

Correlation Between Condylar Position and Dimension of Tongue in Different Skeletal Patterns- A CBCT Study

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Abstract: Background: This study aimed to define the co-relation between posture and dimension of the tongue and condylar positions in different skeletal patterns through cone beam computed tomography (CBCT). Method: 45 Pretreatment CBCT of patients between the age of 18-30 years were obtained. The sample size was divided into 15 subjects under Group 1 (Normodivergent) 15 subjects under Group 2 (hypodivergent) and Group 3 (Hyperdivergent) based on SNGoGn angle. Condylar position and position and dimension of tongue were assessed via evaluation of their CBCT by transferring DICOM file to NEMOCEPH software and linear measurements were obtained. Results: Significant differences were observed in left anterior, left posterior, and right posterior condylar positions, while right anterior position was not significant. The hyperdivergent group demonstrated increased posterior joint space and reduced anterior joint space, indicating posterior condylar positioning. Tongue dimensions (TGL, TGH) and airway parameters (D1-D5) did not show statistically significant differences across groups ($p > 0.05$). Conclusion: vertical skeletal growth pattern appears to significantly influence condylar position, with hyperdivergent individuals demonstrating a more posteriorly positioned condyle. In contrast, tongue dimensions and airway parameters showed no significant association with skeletal divergence

Keywords: condylar position, CBCT, SNGoGn, skeletal pattern, Tongue Position, tongue dimension

1. Introduction

The morphology and functional posture of the tongue play a pivotal role in the development and stability of the dentofacial complex. Previous studies have emphasized that tongue dimensions and resting posture significantly influence occlusion, dental arch form, and the risk of post-treatment relapse (1). Tooth position is maintained through a delicate equilibrium between the forces exerted by the tongue and the surrounding circumoral musculature, highlighting the importance of soft tissue balance in orthodontic diagnosis and treatment planning (1). In addition, variations in tongue posture have been associated with different skeletal patterns, particularly in vertical discrepancies, although findings remain inconsistent across studies. (3).

Parallel to soft tissue considerations, the temporomandibular joint (TMJ), especially the condylar position within the glenoid fossa, is a critical determinant of craniofacial morphology and functional adaptation. The condylar position has been shown to vary with skeletal growth patterns, with evidence suggesting a significant association between condylar position and vertical skeletal morphology (2). Furthermore, recent CBCT-based investigations have demonstrated that condylar position, in conjunction with sagittal and vertical skeletal patterns, can influence adjacent anatomical structures such as the pharyngeal airway, reflecting the complex interplay between skeletal and functional components.(4) Despite extensive research on tongue characteristics and condylar position independently, limited studies have explored their interrelationship within different skeletal patterns using three-dimensional imaging. Given the advantages of cone beam computed tomography

(CBCT) in providing accurate, distortion-free evaluation of both hard and soft tissues, it offers a reliable modality for such comprehensive assessment. Therefore, the present study aims to investigate the correlation between condylar position and tongue dimensions across various skeletal patterns using CBCT, to enhance understanding of their combined role in craniofacial morphology and to support more precise orthodontic diagnosis and treatment planning.

2. Materials and Methods

Pretreatment CBCT head scans of 45 patients were obtained from NewTom cone beam imaging machine from A.J Institute of Dental Sciences Mangalore. The exposure parameter included tube voltage of 110 kVp, tube current of 5mA. The data was obtained as digital imaging and communication in medicine (DICOM) file

The inclusion criteria comprised subjects with a Class II skeletal relationship ($ANB > 4^\circ$), categorized based on vertical skeletal pattern into hypodivergent ($SN-GoGn < 26^\circ$), normodivergent ($SN-GoGn 26-38^\circ$), and hyperdivergent ($SN-GoGn > 38^\circ$). The selected individuals were within the age range of 18-30 years, had complete permanent dentition, and exhibited no carious lesions or periodontal disease.

