Hyoid Bone Position and Facial Morphology
A Comprehensive Review with a Lateral Cephalometric Framework

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Abstract—**Background: The hyoid bone is a mobile, non-articulating skeletal structure suspended by supra- and infrahyoid muscles and linked functionally to the mandible, tongue, cranial base, cervical spine, pharynx and larynx. Because it participates in respiration, deglutition, phonation and postural balance, its radiographic position has long attracted orthodontic interest. Differences reported among sagittal and vertical facial patterns, however, are not fully consistent because studies use heterogeneous reference planes, age ranges, postural protocols and definitions of skeletal pattern.**

Objective: To critically review the anatomy, physiology and lateral cephalometric assessment of hyoid position in different facial patterns; synthesize evidence relating the hyoid to sagittal and vertical dysplasia, sex, age, breathing pattern, upper-airway morphology and orthodontic intervention; and provide a reproducible framework for future observational studies.

Methods: A structured narrative approach is proposed using peer-reviewed orthodontic, radiologic, sleep-medicine and anatomy literature. Evidence is organized according to sagittal skeletal class, vertical growth pattern, measurement system and major confounders. Particular emphasis is placed on the hyoid triangle and on the methodological limitations of two-dimensional cephalometry.

Results: Most studies suggest that hyoid position adapts to mandibular morphology and airway demands rather than following a single class-specific rule. Class III subjects often show a relatively anterior hyoid, whereas Class II mandibular retrognathism is frequently associated with a relatively posterior or inferior position. Vertical-pattern findings are less uniform. Sex, age, natural head posture, cervical inclination, tongue posture and respiratory status materially influence measurements.

Conclusion: Hyoid location is best interpreted as one component of an integrated cranio-cervico-mandibular functional unit. Standardized acquisition and reporting, multivariable analysis and three-dimensional or longitudinal confirmation are necessary before hyoid measures can be treated as diagnostic or prognostic markers.

Index Terms—**hyoid bone; facial pattern; skeletal malocclusion; lateral cephalometry; hyoid triangle; craniofacial morphology; upper airway; orthodontics.**

I. INTRODUCTION

The hyoid bone occupies a strategically important position at the interface of the craniofacial skeleton, cervical column and upper airway. It lies in the anterior neck, usually near the third cervical vertebral level, and differs from most bones because it has no direct bony articulation. Its spatial location is maintained dynamically by muscular and fascial connections. Superiorly, the suprahyoid complex links the hyoid to the mandible, cranial base and tongue; inferiorly, the infrahyoid complex links it to the sternum, scapula, clavicular region and laryngeal framework. The result is a mobile platform whose position changes with mandibular movement, tongue activity, swallowing, breathing and head posture [1-4]. Orthodontists are interested in the hyoid because craniofacial form and oropharyngeal function are interdependent. A retrognathic mandible may reduce the anterior skeletal boundary available to the tongue; a hyperdivergent pattern may coexist with altered craniocervical posture; and airway obstruction may encourage compensatory head extension and inferior positioning of the tongue-hyoid complex. These associations do not establish simple causation, but they explain why the hyoid is frequently evaluated in studies of malocclusion, mouth breathing, obstructive sleep apnea (OSA), functional appliances and orthognathic surgery [5-10]. Lateral cephalometry offers a readily available method for assessing the

hyoid relative to cranial, mandibular and cervical landmarks. Broadbent's standardization of cephalometric radiography enabled serial and comparative study of craniofacial relationships [11]. Early hyoid studies used cranial planes, but these measures were vulnerable to changes in head posture. Bibby and Preston therefore proposed the hyoid triangle, constructed from retrognathion, the anteroinferior point of the third cervical vertebra and hyoidale, to express the hyoid in relation to structures with close functional connections [1]. The published evidence remains heterogeneous. Investigators have classified sagittal pattern using ANB, Wit's appraisal or jaw-specific measures, while vertical pattern has been defined with mandibular-plane angles, the Jarabak ratio, facial axis or combinations of variables. The landmark called "H" is also not completely uniform across reports. These variations can reverse the apparent direction of a difference. A critical review should therefore compare not only conclusions, but also acquisition posture, coordinate system, reference plane and adjustment for age and sex.

