Correlation Between Condylar Position and Upper Airway Dimension in Skeletal Class II with Different Skeletal Morphology in South Indian Population: A CBCT Study

Priyanka C[1], Rohan Rai[2], Pooja Mastammanavar[3], Priyanka B J[4], Bhoomika Gowda[5]

Abstract: ***Background & Objectives:** The spatial configuration of the temporomandibular joint (TMJ) and upper airway patency are intricately related to craniofacial skeletal morphology. In skeletal Class II malocclusions, vertical facial divergence may introduce distinct biomechanical adaptations. This study evaluated the influence of vertical growth patterns on condylar position within the glenoid fossa and pharyngeal airway dimensions in skeletal Class II individuals using three-dimensional Cone Beam Computed Tomography (CBCT). **Methods**: A cross-sectional CBCT investigation was conducted on 45 skeletal Class II adult subjects (37 females, 8 males; mean age 21.73 \pm 2.78years) categorized into three equal vertical growth groups (n = 15each): normodivergent, hypodivergent, and hyperdivergent. Cephalometric parameters ({ANB},{SN-GoGn}), joint spaces (anterior and posterior spaces for both left and right condyles), and pharyngeal airway dimensions (oropharynx, hypopharynx, and total airway) were measured. Group comparisons were performed using one-way ANOVA with Tukey post hoc testing, and bivariate associations were evaluated using Pearson correlation coefficients (0.05). **Results**: Skeletal Parameters: Significant intergroup differences were observed for {ANB}(p < 0.001) and {SN-GoGn} (p < 0.001), with the hyperdivergent group exhibiting the highest mean values (6.67^\circ \pm 1.88^\circand 42.13^\circ \pm 3.64^\circ, respectively). Condylar Position: Hyperdivergent individuals exhibited significant posterior condylar displacement, characterized by reduced anterior joint space (left: 1.64 \pm 0.44{ mm}) and increased posterior joint space (left: 3.45 \pm 0.64\{ mm}; right: 3.37 \pm 0.63\{ mm}) compared to hypodivergent subjects (p < 0.005). In contrast, hypodivergent subjects maintained concentric condylar positioning. Airway Dimensions: Airway dimensions diminished progressively with increasing vertical divergence. Total airway dimension was significantly lower in the hyperdivergent group (14.29 \pm 2.34\{ mm}) than in the normodivergent group (16.71 \pm 1.57{ mm}; p = 0.003). Significant intergroup reductions were also confirmed in the oropharynx (p = 0.024) and hypopharynx (p = 0.024). Correlation Analysis: Both vertical divergence {SN-GoGn}$: $r = -0.297, p = 0.048) and sagittal severity ({ANB}: $r = -0.299, p = 0.046) inversely correlated with total airway dimension. Oropharyngeal dimension demonstrated a predominant positive correlation with total airway space ($r = 0.897, p < 0.001). **Conclusion**: Vertical skeletal divergence significantly alters TMJ spatial morphology and compromises pharyngeal airway capacity in skeletal Class II individuals. Hyperdivergent Class II patients demonstrate pronounced posterior condylar positioning and severe airway constriction, driven primarily by oropharyngeal narrowing. Comprehensive 3D CBCT assessment is critical to incorporate joint health and airway preservation into vertical treatment planning.*

Keywords: Cone Beam Computed Tomography (CBCT), Skeletal Class II, Vertical Growth Patterns, Condylar Position, Upper Airway, Oropharynx, Temporomandibular Joint

1. Introduction

A joint is the articulation between two or more bones and can be classified structurally or functionally. Structurally, joints are categorized according to the type of connective tissue present as fibrous, cartilaginous, or synovial joints, whereas functionally they are classified based on the degree of movement they permit into synarthrosis, amphiarthrosis, and diarthrosis. The temporomandibular joint (TMJ) is a unique bilateral synovial diarthrodial joint that permits both rotational and translational movements and plays a pivotal role in mastication, speech, swallowing, and overall craniofacial function.

The morphology of the mandibular condyle and glenoid fossa has evolved according to functional demands. Among mammals, carnivores possess broad condyles that articulate within deep glenoid fossae, facilitating powerful hinge-like movements, whereas herbivores exhibit shallower fossae that allow greater lateral mandibular excursions required for grinding food. In humans, the adoption of upright posture and bipedal locomotion has resulted in significant morphological and functional adaptations of the craniofacial complex, particularly the TMJ and masticatory apparatus.