The exclusion criteria included subjects with Class I and Class III skeletal relationships, those with mixed dentition, individuals with a positive history of temporomandibular joint (TMJ) surgery and/or trauma, and patients presenting with craniofacial anomalies, syndromes, or systemic diseases that could affect the joint



Figure 1

Evaluation of Tongue Position and Dimension

For each sample, to eliminate superimposition, the right half of the CBCT image was removed in the coronal view. Subsequently, specific anatomical landmarks were identified for the evaluation of skeletal and tongue parameters. These landmarks were utilized in various analyses, including Jarabak ratio (S/Go/N/Me), mandibular plane angle (S/N/Go/Me), ANB angle (A/N/B), Wits appraisal (A/B), inclination angle (Se/N/ANS/PNS), tongue length (EB/TT), and mandibular length (Go/Gn/Pog/Me).

Skeletal Landmarks (1)

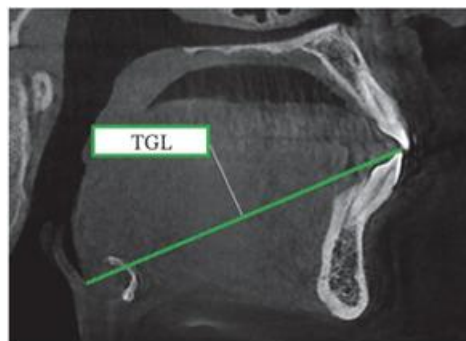
- **N (Nasion):** Most anterior point of the frontonasal suture
- **S (Sella):** Geometric center of the sella turcica
- **Se:** Midpoint at the entrance of the sella turcica
- **ANS (Anterior Nasal Spine):** Tip of the anterior nasal spine
- **PNS (Posterior Nasal Spine):** Posterior tip of the palatine bone
- **Point A:** Deepest point on the anterior contour of the maxilla between ANS and the incisor region
- **Point B:** Deepest point on the anterior contour of the mandible between the incisor region and chin
- **Go (Gonion):** Midpoint at the junction of the ramus and body of the mandible
- **Pog (Pogonion):** Most anterior point on the mandibular symphysis

- **Gn (Gnathion):** Most anteroinferior point on the mandibular symphysis
- **Me (Menton):** Lowest point on the mandibular symphysis
- **EB:** Base of the epiglottis
- **TT:** Most anterior point of the tongue tip

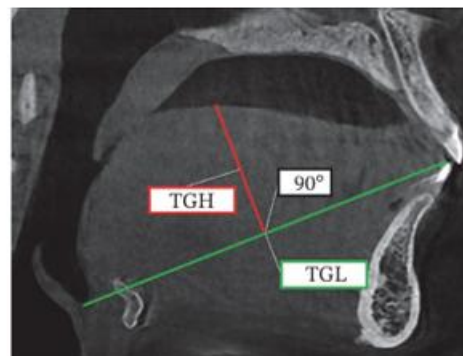
Tongue Analysis

The following parameters were evaluated (Figure 2):

- **Tongue Length (TGL):** Measured as the distance between the base of the epiglottis (EB) and the tip of the tongue (TT) in the midsagittal plane.
- **Tongue Height (TGH):** Determined as the perpendicular distance from the midpoint of the tongue length (TGL) to the posterior surface of the tongue.
- **Mandibular Length (Go–Gn):** Defined as the linear distance from Gonion (Go) to the most anterior point of the mandibular base, identified by projecting a perpendicular line from Pogonion (Pog) onto the mandibular plane (Go–Me).
- **Tongue Position:** A horizontal reference line was drawn from the incisal edge of the lower central incisor to the cervical distal third of the lower second molar. Taking the cervical region of the second molar as the reference centre, angular lines were constructed at 30°, 60°, 90°, 120°, and 150°. Along these locations, the distances from the center to the tongue surface were recorded as D1 to D5, while the distances between the tongue surface and the palate were measured as D1' to D5'.



(a)



(b)

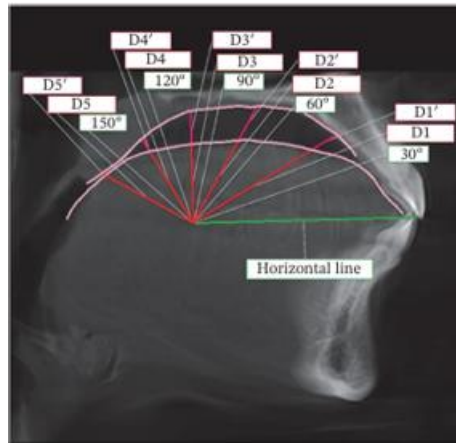


Figure 2

Evaluation of Condylar Position

The axial view in which the condylar process had the widest mediolateral diameter was used as the reference for secondary reconstruction. On this axial view, sagittal slices 0.5 mm in thickness was reconstructed.