1.1 Aim of the review

This review examines whether and how hyoid position differs among sagittal and vertical facial patterns, explains the biological mechanisms that may underlie reported associations, evaluate lateral cephalometric methods and propose a robust protocol for an original cross-sectional study.

II. ANATOMY AND FUNCTIONAL BIOMECHANICS

The adult hyoid is U-shaped and consists of a central body, paired greater cornua and paired lesser cornua. Ossification and fusion continue through growth, so hyoid form and landmark definition may vary in children and adolescents. The anterior-superior point of the body is commonly selected as hyoidale because it is usually identifiable on a lateral cephalogram, although superimposition of the paired cornua and variable image quality can complicate tracing [1,12].

The suprahyoid muscles include the digastric, mylohyoid, geniohyoid and stylohyoid. Together they can elevate the hyoid during swallowing, stabilize it for mandibular depression, and link its position to the symphysis and cranial base. The genioglossus and intrinsic/extrinsic tongue muscles contribute to the tongue-hyoid relationship. The infrahyoid group sternohyoid, omohyoid, sternothyroid and thyrohyoid depresses or stabilizes the hyoid and larynx. Middle pharyngeal constrictor fibers and fascial attachments further couple hyoid motion to the pharynx [2-4].

This suspension system behaves as a force equilibrium rather than a fixed linkage. If the mandible is advanced, tension in geniohyoid, mylohyoid and tongue-related structures may translate the hyoid anteriorly or superiorly, but compensatory activity of infrahyoid muscles and changes in head posture can modify the net displacement. If the mandible rotates clockwise, an inferior change in the hyoid relative to the cranial base may coexist with little change relative to the mandibular plane. Consequently, the same biological event can produce different cephalometric findings depending on the reference system [7,13].

During inspiration, upper-airway dilator activity helps maintain patency. Anterior traction on the hyoid can stiffen and enlarge the hypopharyngeal airway in experimental and clinical contexts. During swallowing, the hyoid moves superiorly and anteriorly to assist laryngeal elevation and airway protection. During speech, smaller rapid excursions occur. A cephalogram is therefore a static sample from a moving system and should not be interpreted as a direct test of muscle function or airway collapsibility.

2.1 The integrated functional unit

The clinically useful model is a cranio-cervico-mandibular functional unit. The mandible provides an anterior attachment, the cervical region provides a posterior reference, the tongue and soft palate occupy the intervening airway-related space, and head posture regulates the spatial relationship of all components. Variation in hyoid position may represent normal compensation that preserves airway calibre rather than pathology. This distinction is central when comparing facial types.

III. FACIAL PATTERNS AND THEIR CLASSIFICATION

Facial pattern can be described in sagittal, vertical and transverse dimensions. Most hyoid studies focus on sagittal skeletal classes and vertical divergence. Dental Angle classification should not substitute for skeletal classification because molar relationship may be affected by tooth position, extraction, growth or

compensation. A transparent study should state the cephalometric thresholds used, identify borderline cases and preferably confirm classification with more than one measure.

3.1 Sagittal patterns

Skeletal Class I generally denotes a balanced maxillomandibular relationship, commonly operationalized as ANB approximately 0°-4°. Skeletal Class II denotes a relatively distal mandible, prominent maxilla or combination, often represented by ANB >4°. Skeletal Class III denotes maxillary retrusion, mandibular prognathism or combination, often represented by ANB <0°. ANB is influenced by cranial-base geometry, vertical rotation and nasion position; Wit's appraisal and jaw-specific variables such as SNA and SNB should therefore be considered when interpreting hyoid relationships [14].

3.2 Vertical patterns

Hypodivergent or horizontal growers show a relatively low mandibular-plane angle, reduced lower anterior facial height and a tendency toward forward mandibular rotation. Normodivergent subjects fall within population-specific reference intervals. Hyperdivergent or vertical growers commonly show a high mandibular-plane angle, increased lower anterior facial height and clockwise mandibular rotation. Frequently used measures include SN-MP, FMA, the Jarabak ratio, Y-axis, facial axis and gonial angle. Single-variable classification can mislabel subjects, and published diagnostic parameters may disagree [15].

3.3 Why classification affects hyoid findings

A sample labelled Class II may contain maxillary prognathism, mandibular retrognathism or both. These subtypes need not have the same tongue-hyoid environment. Likewise, a hyperdivergent Class II group combines sagittal and vertical influences. Failure to stratify or adjust for vertical pattern can create an apparent sagittal difference, and vice versa. Age and sex distribution can further confound comparisons because the hyoid descends with growth and is often located lower in males.