The spatial relationship between the mandibular condyle and the glenoid fossa has long been considered an important determinant of normal TMJ function. Non-concentric condyle-fossa relationships are frequently associated with abnormal TMJ function, whereas asymptomatic individuals generally exhibit a more concentric condylar position. Posterior positioning of the condyle has been associated with centric relation interferences, reduced posterior occlusal support, molar tipping, excessive overbite, and temporomandibular disorders (TMDs), including joint pain and clicking. Several studies have demonstrated a significant association between posterior condylar position and TMJ disorders.

Skeletal Class II malocclusion is one of the most prevalent dentofacial deformities, affecting approximately 20-30% of children during growth and development. Previous cephalometric investigations have demonstrated that skeletal Class II individuals tend to exhibit inferiorly positioned condyles and increased superior joint spaces. Furthermore, condylar morphology and condyle-fossa relationships vary according to sagittal and vertical skeletal patterns. Hyperdivergent individuals generally present with smaller condyles and steeper condylar inclinations, whereas hypodivergent individuals more commonly exhibit posterior

International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Impact Factor 2025: 7.089

condylar positioning. Conversely, anterior condylar positioning has been reported more frequently in high-angle skeletal patterns.

Beyond its influence on temporomandibular joint function, craniofacial morphology has a profound effect on upper airway dimensions. The upper airway, comprising the nasopharynx, oropharynx, and hypopharynx, plays a critical role in respiration, craniofacial growth, and dentofacial development. Alterations in airway morphology have been associated with mouth breathing, sleep-disordered breathing, obstructive sleep apnea, and abnormal facial growth patterns. Airway dimensions are influenced by several anatomical factors, including tongue posture, soft palate morphology, mandibular position, and skeletal configuration.

Numerous studies have demonstrated that skeletal Class II individuals, particularly those with hyperdivergent facial patterns, possess significantly smaller airway volumes and reduced minimum cross-sectional areas compared with Class I subjects or hypodivergent individuals. Posterior positioning of the mandible and associated alterations in condylar position may contribute to posterior displacement of the tongue and surrounding soft tissues, thereby reducing pharyngeal airway dimensions. These observations suggest that condylar position and upper airway morphology may not be independent entities but rather components of an interconnected craniofacial functional complex.

Traditionally, lateral cephalometric radiography has been employed to evaluate both condylar position and airway dimensions. However, its two-dimensional representation of three-dimensional structures is associated with magnification errors, superimposition of anatomical structures, distortion, and poor reproducibility, limiting accurate assessment of joint morphology and airway volume.

The introduction of Cone Beam Computed Tomography (CBCT) has significantly enhanced the diagnostic capability of orthodontics by providing accurate three-dimensional visualization of craniofacial structures with relatively low radiation exposure compared with conventional computed tomography. Since its introduction into dentistry in the late 1990s, CBCT has become an indispensable diagnostic tool for evaluating the temporomandibular joint, craniofacial skeleton, and upper airway. It enables precise qualitative and quantitative assessment of condylar morphology, joint spaces, airway volume, minimum cross-sectional area, and airway dimensions with minimal distortion and near 1:1 anatomical accuracy.

Although several CBCT studies have independently evaluated condylar position and upper airway morphology, only limited evidence is available regarding the relationship between these two structures, particularly among skeletal Class II patients exhibiting different vertical growth patterns. Since mandibular position influences both condylar orientation within the glenoid fossa and the surrounding pharyngeal airway, understanding this relationship may provide valuable insights into craniofacial growth, temporomandibular joint function, airway patency, and orthodontic treatment planning.

