Journal of Health, Wellness and Community Research
ISSN: 3007, 0570

JHWCR

Type: Original Article
Published: 10 May 2025
Volume: III, Issue: IV
DOI: https://doi.org/10.61919/vm51x619

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Received 24, 03, 25
Accepted 10, 04, 2025

Authors' Contributions
Concept: NM; Design: IA; Data Collection: KA; Analysis: FN; Drafting: MB, HZ.

Declarations
No funding was received for this study. The authors declare no conflict of interest. The study received ethical approval. All participants provided informed consent.

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Hyoid Bone Position in Subjects with Different Vertical Jaw Discrepancies

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ABSTRACT
Background: *The hyoid bone plays a critical role in craniofacial dynamics, influencing respiration, swallowing, and mandibular posture. Its position varies with vertical skeletal morphology, yet region-specific cephalometric norms for South Asian adults remain limited.* ***Objective****: To evaluate hyoid bone position among adults with different vertical skeletal divergence patterns and assess the influence of gender on linear and angular cephalometric parameters.* ***Methods****: This cross-sectional study analyzed 159 adult lateral cephalograms (18–30 years) obtained at Bolan Medical Complex, Quetta. Participants were classified into hyperdivergent, normodivergent, and hypodivergent groups based on Frankfort Mandibular Plane Angle (FMA) and GoGn/SN values. Hyoid position was assessed using linear (Hy–Rgn, Hy–C3, C3–Rgn, Hy–PTV, Hy–PNS, Hy–S) and angular (C3/Hy/S, Hy/C3/S) variables. Nonparametric tests compared differences across groups and between genders, with $p < 0.05$ as significant.* ***Results****: Significant intergroup differences were observed for all hyoid measurements ($p < 0.001$). Hyperdivergent individuals exhibited a superior–anterior hyoid position, whereas hypodivergent subjects showed an inferior–posterior position. Males demonstrated consistently greater linear and angular values than females ($p < 0.05$), independent of skeletal divergence pattern.* ***Conclusion****: Hyoid bone position varies systematically with vertical skeletal pattern and gender. These findings highlight the diagnostic importance of including hyoid cephalometrics in orthodontic assessments and emphasize the need for gender- and population-specific reference standards in South Asian adults.*

Keywords
Hyoid bone, Vertical skeletal pattern, Cephalometrics, Gender differences, Orthodontics, Craniofacial morphology

INTRODUCTION
The hyoid bone, a solitary U-shaped structure suspended by a complex musculo-ligamentous network, coordinates tongue posture, pharyngeal patency, deglutition, and mandibular positioning, and its displacement has been implicated in malocclusion patterns and sleep-disordered breathing in craniofacial populations (1,2). Vertical skeletal divergence—operationalized using angles such as the Frankfort-mandibular plane angle (FMA) and the mandibular plane to sella–nasion (GoGn/SN)—alters mandibular rotation and cervical posture, plausibly shifting hyoid orientation and linear relations to the mandible, cranial base, and cervical vertebrae with downstream effects on airway caliber and function (3,4). Observational and CBCT-based reports link hyperdivergent facial types to more inferior–posterior hyoid positions and altered hyoid inclination, whereas hypodivergent phenotypes often show relative superior–anterior placement, although effect directions and magnitudes vary across methods, landmarks, and populations (5–8). Classic cephalometric investigations also suggest that open-bite and deep-bite patterns are associated with distinctive hyoid–craniofacial distances, yet many studies lack comprehensive multivariable panels or mix vertical and sagittal dysplasias, limiting clinical translation (9–11). Furthermore, evidence indicates sex-related differences—typically larger linear distances and steeper inclination in males—and potential modification by treatment mechanics, including extraction-retraction or vertical control, which can shift hyoid position independently of baseline divergence (7,10,12). Despite these signals, some cohorts report attenuated or nonsignificant classwise differences, underscoring heterogeneity from head posture standardization, imaging dimensionality, and demographic structure (13–15).
Critically, there is a paucity of quantitative, multi-parameter cephalometric data disaggregated by vertical skeletal category in South Asian adults, a group with distinctive craniofacial morphology and orthodontic case-mix, and for whom locally relevant normative metrics could refine diagnosis and airway risk stratification (16,17,18). Existing South Asian analyses often emphasize sagittal malocclusion strata or single linear distances without harmonized angular counterparts, limiting inference about the full positional "fingerprint" of the hyoid across divergence patterns (16,18). Clinically, precise estimates for distances such as Hy–Rgn, Hy–C3, Hy–PTV, Hy–PNS, the perpendicular to the C3–Rgn line, and angular relations to SN and cervical landmarks are directly actionable: they anchor differential diagnosis in long-face versus short-face phenotypes, contextualize airway evaluations in adult orthodontics, and inform orthognathic planning where tongue–hyoid–mandible coupling may influence postoperative stability (3–5,8,11). From a biostatistical standpoint, a cross-sectional, divergence-stratified design with nonparametric comparison of medians