For a study specifically addressing "different facial patterns," the strongest design is factorial: sagittal class (I, II, III) and vertical pattern (hypodivergent, normodivergent, hyperdivergent), with sex and age included as covariates. If sample size is insufficient for nine cells, the title and objectives should be narrowed to the dimension actually tested.

IV. LATERAL CEPHALOMETRIC EVALUATION OF THE HYOID

A standardized lateral cephalogram should be obtained in natural head position or a clearly specified cephalostat position, with teeth in centric occlusion, lips relaxed and the patient instructed not to swallow during exposure. The breathing phase and tongue posture are difficult to control but should be standardized as far as practical. Magnification must be calibrated before linear measurement. Repeated exposures solely for research are ethically inappropriate; archived diagnostic images are commonly used in retrospective designs.

4.1 Principal landmarks

Landmark	Definition	Use
H (hyoidale)	Most anterosuperior point on the hyoid body	Primary hyoid landmark
C3	Most anteroinferior point of C3	Posterior triangle point
RGn	Most posteroinferior point of mandibular symphysis	Anterior triangle point
S and N	Sella and nasion	Cranial-base reference
Go, Me, Gn	Mandibular landmarks	Mandibular plane and facial pattern
ANS, PNS	Palatal landmarks	Palatal plane reference

4.2 Hyoid triangle

The hyoid triangle joins C3, H and RGn. C3-RGn forms the anteroposterior base. The perpendicular distance from H to C3-RGn expresses vertical hyoid position; its sign should be defined because some software records a point below the line as negative. C3-H and H-RGn represent posterior and anterior sides. This system reduces reliance on remote cranial planes and expresses the hyoid relative to functionally related mandibular and cervical structures [1].

4.3 Additional linear and angular measures

Common variables include H-MP, H-FH, H-SN, H-N perpendicular, H-PNS, C3-H, H-RGn and angles between the hyoid axis and mandibular, palatal or

cranial planes. Because a distance may represent different directions in different coordinate systems, each variable requires a diagram and operational definition. Reporting only abbreviations prevents replication.

Digital tracing can improve efficiency but does not eliminate landmark error. At least 20%-30% of images should be retraced after a two-week interval. Intraclass correlation coefficients are preferred for continuous measures; Dahlberg's formula can quantify random error, and paired testing can detect systematic bias. Reliability must be reported for classification variables as well as hyoid measurements.

V. HYOID POSITION IN SAGITTAL FACIAL PATTERNS

The broad trend in the literature is that hyoid position is associated with sagittal mandibular morphology, but the magnitude and even direction depend on the reference frame. Kuroda and colleagues described the hyoid body as relatively posterior in Class II and anterior in Class III when referenced to the cranial base [16]. Adamidis and Spyropoulos reported a more anterior hyoid and altered hyoid-axis inclination in Class III compared with Class I subjects [17]. Subsequent studies have variably confirmed, qualified or failed to reproduce these findings.

5.1 Class I pattern

Class I groups are commonly treated as controls, but they are not necessarily functionally homogeneous. Individuals can be hyperdivergent or hypodivergent, nasal or oral breathers, and at different growth stages. The classic hyoid-triangle literature suggests a relatively stable C3-H relationship in normal samples, whereas distances to the symphysis vary more with mandibular size and position [1,18]. Population-specific norms are preferable to a universal "normal" value.

5.2 Class II pattern

In mandibular retrognathism, the tongue's anterior skeletal attachment is positioned posteriorly. The hyoid may also appear posterior relative to cranial coordinates, or it may move inferiorly as a compensatory mechanism that helps preserve pharyngeal space. Some studies find the hyoid closer to the mandibular plane in Class II; others report no significant difference between Class I and II after using mandibular or cervical references [5,19]. The distinction between maxillary protrusion and mandibular retrusion is therefore essential.

5.3 Class III pattern

Class III subjects frequently demonstrate a more anterior hyoid relative to cranial or cervical references, consistent with a forward mandibular position and anterior tongue-hyoid attachment. However, H-RGn can increase because the mandible advances more than the hyoid, which may be described as the hyoid being relatively posterior to the symphysis. These statements are not contradictory; they arise from different reference structures. Vertical findings in Class III are inconsistent, with reports of superior, inferior or unchanged position depending on facial height and reference plane [6,17,20].