Anterior joint space(A): the narrowest distance between the most anterior point of the condyle and the posterior wall of the anterior eminence.

Posterior joint space(P): the narrowest distance between the most posterior point of the condyle and the posterior wall of the mandibular fossa.

Condylar position in the glenoid fossa was determined using the following formula proposed by Pullinger and Hollender

$$\text{Linear ratio} = (P - A) / (P + A) \times 100$$

where P was the value of the narrowest posterior joint space and A the narrowest anterior joint space. A ratio $> +12\%$ indicates an anterior condylar position whereas a ratio $< -12\%$ indicates a posterior condylar position. The linear ratio between $+12\%$ and -12% was considered a concentric condylar position.

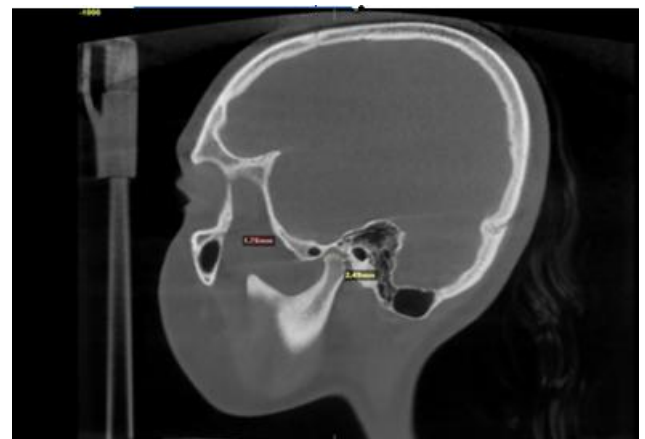


Figure 3

3. Results

Among 45 subjects (15 per group), SnGoGn and ANB confirmed appropriate classification by growth pattern ($p < 0.001$), rising from hypodivergent to hyperdivergent. Posterior condylar position increased significantly with divergence on both sides ($p < 0.001$), most notably in the hyperdivergent group, while anterior position differed significantly only on the left ($p = 0.011$). Post-hoc tests showed the hyperdivergent group differed significantly from both other groups in skeletal divergence and posterior condylar position, whereas normodivergent and hypodivergent groups differed only in SnGoGn and left posterior condylar position. Spearman's correlation confirmed SnGoGn was positively correlated with posterior condylar position bilaterally ($r = 0.696$ and 0.519 , $p < 0.001$). Tongue dimensions and airway parameters showed no significant differences or correlations with growth pattern. Overall, a more vertical growth pattern is associated with posterior condylar displacement, independent of tongue posture or airway dimensions.

Table 1: Descriptive statistics (mean $\pm$ SD) for skeletal, condylar, tongue, and airway parameters by growth-pattern group.

Parameter	Normodivergent (n = 15)	Hypodivergent (n = 15)	Hyperdivergent (n = 15)
Age (years)	22.00 $\pm$ 2.95	21.37 $\pm$ 2.94	21.87 $\pm$ 2.77
ANB ($^{\circ}$)	4.53 $\pm$ 1.50	3.73 $\pm$ 1.33	6.66 $\pm$ 1.87
SnGoGn ($^{\circ}$)	31.66 $\pm$ 6.00	21.40 $\pm$ 3.52	42.13 $\pm$ 3.64
Left condyle – anterior (mm)	2.23 $\pm$ 0.51	1.97 $\pm$ 0.43	1.63 $\pm$ 0.44
Left condyle – posterior (mm)	2.71 $\pm$ 0.63	2.01 $\pm$ 0.46	3.45 $\pm$ 0.64
Right condyle – anterior (mm)	2.15 $\pm$ 0.55	2.19 $\pm$ 0.56	1.87 $\pm$ 0.43
Right condyle – posterior (mm)	2.56 $\pm$ 0.63	2.29 $\pm$ 0.62	3.37 $\pm$ 0.63