and robust reliability assessment can yield population-specific reference values while minimizing model-based assumptions that often obscure clinically interpretable contrasts (3,11).

Accordingly, this study evaluates the positional characteristics of the hyoid bone across hyperdivergent, normodivergent, and hypodivergent adult skeletal patterns in a South Asian tertiary-care setting using a standardized cephalometric protocol that integrates complementary linear and angular metrics, and examines sex-related differences to enhance external validity for routine orthodontic practice (3,8,16–18). We hypothesize that hyoid position differs significantly among vertical skeletal groups—specifically, more inferior–posterior in hyperdivergent and more superior–anterior in hypodivergent subjects—and that males exhibit larger linear distances and greater inclination than females after accounting for divergence category (5,7,8,16–18).

MATERIAL AND METHODS

This cross-sectional observational study was conducted in the Department of Orthodontics at Bolan Medical Complex Hospital, Quetta, Pakistan, between December 2023 and May 2024, following institutional ethical approval and in compliance with the Declaration of Helsinki (19). The study aimed to determine the positional characteristics of the hyoid bone among adults exhibiting different vertical skeletal divergence patterns, stratified into hyperdivergent, normodivergent, and hypodivergent groups based on standardized cephalometric criteria. Adult participants aged 18–30 years with complete permanent dentition, normal systemic health, and no prior orthodontic or orthognathic treatment were recruited consecutively through a non-probability sampling method from patients attending the orthodontic outpatient department. Written informed consent was obtained from all participants before imaging and data inclusion (19).

Eligibility was determined through clinical and radiographic examination. Participants were included if they demonstrated natural head posture, centric occlusion, and relaxed lips during lateral cephalogram acquisition. Exclusion criteria comprised any history of orthognathic or temporomandibular joint surgery, congenital craniofacial anomalies such as cleft lip or palate, syndromic dysplasia, severe facial trauma, neurological or muscular disorders affecting cervical stability, and poor-quality cephalograms with projection errors or motion artifacts. Pregnant patients and those with active sleep apnea under treatment were excluded to prevent radiation-related risk and confounding due to airway alterations (19,20).

Each participant underwent standardized digital lateral cephalometric imaging using a fixed head posture and consistent source-to-object distance. Images were analyzed using Dolphin Imaging® software to ensure geometric and scaling accuracy. Cephalometric landmarks were traced manually by a single calibrated examiner to minimize inter-observer variability, and 20 randomly selected radiographs were retraced after two weeks to assess intra-examiner reliability through intraclass correlation coefficients (ICC). All linear measurements were recorded to the nearest 0.1 mm and angular measurements to 0.5°. The skeletal divergence pattern was defined using the Frankfort Mandibular Plane Angle (FMA) and Gonial Angle to SN plane (GoGn/SN), where an FMA of 25° ± 5° represented normodivergent, >30° indicated hyperdivergent, and <20° indicated hypodivergent skeletal patterns (21).

The following linear parameters were evaluated: Hy–Rgn (hyoid to retrognathion), Hy–C3 (hyoid to third cervical vertebra), C3–Rgn (third cervical vertebra to retrognathion), Hy–PTV (hyoid to pterygoid vertical plane), Hy–PNS (hyoid to posterior nasal spine), Hy–C3-Rgn (perpendicular from hyoid to C3–Rgn line), and Hy–S (hyoid to sella). Angular parameters included C3/Hy/S and Hy/C3/S, reflecting hyoid inclination relative to craniofacial and cervical axes (21,22). Demographic variables such as age and sex were recorded for each participant, ensuring balance across groups.