2. Materials & Methods

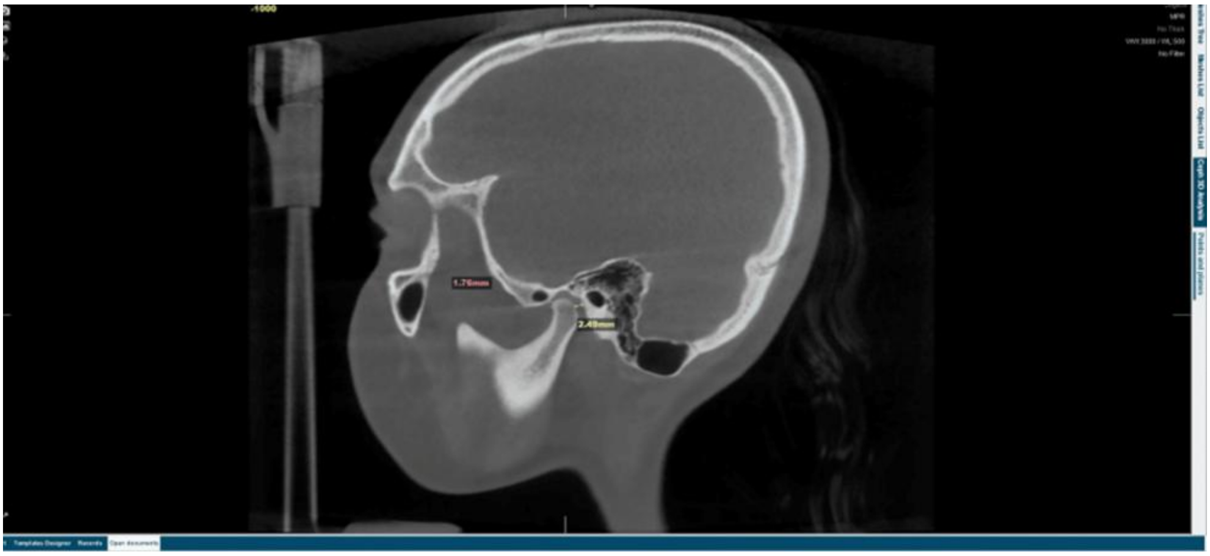

Figure 1: Linear measurement of left condyle in sagittal plane

International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Impact Factor 2025: 7.089

