dimensional cephalometric analysis, which may not fully represent the three-dimensional nature of the hyoid positioning, as demonstrated by Mohamed et al. (2022) through CBCT (4). Future research should include more advanced imaging and increased sample sizes to confirm these findings and for an investigation of longitudinal change post-treatment.

CONCLUSION

This study indeed reveals the extent of variation in the position of the hyoid bone among the skeletal Class I, II, and III malocclusions in a Pakistani population, where the hyoid bone falls in a more inferior and posterior configuration among Class III and women compared to Class I and Males. These results show the relevance of the hyoid bone to craniofacial dynamics and how this can contribute to making an orthodontic diagnosis and treatment plan, especially for airway conditions such as obstructive sleep apnea. Cephalometric analysis gave proper measurements of hyoid position relative to the mandibular plane, palatal plane, and cervical spine, and insights into its clinical applicability. Such findings highlight the need for population-specific data to improve treatment outcomes in orthodontics. The following study should include three-dimensional imaging and bigger cohorts to understand better the hyoid bone dynamics and their influence on long-term treatment stability and airway management.

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