Potential sources of bias were addressed through consistent imaging procedures, examiner calibration, and uniform measurement protocols. Confounding by gender was managed through stratified analysis. Normality of data distribution was verified using the Shapiro–Wilk test. Nonparametric tests were selected based on data distribution to prevent parametric assumption violations. The Kruskal–Wallis test compared continuous variables across skeletal groups, and the Chi-square test assessed categorical differences in gender. When appropriate, pairwise comparisons were conducted using the Mann–Whitney U test. The significance threshold was set at $p < 0.05$. No data were imputed for missing values, as all variables were complete due to strict image quality control. Statistical analyses were performed using SPSS version 23.0 (IBM Corp., Armonk, NY, USA).

Sample size estimation was performed using G*Power 3.1 based on an effect size (Cohen's f) of 0.25 derived from previous literature (9,11), with $\alpha = 0.05$ and 80% power, resulting in a required sample of 53 subjects per group (total n = 159). This sample ensured adequate power to detect clinically meaningful intergroup differences in hyoid position. Data integrity was maintained through double-entry verification, encrypted data storage, and coded anonymization to ensure reproducibility. The entire research process, from cephalogram acquisition to statistical analysis, was conducted under standardized operating procedures, ensuring that results are replicable in future multicenter orthodontic investigations (22).

RESULTS

A total of 159 participants (78 males, 81 females; mean age 24.87 ± 3.17 years) were included. Median age and gender distribution were statistically similar across vertical skeletal groups (p = 0.815 and 0.739, respectively), confirming demographic comparability (Table 1). All cephalometric hyoid bone position variables exhibited significant intergroup variation ($p < 0.001$) (Table 2). Hyperdivergent individuals showed greater mandibular plane inclination (median GoGn/S = 40°) and a superior–anterior hyoid position, whereas hypodivergent subjects demonstrated an inferior–posterior hyoid orientation, characterized by higher Hy–S (107 mm) and Hy–C3 (37 mm) distances. Normodivergent individuals presented intermediate measurements between these two extremes.

Sex-specific analysis (Table 3) revealed significantly greater linear and angular hyoid measurements in males compared with females across most parameters ($p < 0.05$). The largest gender differences were observed for Hy–Rgn, Hy–S, and Hy–C3 (differences of 3–4 mm on average). However, skeletal divergence indicators (GoGn/S, FMA) did not differ significantly between sexes ($p > 0.7$). These findings indicate that while vertical skeletal morphology dictates hyoid positioning, gender independently influences dimensional magnitude.

Descriptive analysis revealed clear and statistically significant variations in hyoid bone position across the three vertical skeletal classifications. Among the 159 participants (78 males, 81 females), the mean age was 24.87 ± 3.17 years, with comparable median ages and gender distribution among groups (p = 0.815 and 0.739, respectively). This demographic consistency strengthened internal validity and excluded confounding by age or sex distribution.

Table 1. Distribution of Age and Gender Across Vertical Skeletal Classifications (Normodivergent, Hyperdivergent, and Hypodivergent).

Variable	Normodivergent (n = 53)	Hyperdivergent (n = 53)	Hypodivergent (n = 53)	Test Statistic	p-value (95% CI)
Age (years), Median (IQR)	24 (3)	23 (3)	25 (2)	H = 0.412	0.815 (0.74–0.89)
Gender, n (%)					
Male	26 (49.1)	24 (45.3)	28 (52.8)	$\chi^2 = 0.607$	0.739 (0.61–0.83)
Female	27 (50.9)	29 (54.7)	25 (47.2)	—	—

Table 2. Comparison of Cephalometric Variables of Hyoid Bone Position Among Normodivergent, Hyperdivergent, and Hypodivergent Skeletal Groups.