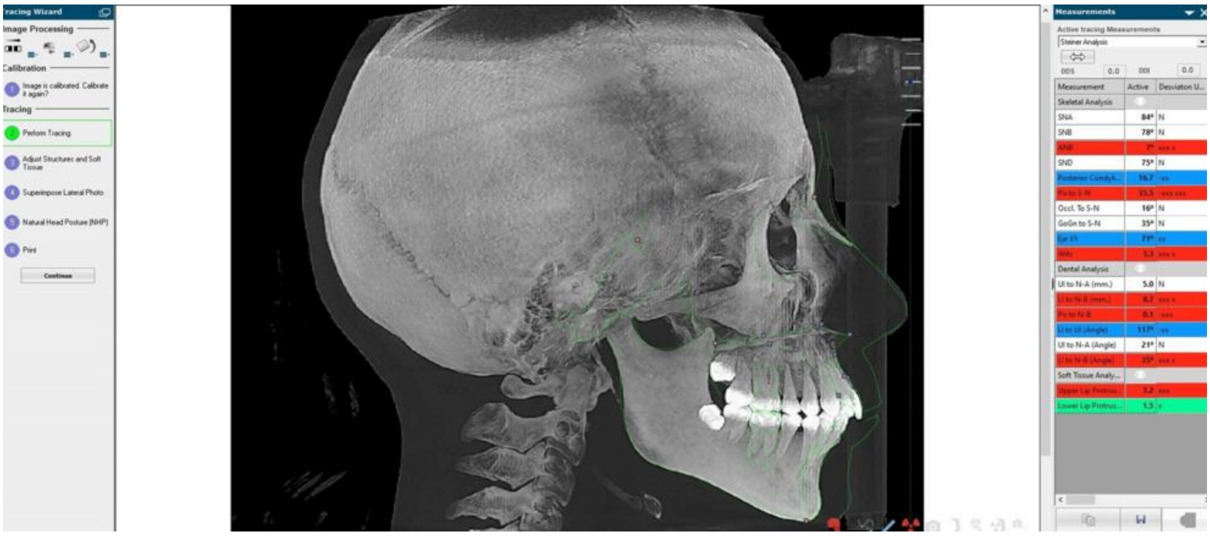

Figure 2: Lateral ceph obtained from DICOM file

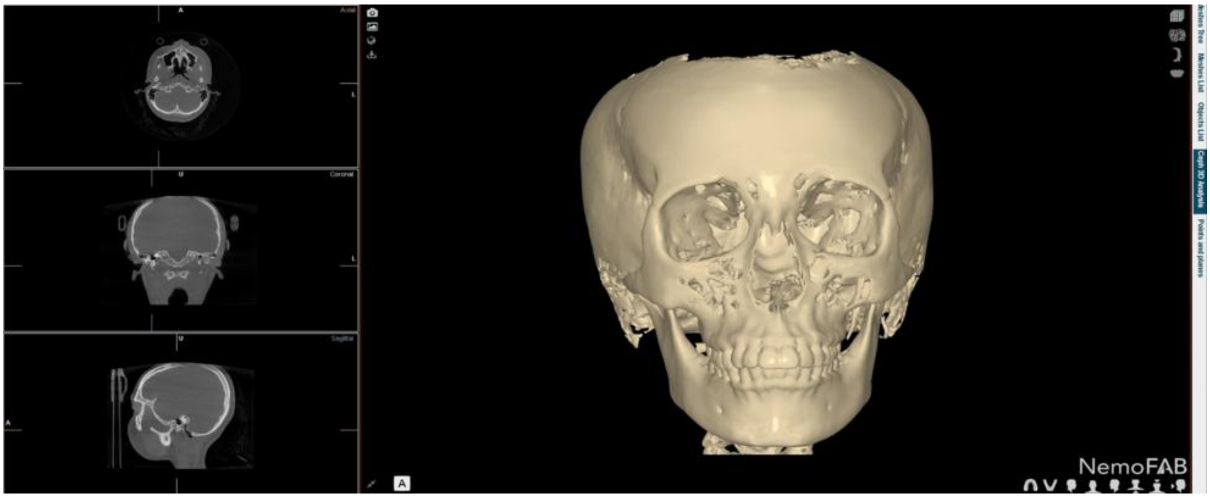

Figure 3: 3D structure from DICOM file in all planes

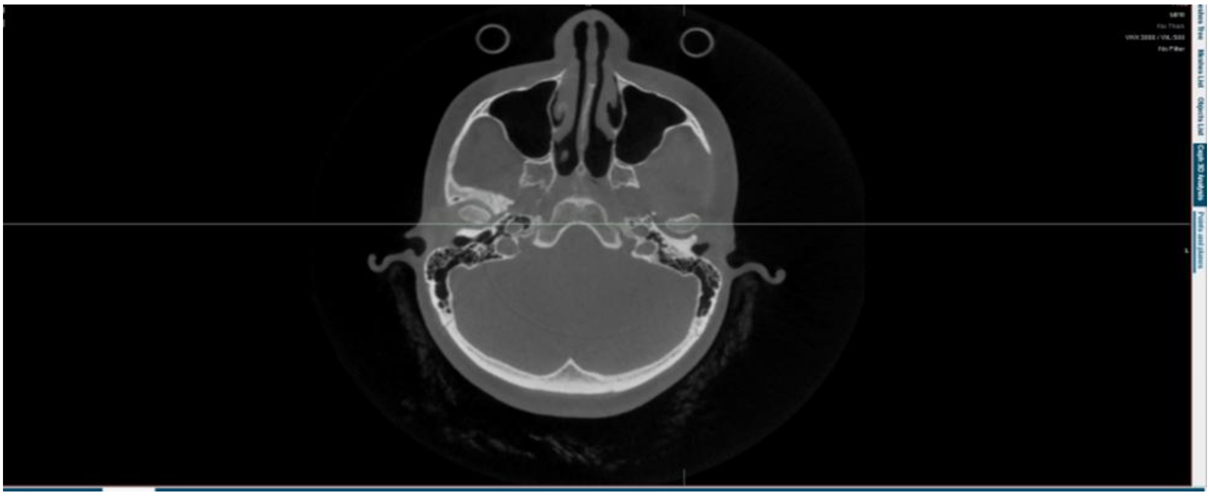

Figure 4: Orientation of left condyle in axial plane

	Superior Limit	Inferior Limit
Oropharynx	Line extending from the PNS to the tip of the odontoid process.	Line extending from the antero-inferior border of the C2 vertebra.
Hypopharynx	Line extending from the antero-inferior border of the C2 vertebra.	Line extending from the horizontal line coming into contact with the most superior margin of the body of the hyoid bone.