Tongue length, TGL (mm)	78.80 ± 5.07	76.14 ± 3.50	77.52 ± 4.15
Tongue height, TGH (mm)	30.87 ± 6.00	33.00 ± 4.57	32.73 ± 4.77
Airway D1 (mm)	35.29 ± 3.31	35.78 ± 3.53	36.66 ± 3.94
Airway D2 (mm)	31.16 ± 3.33	30.95 ± 3.56	30.88 ± 2.66
Airway D3 (mm)	22.79 ± 4.06	23.30 ± 3.35	22.83 ± 2.65
Airway D4 (mm)	18.50 ± 2.95	18.97 ± 2.16	18.27 ± 2.55
Airway D5 (mm)	18.42 ± 2.85	18.74 ± 2.34	17.77 ± 1.89

Values are mean ± standard deviation. ANB, SNA–SNB angle; SnGoGn, mandibular plane angle; TGL/TGH, tongue length/height; D1–D5, airway dimensions at five levels.

Table 2: Kruskal–Wallis comparison of parameters among normodivergent, hypodivergent, and hyperdivergent groups.

Parameter	Normo (mean rank)	Hypo (mean rank)	Hyper (mean rank)	χ^2	p
ANB	20.2	15.33	33.47	15.72	<0.001*
SnGoGn	22	9	38	36.79	<0.001*
Left condyle – anterior	29.7	23.93	15.37	9.06	0.011*
Left condyle – posterior	23.17	11.4	34.43	23.08	<0.001*
Right condyle – anterior	25.3	25.8	17.9	3.41	0.181
Right condyle – posterior	20.07	14.93	34	16.95	<0.001*
TGL	25.9	19.67	23.43	1.71	0.424
TGH	19.97	24.67	24.37	1.2	0.549
D1	20.7	22.6	25.7	1.11	0.931
D2	23.77	23.23	22	0.14	0.931
D3	22.6	23.47	22.93	0.03	0.983
D4	23.1	24.67	21.23	0.52	0.773
D5	24.4	25.4	19.2	1.94	0.38

* $p < 0.05$, statistically significant. χ^2 = Kruskal–Wallis test statistic ($df = 2$).

Table 3: Post-hoc pairwise comparisons (Mann–Whitney U with Bonferroni correction) between growth-pattern groups.

Parameter	Normo vs Hypo (p)	Normo vs Hyper (p)	Hypo vs Hyper (p)
ANB	0.25	0.004*	<0.001*
SnGoGn	<0.001*	<0.001*	<0.001*
Left condyle – anterior	0.191	0.004*	0.059
Left condyle – posterior	0.004*	0.005*	<0.001*
Right condyle – anterior	0.835	0.1	0.124
Right condyle – posterior	0.177	0.001*	<0.001*
TGL	0.191	0.618	0.442
TGH	0.406	0.289	0.835
D1	0.708	0.289	0.533
D2	0.901	0.724	0.787
D3	0.723	0.917	0.95
D4	n.s.†	0.708	0.467
D5	0.868	0.299	0.183

Values are p-values; * $p < 0.017$ (Bonferroni-corrected threshold), statistically significant. †Source value for this cell was not reliably recorded in the original data; classified as non-significant, consistent with the overall pattern for this parameter.

Table 4: Spearman's correlation coefficients (r) between skeletal divergence, tongue dimensions, and condylar/airway parameters

Variable	LCA	LCP	RCA	RCP	D1	D2	D3	D4	D5
SnGoGn	-0.23	0.696*	-0.236	0.519*	0.174	-0.016	-0.082	0.012	-0.15
TGL	0.048	0.08	-0.108	-0.026	-0.119	0.14	-0.084	-0.096	-0.009
TGH	-0.107	0.031	0.014	0.031	-0.024	0.097	0.217	0.113	0.083

* $p < 0.001$, statistically significant. LCA/LCP, left condyle anterior/posterior joint space; RCA/RCP, right condyle anterior/posterior joint space; D1–D5, airway dimensions; SnGoGn, mandibular plane angle (skeletal divergence); TGL/TGH, tongue length/height.