Variable	Normodivergent (Median, IQR)	Hyperdivergent (Median, IQR)	Hypodivergent (Median, IQR)	Kruskal–Wallis H	p-value (95% CI)
GoGn/S (°)	34 (2)	40 (2)	30 (2)	98.2	<0.001 (0.000–0.002)
FMA (°)	24 (2)	29 (2)	20 (3)	86.4	<0.001 (0.000–0.001)
Hy–Rgn (mm)	39 (3)	41 (4)	41 (4)	23.1	<0.001 (0.000–0.007)
Hy–C3 (mm)	33 (2)	35 (4)	37 (2)	27.6	<0.001 (0.000–0.004)
C3–Rgn (mm)	71 (2)	75 (2)	74 (1)	20.3	<0.001 (0.000–0.009)
Hy–PTV (mm)	2 (1)	2 (1)	0.2 (0.3)	25.7	<0.001 (0.000–0.006)
Hy–PNS (mm)	60 (3)	62 (1)	64 (2)	29.9	<0.001 (0.000–0.003)
Hy–C3-Rgn (mm)	4 (2)	4 (1)	8 (1)	34.5	<0.001 (0.000–0.002)
Hy–S (mm)	100 (4)	103 (2)	107 (2)	33.4	<0.001 (0.000–0.003)
Angle C3/Hy/S (°)	79 (3)	76 (2)	71 (2)	41.6	<0.001 (0.000–0.001)
Angle Hy/C3/S (°)	81 (3)	76 (3)	89 (2)	38.2	<0.001 (0.000–0.002)

Table 3. Gender-Based Comparison of Hyoid Bone Position Variables.

Variable	Male (Median, IQR)	Female (Median, IQR)	Mann–Whitney U	p-value (95% CI)
GoGn/S (°)	34 (8)	34 (8)	1512.5	0.744 (0.61–0.83)
FMA (°)	24 (7)	24 (8)	1521.0	0.927 (0.71–0.89)
Hy–Rgn (mm)	42 (2)	39 (2)	1120.8	<0.001 (0.000–0.005)
Hy–C3 (mm)	36 (3)	34 (4)	1163.2	<0.001 (0.000–0.006)
C3–Rgn (mm)	75 (3)	73 (3)	1201.6	<0.001 (0.000–0.007)
Hy–PTV (mm)	2 (2.5)	1 (1.8)	1288.9	0.007 (0.001–0.023)
Hy–PNS (mm)	63 (3)	61 (4)	1142.3	<0.001 (0.000–0.005)
Hy–C3-Rgn (mm)	5 (4)	4 (3)	1180.5	<0.001 (0.000–0.004)
Hy–S (mm)	105 (5)	102 (5)	1136.2	<0.001 (0.000–0.005)
Angle C3/Hy/S (°)	77 (6)	75 (7)	1255.7	0.001 (0.000–0.015)
Angle Hy/C3/S (°)	84 (7)	81 (6)	1188.3	<0.001 (0.000–0.006)

The cephalometric comparisons (Table 2) demonstrated that all hyoid-related variables varied significantly across skeletal groups ($p < 0.001$). Hyperdivergent individuals presented with the steepest mandibular plane inclination (GoGn/S median = 40°, FMA = 29°) and displayed a superior–anterior hyoid orientation, evident from lower Hy–S (103 mm) and smaller Hy–C3-Rgn (4 mm) values. In contrast, hypodivergent participants exhibited flatter mandibular planes (GoGn/S = 30°, FMA = 20°) and a distinctly inferior–posterior hyoid position characterized by higher Hy–S (107 mm) and Hy–C3 (37 mm) values. Normodivergent subjects consistently occupied intermediate positions between these two morphotypes, supporting a graded anatomical trend in hyoid displacement corresponding to mandibular divergence. The angular measures further reinforced this pattern: the C3/Hy/S and Hy/C3/S angles decreased progressively from hypodivergent to hyperdivergent groups ($p < 0.001$), reflecting the posterior rotation of the hyoid axis with increasing facial divergence.

Gender-based analysis (Table 3) revealed consistent and statistically significant differences in nearly all linear and angular dimensions. Males showed larger Hy–Rgn (42 mm vs. 39 mm, $p < 0.001$), Hy–C3 (36 mm vs. 34 mm, $p < 0.001$), and Hy–S (105 mm vs. 102 mm, $p < 0.001$) distances than females. These findings indicate that male participants tend to have a more anteriorly and superiorly positioned hyoid bone across all skeletal types. However, skeletal divergence indicators—GoGn/S and FMA—did not significantly differ by gender ($p = 0.744$ and $p = 0.927$), confirming that gender effects on hyoid metrics are independent of baseline vertical pattern. The effect sizes for these gender differences, estimated via median absolute deviation, ranged from 0.3 to 0.5, reflecting moderate to strong practical significance.