The safest synthesis is that the hyoid participates in adaptation to sagittal morphology but is not a deterministic marker of skeletal class. Jaw-specific diagnosis, vertical pattern, cervical posture and airway state must accompany any class comparison.

VI. HYOID POSITION IN VERTICAL FACIAL PATTERNS

Vertical morphology changes mandibular rotation, lower facial height, floor-of-mouth geometry and cervical posture, all of which can influence the hyoid. Hyperdivergent subjects are often hypothesized to exhibit an inferior hyoid because clockwise mandibular rotation and increased lower anterior facial height lengthen the vertical relationship between cranial and mandibular structures. Hypodivergent subjects may show a relatively superior hyoid. Yet published results are variable, particularly when H is measured relative to the mandibular plane, which itself rotates as part of the facial pattern.

6.1 Hyperdivergent pattern

A high mandibular-plane angle can increase H-SN or H-FH even if the hyoid maintains a stable relationship to the mandible and cervical spine. Mouth breathing, lip incompetence and forward head posture may coexist and contribute independently. Some contemporary studies report altered hyoid-triangle dimensions in vertical growers, while others find no clinically important group difference after adjusting

for sex or sagittal class. Thus, "inferior" should always specify inferior to which plane.

6.2 Hypodivergent pattern

Horizontal growers generally have a shorter lower anterior facial height, stronger mandibular morphology and a reduced mandibular-plane angle. The hyoid may appear superior relative to cranial horizontal planes but not necessarily relative to the mandibular plane. Greater sagittal mandibular length can also increase H-RGn. Without an anteroposterior coordinate system, a single perpendicular distance may conceal combined horizontal and vertical changes.

6.3 Methodological interpretation

The most informative approach uses two coordinate systems: a cranial or true-horizontal system to show absolute radiographic location, and a local hyoid-triangle or mandibular-cervical system to show functional relationships. If both change in the same direction, confidence in a pattern-related difference increase. If they disagree, the discrepancy itself reveals whether the result is driven by mandibular rotation, cervical posture or true displacement of H.

Recent systematic evaluation of vertical skeletal pattern continues to emphasize heterogeneity in landmark definitions and classification thresholds. This supports cautious synthesis and discourages presentation of one fixed hyoid position as diagnostic of a vertical facial type. Longitudinal data are needed to distinguish developmental descent of the hyoid from cross-sectional differences among growth patterns.

VII. AGE, SEX, GROWTH AND POPULATION VARIATION

The hyoid descends relative to the cranial base during growth as the cervical spine, pharynx and laryngeal complex mature. Mandibular length and anterior facial height also increase, so age can affect nearly every linear hyoid variable. Cross-sectional studies that combine children, adolescents and adults without adjustment risk attributing developmental change to facial pattern. Growth status should be evaluated with chronological age and, when appropriate, cervical vertebral maturation or another justified maturity indicator. Sexual dimorphism becomes more evident after puberty. Males often have a larger craniofacial skeleton, longer pharynx and more inferior hyoid than females. The 2018 study of different skeletal patterns found sex-related differences alongside class-related findings, underscoring the need for sex matching or statistical adjustment [5]. Reporting only pooled means can conceal opposing or unequal effects in male and female subgroups.

Population ancestry, body size and sampling source also matter. Cephalometric norms are population-specific, and patients attending an orthodontic clinic are not a random sample of the general population. Studies drawn from treatment records can overrepresent severe malocclusion and particular socioeconomic or referral groups. Multi-centre recruitment and transparent demographic reporting improve external validity.

7.1 Recommended controls

- Use a restricted age range or adjust for age and skeletal maturity.
- Match groups by sex or include sex and interaction terms in regression.
- Record height, weight and body mass index when airway interpretation is planned.
- Exclude syndromes and craniofacial anomalies unless they are the focus of study.
- Separate growing from non-growing subjects rather than pooling them.
- Report the source population and ethnicity with appropriate sensitivity.

A statistically significant sex or age difference is not automatically clinically meaningful. Measurement error and normal within-group variability should be considered. Confidence intervals, standardized effect sizes and minimal detectable change are more informative than P values alone.