Figure 5: Methodology used was described by Meehan

- Pre-treatment CBCT head scans of 45 patients were obtained from a 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

Inclusion Criteria:
- Class II skeletal relationship (ANB>4)
- hypodivergent, SN-GoGn is less than 26
- normodivergent, SN-GoGn is 26-38
- hyperdivergent, SN-GoGn is more than 38
- Age: 18-30 years.
- Permanent dentition.
- No carious or periodontal lesion

Exclusion Criteria:
- Mixed dentition.
- Positive history of TMJ surgery and/or TMJ trauma.
- Craniofacial anomalies,syndromes or systemic diseases which may affect joint
- Presence of craniofacial malformation or systemic muscle or joint anomalies
- Presence of uncontrolled systemic diseases

Assessment of Pre-Treatment CBCT in NEMOCEPH Software:
The axial view in which the condylar process had the widest mediolateral diameter will be used as the reference for secondary reconstruction. On this axial view, sagittal slices 0.5 mm in thickness will be 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 will be determined using the following formula proposed by Pullinger and Hollender: Linear ratio = (P - A)/(P + A) 100. 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.

Methodology used was described by Meehan:

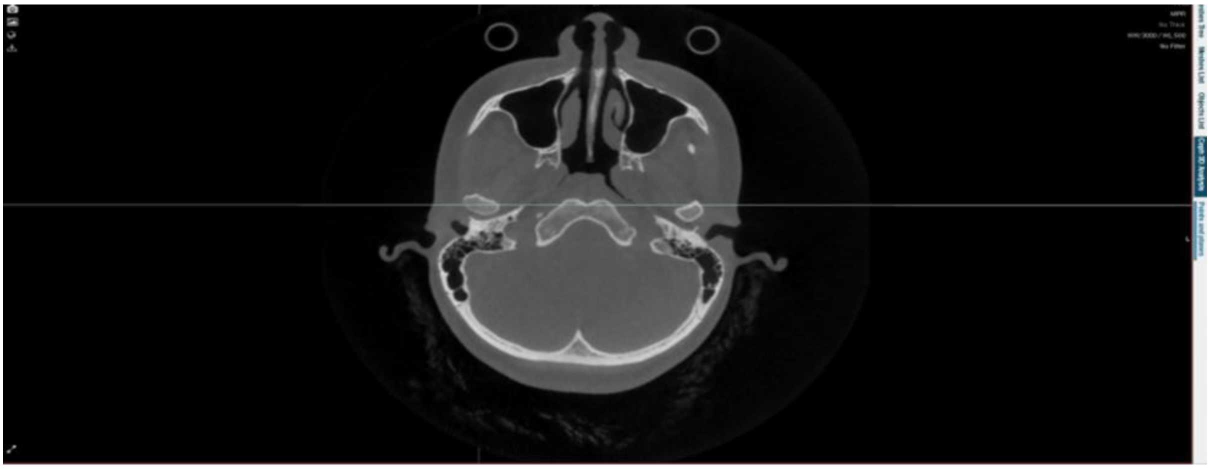