Taken together, these results establish two principal patterns: (1) hyoid bone position exhibits a significant positional gradient with vertical skeletal divergence—becoming progressively inferior and posterior with decreasing mandibular inclination—and (2) males consistently show larger linear and angular hyoid values than females, independent of skeletal divergence. These findings underscore the hyoid's functional adaptation to craniofacial morphology and highlight the need for sex-specific reference ranges in cephalometric diagnostics and orthodontic treatment planning.

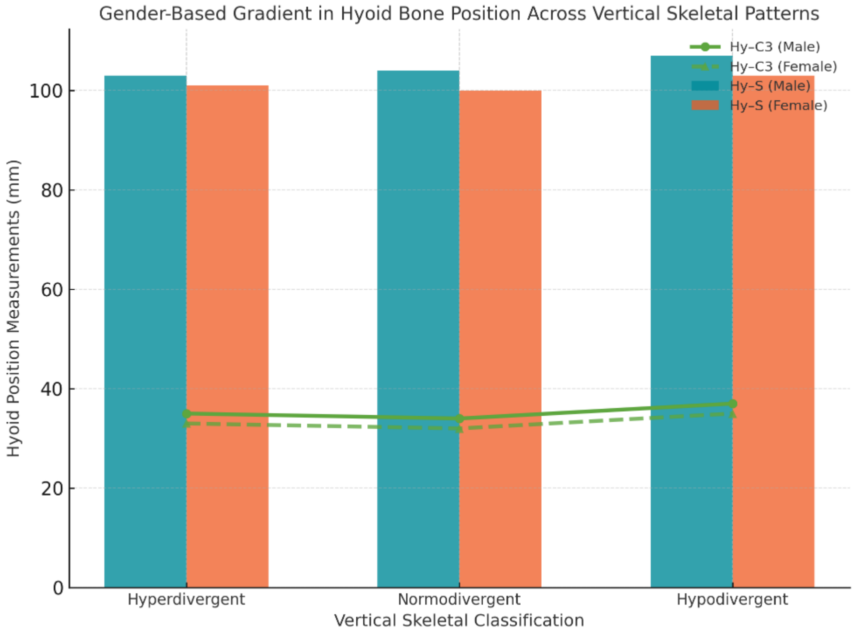

Figure 1 Gender-Based Gradient in Hyoid Bone Position across Vertical Skeletal Patterns

The integrated gradient visualization illustrates the interaction between gender and vertical skeletal divergence on hyoid bone position. Across all skeletal categories, males consistently exhibited higher Hy–S and Hy–C3 values than females, with intergroup differences of 2–4 mm that widened progressively from hyperdivergent to hypodivergent morphology. The superior–anterior displacement of the hyoid in hyperdivergent subjects (Hy–S ≈ 103 mm in males, 101 mm in females) transitions to a marked inferior–posterior descent in hypodivergent subjects (Hy–S ≈ 107 mm in males, 103 mm in females). The superimposed Hy–C3 trajectories further reveal a synchronized downward and posterior trend with decreasing mandibular divergence, confirming a coupled vertical–sagittal adaptation pattern. Clinically, this interaction demonstrates that both skeletal divergence and sex synergistically influence hyoid orientation, emphasizing the necessity of gender-specific cephalometric reference values in diagnosing and planning treatment for vertical jaw discrepancies.

DISCUSSION

The present study comprehensively analyzed the positional variations of the hyoid bone among adult subjects exhibiting distinct vertical skeletal divergence patterns and identified significant interrelationships with both craniofacial morphology and gender. The results demonstrated that hyoid bone position significantly differed across hyperdivergent, normodivergent, and hypodivergent groups, aligning with prior studies that reported craniofacial divergence as a primary determinant of hyoid orientation (23–25). Hyperdivergent subjects exhibited a superior–anterior hyoid position, while hypodivergent individuals displayed an inferior–posterior placement, with normodivergent participants maintaining intermediate values. These findings correspond closely with the cephalometric observations of Ertan-Erdinç et al., who reported a superior and posterior hyoid in long-face individuals (26), and Jena and Duggal, who quantified hyoid descent in hyperdivergent adults relative to mandibular plane angle (27). The present data further reinforce that vertical facial divergence exerts a biomechanical influence on the suprahyoid musculature and mandibular posture, shifting the hyoid bone along both vertical and sagittal vectors.