VIII. BREATHING PATTERN, HEAD POSTURE AND THE UPPER AIRWAY

The hyoid is frequently discussed as an airway-related structure because anterior hyoid traction can enlarge or stiffen the hypopharyngeal region. Nevertheless, a two-dimensional hyoid coordinate does not measure airway volume, resistance or collapsibility. The upper airway is three-dimensional and changes with wakefulness, respiration, body position and

neuromuscular tone. Cephalometric associations should therefore be described as anatomical relationships, not diagnoses of sleep-disordered breathing.

8.1 Mouth breathing and obstruction

Nasal obstruction may encourage oral breathing, altered tongue posture and extension of the head. Some studies report a lower or posterior hyoid in oral breathers, whereas others find a stable hyoid-triangle relationship [21]. The disagreement can reflect inconsistent clinical definitions of mouth breathing, transient obstruction, adenoidal status and uncontrolled head posture. Objective rhinologic assessment is preferable when respiratory pattern is a principal variable.

8.2 Head and cervical posture

Small changes in head extension can change cranial-plane distances even when the hyoid remains stable relative to C3 and the mandible. Natural head position, mirror-guided positioning and recording of cranio-cervical angles improve comparability. Current research continues to demonstrate relationships among forward head posture, craniofacial measures and hyoid location. Standardizing cervical posture is therefore not a minor technical detail; it is a prerequisite for valid comparison.

8.3 Obstructive sleep apnea

An inferiorly positioned hyoid is one of several cephalometric features associated with OSA, particularly in adults. Other factors include obesity, mandibular retrusion, soft-palate dimensions, tongue volume, airway length and neuromuscular control. Hyoid position may help characterize craniofacial risk, but it cannot confirm or exclude OSA. Screening questionnaires and referral for sleep assessment are appropriate when symptoms such as snoring, witnessed apneas, daytime sleepiness or growth/behavioral consequences in children are present [8-10].

In a facial-pattern study, airway widths may be recorded as secondary variables, but conclusions should remain proportionate to the design. Polysomnography or validated respiratory testing is required for disease-level inference.

IX. EFFECTS OF ORTHODONTIC AND SURGICAL INTERVENTIONS

9.1 Functional appliances

Mandibular advancement with removable or fixed functional appliances changes the attachment geometry of the geniohyoid, mylohyoid, genioglossus and associated soft tissues. Several studies describe anterior or cranial adaptation of the hyoid, while others show caudal displacement relative to cranial landmarks because treatment also increases lower facial height. A 2025 prospective cohort found that functional treatment in skeletal Class II produced anterior and cranial changes in the hyoid relative to local structures, with outcomes influenced by initial hyoid position [7]. The finding reinforces the importance of reference plane and growth pattern.

9.2 Orthognathic surgery

Mandibular setback can move the tongue-hyoid complex posteriorly and may narrow parts of the pharyngeal airway, followed by partial adaptation over time. Mandibular advancement and maxillomandibular advancement generally move related soft tissues forward and are established components of selected OSA treatment pathways. Surgical studies must distinguish immediate postoperative change from long-term neuromuscular adaptation and should include three-dimensional imaging or functional outcome measures when airway claims are made.

9.3 Extraction and retraction mechanics

Incisor retraction may alter tongue space, but evidence that routine premolar extraction causes clinically important airway or hyoid harm is inconsistent and vulnerable to confounding. Treatment decisions should not be based on isolated hyoid measures. Baseline facial morphology, anchorage, magnitude of incisor movement, growth, weight and respiratory health all influence observed change.

9.4 Clinical interpretation

Pre- and post-treatment cephalograms can document positional change, but the expected technical error should be calculated. A small statistically significant shift may fall within tracing uncertainty or normal postural variation. The hyoid should be incorporated into a broader assessment of mandibular position,

tongue posture, airway symptoms and cervical balance rather than promoted as a solitary treatment target.

X. CRITICAL APPRAISAL OF THE EVIDENCE

Most evidence on hyoid position and facial pattern is cross-sectional. Such studies can identify association but cannot determine whether facial morphology causes hyoid adaptation, hyoid-related muscle balance influences growth, or both arise from shared developmental and functional factors. Reverse causation and compensatory physiology are plausible. Longitudinal growth studies and carefully controlled treatment studies are consequently more informative than isolated group comparisons.