4. Discussion

The present CBCT-based study evaluated the relationship between condylar position, tongue dimensions, and airway parameters across different vertical skeletal patterns. The sample was well standardized, with comparable age and gender distribution among the normo divergent, hypodivergent, and hyperdivergent groups, thereby minimizing confounding effects and strengthening the internal validity of the findings.

Skeletal classification using ANB and SnGoGn angles demonstrated statistically significant differences among the groups, confirming appropriate grouping. The hyperdivergent group exhibited significantly higher SnGoGn and ANB values, consistent with increased vertical skeletal divergence and a tendency toward skeletal Class II patterns. These findings are in agreement with established cephalometric principles, where vertical growth patterns are closely associated with sagittal discrepancies.

A key finding of this study was the significant variation in condylar position among the groups, particularly in the posterior joint space. The hyperdivergent group consistently demonstrated increased posterior condylar space along with reduced anterior joint space, indicating a posterior positioning of the condyle within the glenoid fossa. This observation was statistically significant for left posterior, right posterior, and left anterior condylar measurements, while right anterior condylar position did not show significant variation. These results suggest that vertical skeletal pattern has a pronounced influence on condylar positioning, especially in the sagittal plane.

Post-hoc comparisons further reinforced these findings. Significant differences were primarily observed between hyperdivergent and the other groups, whereas differences between normodivergent and hypodivergent groups were minimal. This indicates that extreme vertical divergence, rather than mild variation, plays a more critical role in altering condylar position. The increased posterior positioning in hyperdivergent individuals may be attributed to clockwise mandibular rotation, altered neuromuscular balance, and adaptive remodelling of the temporomandibular joint.

The correlation analysis supported these observations, revealing a strong positive correlation between SnGoGn and posterior condylar position bilaterally. This suggests that as vertical skeletal divergence increases, the condyle tends to be positioned more posteriorly. In contrast, anterior condylar position did not show a significant correlation, indicating that posterior joint space is a more sensitive indicator of skeletal pattern changes.

In contrast to condylar parameters, tongue dimensions (tongue length and tongue height) did not show statistically significant differences among the groups, nor did they correlate with skeletal divergence or condylar position. This suggests that tongue size and posture, at least as measured in this study, remain relatively stable across different vertical growth patterns. These findings challenge the assumption that tongue morphology significantly contributes to vertical skeletal discrepancies and indicate that its role may be more functional than structural.

Similarly, airway dimensions (D1–D5) did not demonstrate significant variation among the groups and showed no meaningful correlation with skeletal pattern or tongue measurements. This lack of association suggests that airway space may be maintained through compensatory mechanisms despite variations in craniofacial morphology. It also indicates that vertical skeletal pattern alone may not be a reliable predictor of airway dimensions.

Overall, the findings of this study highlight that condylar position, particularly posterior joint space, is significantly influenced by vertical skeletal pattern, whereas tongue dimensions and airway parameters appear to be independent of such variations. Clinically, this suggests that greater attention should be given to temporomandibular joint evaluation in hyperdivergent patients, as altered condylar positioning may have implications for diagnosis, treatment planning, and long-term stability.

However, certain limitations should be considered. The sample size was relatively small, and the cross-sectional design limits the ability to infer causality. Additionally, tongue posture is dynamic and may not be fully captured in static CBCT imaging. Future longitudinal studies with larger samples and functional assessments are recommended to further elucidate these relationships.

5. Conclusion

- Vertical skeletal pattern significantly influences condylar position, particularly the posterior joint space.
- Hyperdivergent individuals exhibit a more posteriorly positioned condyle compared to normodivergent and hypodivergent groups.
- Posterior condylar position shows a strong positive correlation with skeletal divergence (SnGoGn angle).
- Anterior condylar position does not demonstrate a consistent or significant association with skeletal pattern.
- Tongue dimensions (length and height) do not vary significantly across different skeletal patterns. These findings challenge the assumption that tongue morphology significantly contributes to vertical skeletal discrepancies and indicate that its role may be more functional than structural.
- No significant correlation exists between tongue dimensions and condylar position.
- Airway dimensions remain relatively constant and are not influenced by vertical skeletal pattern.
- Overall, condylar position—rather than tongue or airway parameters—is the primary variable associated with skeletal divergence in this study.

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