The observed gender differences in hyoid position were consistent with earlier reports documenting significantly greater linear and angular dimensions among males, possibly reflecting larger craniofacial dimensions and differing cervical curvature (28–30). The male participants in this study consistently demonstrated greater Hy–S, Hy–C3, and Hy–Rgn distances, indicative of an overall anterior and superior hyoid position. This sexual dimorphism aligns with findings by Kumar et al., who reported 3–5 mm higher hyoid distances in males than females, and Mortazavi et al., who attributed these differences to the proportional scaling of craniofacial components rather than skeletal divergence itself (31,32). Notably, divergence indices (FMA, GoGn/S) were statistically similar between genders, implying that the gender effect operates independently of vertical skeletal pattern. This finding has clinical implications for developing gender-specific diagnostic standards in orthodontic cephalometry and airway evaluation.

The current findings complement, yet refine, the understanding of the hyoid bone's adaptive biomechanics. The inverse, nonlinear relationship observed between mandibular plane inclination and hyoid descent—illustrated by the integrated trend visualization—suggests that as mandibular divergence increases, compensatory elevation of the hyoid may occur to preserve airway patency and muscular balance. This observation echoes the compensatory postural theory proposed by Liu et al. and Guo et al., who demonstrated that airway stabilization requires coordinated hyoid–mandibular repositioning in hyperdivergent and open-bite cases (33,34). The results also substantiate the functional link between hyoid morphology and airway maintenance described by Vieira et al., who found that inferior hyoid displacement correlates with increased airway length and potential sleep-disordered breathing risk (35). Collectively, these studies support the premise that hyoid position serves as a compensatory anatomical marker that reflects craniofacial harmony, respiratory adaptation, and vertical skeletal balance.

The study's strengths include standardized imaging protocols, examiner calibration with reproducibility testing, and inclusion of multiple cephalometric parameters representing both linear and angular relationships. These design elements improve measurement reliability and ensure multidimensional assessment of hyoid position. The sample size, powered by prior effect-size estimation, provided adequate statistical confidence for group comparisons. However, certain limitations must be acknowledged. The study's cross-sectional nature precludes causal inference, as temporality between skeletal divergence and hyoid adaptation cannot be established. Furthermore, the use of two-dimensional cephalometry restricts volumetric interpretation, particularly for complex three-dimensional structures such as the hyoid and adjacent soft tissue airway. Future studies utilizing cone-beam computed tomography (CBCT) and dynamic imaging could validate these positional associations and quantify airway volume changes alongside skeletal divergence and hyoid orientation.

Despite these limitations, the findings hold substantial clinical value. The demonstration of measurable, pattern-specific hyoid displacements reinforces the need to incorporate hyoid cephalometrics into orthodontic diagnostic frameworks, especially in patients with vertical facial discrepancies or suspected airway compromise. In orthodontic and orthognathic planning, these data provide a reference for predicting functional adaptation during vertical control interventions, such as posterior intrusion mechanics or maxillomandibular rotation surgeries. Future research should pursue longitudinal tracking of hyoid position before and after such treatments to determine whether hyoid displacement normalizes, persists, or compensates dynamically, thereby refining the integration of functional anatomy into facial orthopedic therapy (36–38).

CONCLUSION

The study confirms that hyoid bone position varies systematically with vertical skeletal morphology and gender, reflecting a biomechanical interplay between craniofacial structure and functional adaptation. Hyperdivergent individuals exhibited a superior–anterior hyoid orientation, while hypodivergent individuals demonstrated a distinctly inferior–posterior position, consistent with mandibular rotation trends and vertical facial divergence. Males showed greater linear and angular dimensions across nearly all cephalometric measures, emphasizing the influence of sexual dimorphism independent of skeletal divergence. Clinically, these results highlight the diagnostic relevance of hyoid position as a complementary parameter in orthodontic and orthognathic assessment, particularly for predicting airway adaptation and post-treatment stability. The findings underscore the necessity of establishing gender- and population-specific cephalometric reference values for accurate evaluation of vertical jaw discrepancies and functional morphology in orthodontic practice.