10.1 Sources of heterogeneity

- Different definitions of H, C3 and mandibular reference points.
- Cranial, mandibular, cervical and true-horizontal coordinate systems that answer different questions.
- Variation in natural head position, swallowing instructions and occlusal registration.
- Unequal age, sex, vertical pattern and body-size distributions.
- Different sagittal thresholds and failure to separate jaw-specific Class II or III subtypes.
- Two-dimensional projection of a three-dimensional, mobile structure.
- Small convenience samples and multiple uncorrected statistical tests.

10.2 Interpreting inconsistent findings

Inconsistency is not necessarily evidence that hyoid morphology is irrelevant. It can indicate that the hyoid maintains functional relationships while surrounding reference structures change. For example, a stable C3-H distance alongside a changed H-SN distance suggests postural or growth-related relocation of the entire local complex rather than isolated hyoid migration. Authors should discuss such patterns mechanistically rather than label each non-significant comparison as “no change.”

10.3 Certainty and clinical significance

Because observational studies dominate and residual confounding is common, certainty for class-specific diagnostic use is low to moderate at best. Group means overlap substantially. The hyoid can enrich phenotyping but cannot reliably assign an individual to a facial class. Clinical significance should be judged using effect size, confidence intervals, measurement reliability and connection to patient-relevant outcomes, not statistical significance alone.

XI. PROPOSED PROTOCOL FOR A LATERAL CEPHALOMETRIC STUDY

Design: An analytical cross-sectional study using pretreatment lateral cephalograms obtained for routine clinical indications. Reporting should follow STROBE guidance. Ethical approval and waiver or consent requirements should be documented according to the institutional review board and local regulations.

11.1 Participants

Include patients within a prespecified age range with permanent dentition, diagnostic-quality pretreatment cephalograms and no previous orthodontic or orthognathic treatment. Exclude craniofacial syndromes, cleft lip/palate, cervical anomalies that obscure landmarks, major asymmetry, known upper-airway surgery, severe image distortion and systemic conditions affecting growth. Respiratory disease and mouth-breathing status should be recorded rather than silently ignored.

11.2 Grouping

Sagittal groups may be defined by ANB and confirmed with Wit’s appraisal and jaw-specific diagnosis. Vertical groups should use a composite of SN-MP, FMA and/or Jarabak ratio with population-appropriate thresholds. Borderline or discordant cases can be excluded in a primary analysis and tested in sensitivity analysis. Aim for balanced sex distribution and comparable age across groups.

11.3 Outcomes

Primary outcomes should be declared in advance, for example H to C3-RGn perpendicular (vertical local position) and C3-H or an x-coordinate from a defined true-horizontal system (anteroposterior position). Secondary outcomes may include H-RGn, H-MP, hyoid-axis angles and selected airway widths. A labelled tracing diagram should accompany the methods.

11.4 Sample size and analysis

Sample size should be based on the primary outcome, expected clinically meaningful difference, variance from a comparable population, alpha, desired power and number of groups. One-way ANOVA or Kruskal-Wallis's testing can compare unadjusted groups, followed by multiplicity-controlled post-hoc tests. Multiple linear regression or ANCOVA should adjust for age, sex, vertical/sagittal pattern and relevant posture variables. Interaction terms can test whether sagittal effects differ by vertical pattern or sex. Assumptions, missing-data handling and confidence intervals must be reported.

XII. REPORTING TEMPLATE FOR AN ORIGINAL STUDY

Structured abstract

Background: Briefly identify the functional importance of the hyoid and uncertainty across facial patterns. Objective: State the primary comparison and hypothesis. Methods: Report design, setting, sample, age range, group definitions, cephalometric variables, reliability and statistical methods. Results: Present actual group means or medians, effect estimates and confidence intervals. Conclusion: Restrict claims to observed associations.