Figure 6: Orientation of right condyle in axial plane

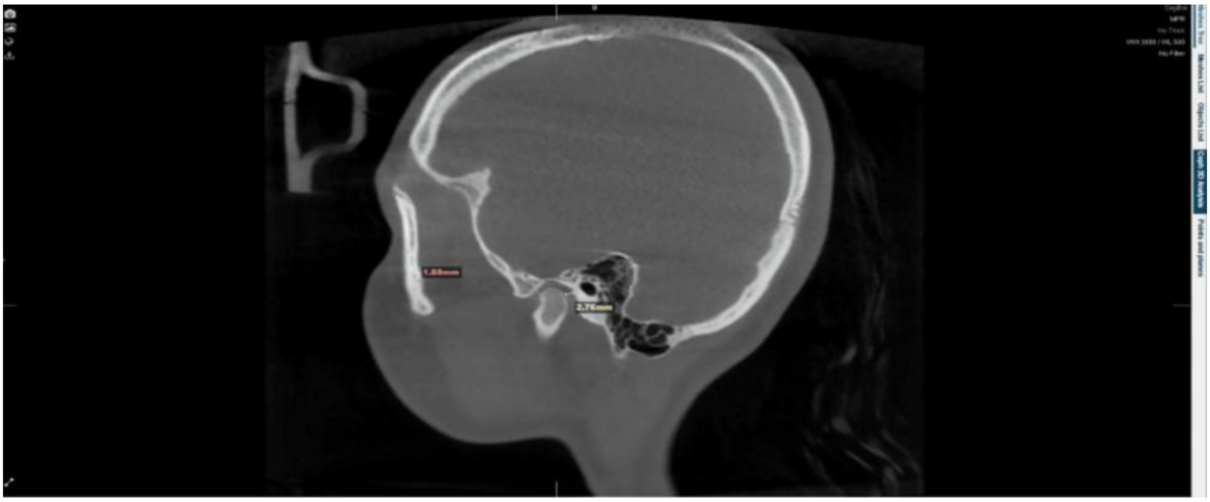

Figure 7: Linear measurement of right condyle in sagittal plane

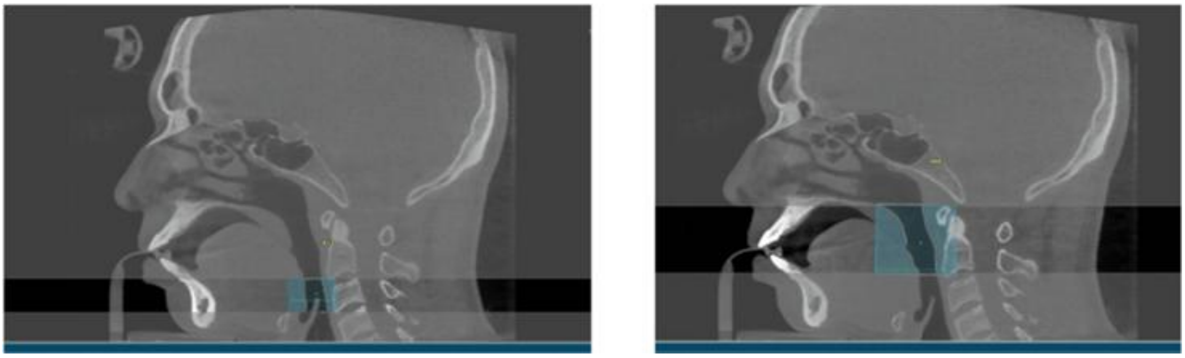

Figure 8: Volumetric analysis

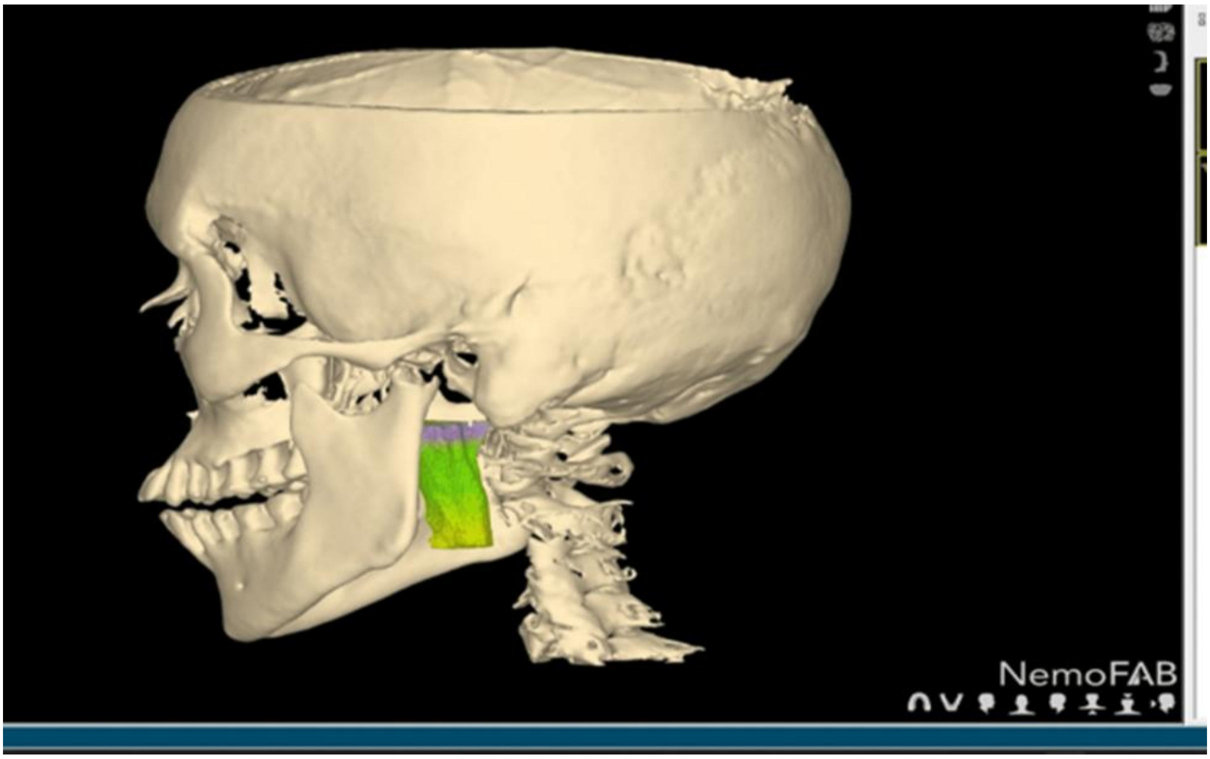

Figure 9: 3D analysis from DICOM file

3. Results

Table 1: Gender wise distribution of participants in the study

			Gender		Total
			Female	Male	
Group	Normodivergent	Count	12	3	15
		% of Total	26.70%	6.70%	33.30%
	Hypodivergent	Count	13	2	15
		% of Total	28.90%	4.40%	33.30%
	Hyperdivergent	Count	12	3	15
		% of Total	26.70%	6.70%	33.30%
Total		Count	37	8	45
		% of Total	82.20%	17.80%	100.00%

Table 2: Age wise distribution of participants

Group	Mean	Std. Deviation	Minimum	Maximum
Normodivergent	22	2.952	18	27
Hypodivergent	21.6	2.898	18	29
Hyperdivergent	21.6	2.64	19	28
Total	21.73	2.775	18	29

Table 3: Comparison of various parameters between the groups using ANOVA

Parameter	Group	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max	p-Value
					Lower Bound	Upper Bound			
ANB	Normodivergent	4.53	1.51	0.39	3.7	5.37	3	7	0
	Hypodivergent	3.73	1.33	0.34	2.99	4.47	2	6	
	Hyperdivergent	6.67	1.88	0.48	5.63	7.71	3	9	
SnGoGn	Normodivergent	31.67	6.01	1.55	28.34	34.99	13	37	0
	Hypodivergent	21.4	3.52	0.91	19.45	23.35	15	25	