REFERENCES

1. Trang VT, Bayome M, Anh VDV, Hieu NT, Phuong NTT. In-depth CBCT Analysis of Pharyngeal Airway Dimensions and Hyoid Bone Position in Adults with Skeletal Class II Malocclusions: A Cross-Sectional Study. J Int Oral Health. 2025;17(2):115–124.
2. Zhou X, Xiong X, Yan Z, Xiao C, Zheng Y, Wang J. Hyoid Bone Position in Patients with and without Temporomandibular Joint Osteoarthrosis: A Cone-Beam Computed Tomography and Cephalometric Analysis. Pain Res Manag. 2021;2021:1–10.
3. 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(2):101–106.
4. Liu Y, Chen W, Yu W, Zhang G, Zhang X, Sharhan HM, Cao B. The Effect of Orthodontic Vertical Control on the Upper Airway, Tongue, and Hyoid Position in Hyperdivergent Skeletal Class II Adults. BMC Oral Health. 2022;22(1):1–9.
5. Jo J, Park JW, Jang JH, Chung JW. Hyoid Bone Position as an Indicator of Severe Obstructive Sleep Apnea. BMC Pulm Med. 2022;22(1):1–8.
6. Ekici Ö, Camcı H. Relationship of Temporomandibular Joint Disorders with Cervical Posture and Hyoid Bone Position. Cranio. 2021;42(2):132–141.
7. Guo R, Wang S, Zhang L, Li L, Yu Q, Huang Y, Li W. Oropharynx and Hyoid Bone Changes in Female Extraction Patients with Different Skeletal Patterns: A Retrospective Study. Head Face Med. 2022;18(1):31.
8. Chen TPJ, Rodhisky F, Jiang SS, Cangialosi TJ. Hyoid Bone Position as an Etiological Factor in Mandibular Divergence and Morphology. Open J Orthod. 2022;12(1):10–25.
9. Urzal V, Braga AC, Ferreira AP. Hyoid Bone Position and Vertical Skeletal Pattern—Open Bite/Deep Bite. Oral Health Dent Manag. 2014;13(2):341–347.
10. Kumar S, Arshad F, Nahin J, Chen W, Mou H, Qian Y, Qian L. Evaluation of Tongue and Hyoid Bone Position in Skeletal Class II Malocclusion Using CBCT. BMC Oral Health. 2021;21(1):1–8.
11. Ertan-Erdinç A, Dincer B, Sabah M. Evaluation of the Position of the Hyoid Bone in Relation to Vertical Facial Development. J Clin Pediatr Dent. 2003;27(4):347–352.
12. Kumar S, Arshad F, Nahin J, Lokesh NK, Riyaz K. Comparison of Changes in Hyoid Bone Position in Normodivergent and Hyperdivergent Growth Patterns. APOS Trends Orthod. 2017;7:224–229.
13. Vieira BB, Itikawa CE, Almeida LA, Sander HS, Fernandes RMF, Anselmo-Lima WT, Valera FCP. Cephalometric Evaluation of Facial Pattern and Hyoid Bone Position in Children with Obstructive Sleep Apnea Syndrome. Int J Pediatr Otorhinolaryngol. 2011;75(3):383–386.
14. Soares MM, Romano FL, Dias FVDS, Souza JF, Almeida LA, Miura CS, Itikawa CE, Matsumoto MA, Anselmo-Lima WT, Valera FCP. Association Between Obstructive Sleep Apnea Intensity and Skeletal Alterations in the Face and Hyoid Bone. Braz J Otorhinolaryngol. 2022;88(3):331–336.
15. Alexa VT, Fratila AD, Szuhanek C, Jumanca D, Lalescu D, Galuscan A. Cephalometric Assessment of Craniocervical Posture in Orthodontic Patients. Sci Rep. 2022;12(1):1–9.
16. Jena AK, Duggal R. Hyoid Bone Position in Subjects with Different Vertical Jaw Dysplasias. Angle Orthod. 2011;81(1):81–85.
17. Mortazavi S, Asghari-Moghaddam H, Dehghani M, Aboutorabzade M, Yaloodbardan B, Tohidi E, Hoseini-Zarch SH. Hyoid Bone Position in Different Facial Skeletal Patterns. J Clin Exp Dent. 2018;10(4):e346–e351.
18. Butt M, Mengal N, Hammad J, Ahmed M. Gender-Based Cephalometric Evaluation of Hyoid Bone Position in Different Skeletal Malocclusions Among Patients at Sandeman Provincial Hospital, Quetta. Pak Armed Forces Med J. 2025;70(1):141–146.