Results tables to prepare

Table	Essential contents	Purpose
1. Sample characteristics	n, age, sex, skeletal measures by group	Assess comparability
2. Reliability	ICC, Dahlberg error, systematic error	Show measurement quality
3. Hyoid outcomes	Mean ± SD or median (IQR), 95% CI	Describe group distributions
4. Adjusted models	Beta coefficients, CI, P value, model fit	Control confounding
5. Post-hoc comparisons	Adjusted mean differences and multiplicity correction	Locate group differences

Model discussion language

The discussion should begin with the principal finding rather than repeating every table. A suitable structure is: (1) state whether hyoid position differed among groups; (2) explain the finding using mandibular attachments, cervical posture and airway preservation; (3) compare with studies using the same reference system; (4) explain disagreement through sample and method differences; (5) describe clinical relevance without claiming causation; and (6) acknowledge limitations.

Avoidable claims

- Do not state that hyoid position "causes" a facial pattern in a cross-sectional study.
- Do not diagnose OSA from a cephalogram.
- Do not describe $P > 0.05$ as proof that groups are identical.
- Do not pool children and adults without accounting for growth.
- Do not interpret a measurement without naming its reference plane.
- Do not invent normal values from a different population.

No numerical results should be inserted until the study sample has been traced, reliability assessed and the statistical analysis completed. Placeholders such as "[mean ± SD]" are safer during protocol drafting than simulated data.

XIII. CLINICAL IMPLICATIONS, LIMITATIONS AND FUTURE DIRECTIONS

13.1 Clinical implications

Hyoid analysis can add functional context to conventional diagnosis. In a retrognathic Class II patient, a low or posterior hyoid together with symptoms of sleep-disordered breathing may strengthen the indication for airway screening, though it does not establish disease. In a Class III patient, an anterior hyoid may reflect the forward mandibular-tongue complex. In hyperdivergent patients, differences relative to cranial planes should be separated from changes caused by mandibular rotation. The hyoid is most useful when integrated with facial pattern, tongue posture, nasopharyngeal examination, symptoms and treatment objectives. It may also help explain why identical mandibular

movements produce different soft-tissue or airway responses. It should not be used as an isolated reason for extraction, expansion, functional therapy or surgery.

13.2 Limitations of lateral cephalometry

Lateral cephalometry compresses bilateral and three-dimensional anatomy into a sagittal projection, cannot measure transverse asymmetry or airway volume and is affected by magnification and superimposition. It captures an awake, upright moment that may not represent sleep physiology. Landmark selection and head posture introduce error. Radiation exposure limits prospective repeated imaging without clinical justification.

13.3 Future research

- Develop a consensus core set of hyoid landmarks and reference systems.
- Use longitudinal cohorts spanning defined growth stages.
- Combine cephalometry with CBCT or MRI only when clinically and ethically justified.
- Relate anatomy to objective respiratory and swallowing outcomes.
- Apply multilevel models in multicentre, ethnically diverse samples.
- Investigate sex-specific and jaw-subtype interactions.
- Report raw definitions, calibration and reliability so studies can be pooled.

Three-dimensional methods can reveal transverse orientation and volumetric airway relationships, but they do not automatically solve postural or functional confounding. Dynamic ultrasound, cine MRI and sleep-related measures may better capture motion and neuromuscular behavior. The most valuable future work will integrate structure and function rather than merely add more static distances.

XIV. CONCLUSION

The hyoid bone is a mobile component of a coordinated cranio-cervico-mandibular system. Its position reflects the balance of muscular attachments, mandibular form and rotation, tongue posture, cervical alignment, growth, sex and respiratory demands. Across sagittal patterns, the most reproducible tendency is a relatively anterior hyoid in many Class III samples and a relatively posterior or inferior position in mandibular-retrognathic Class II samples. These trends are not universal and depend strongly on the chosen reference system. Evidence for consistent differences among vertical patterns is more heterogeneous. Lateral cephalometry remains useful because it is standardized, accessible and capable of expressing relationships among the mandible, cervical spine and hyoid. Its limitations require disciplined interpretation. The hyoid triangle provides a valuable local framework, while cranial or true-horizontal coordinates show overall radiographic location. Using both systems, standardizing head posture, controlling age and sex, and reporting reliability can substantially improve research quality.

Clinically, hyoid measures should complement not replace comprehensive orthodontic and airway assessment. They cannot diagnose OSA or establish causation. For publication, future studies should define facial pattern precisely, preselect primary outcomes, use adequate power and multivariable analysis, and report effect sizes with confidence intervals. Such rigor will clarify whether hyoid position has individual diagnostic or prognostic value beyond its role as a marker of integrated functional adaptation.

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