	Hyperdivergent	42.13	3.64	0.94	40.12	44.15	38	51	
Left Condyle Anterior	Normodivergent	2.23	0.51	0.13	1.95	2.52	1.54	3.5	0.004
	Hypodivergent	1.97	0.44	0.11	1.73	2.21	1.34	2.8	
	Hyperdivergent	1.64	0.44	0.11	1.39	1.88	1.1	2.34	
Left Condyle Posterior	Normodivergent	2.72	0.63	0.16	2.37	3.07	1.56	4.09	0
	Hypodivergent	2.02	0.47	0.12	1.76	2.28	1.4	2.8	
	Hyperdivergent	3.45	0.64	0.17	3.1	3.81	2.25	4.71	
Right Condyle Anterior	Normodivergent	2.15	0.56	0.14	1.84	2.46	1.5	3.7	0.213
	Hypodivergent	2.19	0.56	0.15	1.88	2.5	1.5	3.09	
	Hyperdivergent	1.88	0.44	0.11	1.64	2.12	1.27	2.9	
Right Condyle Posterior	Normodivergent	2.57	0.64	0.16	2.22	2.92	1.9	4.07	0
	Hypodivergent	2.29	0.62	0.16	1.95	2.64	1.56	3.5	
	Hyperdivergent	3.37	0.63	0.16	3.02	3.72	2.66	4.58	
Oropharynx	Normodivergent	13.05	1.3	0.33	12.33	13.77	10.27	14.39	0.024
	Hypodivergent	12.01	1.01	0.26	11.45	12.57	10.21	13.42	
	Hyperdivergent	11.57	1.92	0.49	10.51	12.63	9.46	16.3	
Hypopharynx	Normodivergent	3.6	0.49	0.13	3.33	3.87	3.12	4.45	0.024
	Hypodivergent	3.05	0.8	0.21	2.6	3.49	2.12	4.5	
	Hyperdivergent	2.94	0.71	0.18	2.55	3.33	2.12	4.5	
Total	Normodivergent	16.71	1.57	0.41	15.84	17.58	13.65	18.84	0.003
	Hypodivergent	15.44	1.41	0.36	14.66	16.23	12.33	17.45	
	Hyperdivergent	14.29	2.34	0.61	12.99	15.58	11.58	20.8	