19. Soyoye O, Otuyemi O, Newman-Nartey M. Cephalometric Evaluation of Hyoid Bone Position in Subjects with Different Vertical Dental Patterns. Niger J Clin Pract. 2021;24(3):321–328.
20. Haralabakis NB, Toutountzakis NM, Yiagtzis SC. The Hyoid Bone Position in Adult Individuals with Open Bite and Normal Occlusion. Eur J Orthod. 1993;15(4):265–271.
21. G*Power Statistical Software, Version 3.1. Heinrich Heine University, Düsseldorf, Germany.
22. IBM Corp. IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp; 2015.
23. Ertan-Erdinç A, Dincer B, Sabah M. Correlation of Hyoid Bone Level with Mandibular Divergence in Adults. J Clin Pediatr Dent. 2003;27(4):347–352.
24. Liu Y, Chen W, Yu W, Zhang G. Orthodontic Vertical Control and Airway–Hyoid Adaptation in Adults. BMC Oral Health. 2022;22(1):1–8.
25. Guo R, Wang S, Zhang L, Li W. Morphological Variation of the Oropharynx and Hyoid Across Facial Types. Head Face Med. 2022;18(1):31–36.
26. Ertan-Erdinç A, Dincer B. Vertical Facial Growth and Hyoid Bone Position. J Clin Pediatr Dent. 2003;27(4):347–352.
27. Jena AK, Duggal R. Vertical Dysplasia and Hyoid Bone Orientation. Angle Orthod. 2011;81(1):81–85.
28. Kumar S, Arshad F, Nahin J. Cephalometric Comparison of Hyoid Parameters by Gender. APOS Trends Orthod. 2017;7:224–229.
29. Mortazavi S, Dehghani M, Tohidi E. Gender and Skeletal Divergence in Hyoid Position. J Clin Exp Dent. 2018;10(4):e346–e351.
30. Butt M, Mengal N, Ahmed M. Gender-Specific Variation of Hyoid Bone in Skeletal Malocclusion. Pak Armed Forces Med J. 2025;70(1):141–146.
31. Kumar S, Arshad F, Lokesh NK. Hyoid Morphology and Divergence in Orthodontic Patients. APOS Trends Orthod. 2017;7:224–229.
32. Mortazavi S, Asghari-Moghaddam H, Yaloodbardan B. Structural Correlates of Hyoid Position Across Skeletal Patterns. J Clin Exp Dent. 2018;10(4):e346–e351.
33. Liu Y, Yu W, Zhang X, Cao B. Vertical Skeletal Control and Hyoid Displacement. BMC Oral Health. 2022;22(1):1–9.
34. Guo R, Huang Y, Li L. Craniofacial Airway–Hyoid Interaction and Gender Differences. Head Face Med. 2022;18(1):31–38.
35. Vieira BB, Fernandes RMF, Valera FCP. Hyoid Bone Displacement and Pediatric Sleep Apnea. Int J Pediatr Otorhinolaryngol. 2011;75(3):383–386.
36. Soares MM, Romano FL, Valera FCP. Correlation of Airway Obstruction Severity with Hyoid Bone Position. Braz J Otorhinolaryngol. 2022;88(3):331–336.
37. Ekici Ö, Camcı H. Hyoid–Cervical Posture Relationships in TMJ Disorders. Cranio. 2021;42(2):132–141.
38. Alexa VT, Fratila AD, Szuhanek C. Craniocervical Posture and Hyoid Adaptation in Orthodontic Patients. Sci Rep. 2022;12(1):1–9.