Table 4: Within group comparison of various parameters using Tuckey post hoc analysis

Parameter	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	95% Confidence Interval		p-value
					Lower Bound	Upper Bound	
ANB	Normodivergent	Hypodivergent	0.8	0.58	-0.609	2.209	0.361
		Hyperdivergent	-2.133*	0.58	-3.543	-0.724	0.002
	Hypodivergent	Normodivergent	-0.8	0.58	-2.209	0.609	0.361
		Hyperdivergent	-2.933*	0.58	-4.343	-1.524	0
	Hyperdivergent	Normodivergent	2.133*	0.58	0.724	3.543	0.002
		Hypodivergent	2.933*	0.58	1.524	4.343	0
SnGoGn	Normodivergent	Hypodivergent	10.267*	1.657	6.241	14.292	0
		Hyperdivergent	-10.467*	1.657	-14.492	-6.441	0
	Hypodivergent	Normodivergent	-10.267*	1.657	-14.292	-6.241	0
		Hyperdivergent	-20.733*	1.657	-24.759	-16.708	0
	Hyperdivergent	Normodivergent	10.467*	1.657	6.441	14.492	0
		Hypodivergent	20.733*	1.657	16.708	24.759	0
Left Condyle Anterior	Normodivergent	Hypodivergent	0.263	0.17	-0.151	0.676	0.281
		Hyperdivergent	.597*	0.17	0.183	1.01	0.003
	Hypodivergent	Normodivergent	-0.263	0.17	-0.676	0.151	0.281
		Hyperdivergent	0.334	0.17	-0.079	0.747	0.134
	Hyperdivergent	Normodivergent	-.597*	0.17	-1.01	-0.183	0.003
		Hypodivergent	-0.334	0.17	-0.747	0.079	0.134
Left Condyle Posterior	Normodivergent	Hypodivergent	.701*	0.214	0.182	1.221	0.006
		Hyperdivergent	-.731*	0.214	-1.251	-0.212	0.004
	Hypodivergent	Normodivergent	-.701*	0.214	-1.221	-0.182	0.006
		Hyperdivergent	-1.433*	0.214	-1.952	-0.913	0
	Hyperdivergent	Normodivergent	.731*	0.214	0.212	1.251	0.004
		Hypodivergent	1.433*	0.214	0.913	1.952	0
Right Condyle Anterior	Normodivergent	Hypodivergent	-0.039	0.191	-0.502	0.425	0.978
		Hyperdivergent	0.275	0.191	-0.189	0.738	0.33
	Hypodivergent	Normodivergent	0.039	0.191	-0.425	0.502	0.978
		Hyperdivergent	0.313	0.191	-0.15	0.777	0.239
	Hyperdivergent	Normodivergent	-0.275	0.191	-0.738	0.189	0.33
		Hypodivergent	-0.313	0.191	-0.777	0.15	0.239
Right Condyle Posterior	Normodivergent	Hypodivergent	0.274	0.23	-0.285	0.833	0.465
		Hyperdivergent	-.806*	0.23	-1.365	-0.247	0.003
	Hypodivergent	Normodivergent	-0.274	0.23	-0.833	0.285	0.465

		Hyperdivergent	-1.080*	0.23	-1.639	-0.521	0
	Hyperdivergent	Normodivergent	.806*	0.23	0.247	1.365	0.003
		Hypodivergent	1.080*	0.23	0.521	1.639	0
Oropharynx	Normodivergent	Hypodivergent	1.035	0.532	-0.258	2.327	0.139
		Hyperdivergent	1.477*	0.532	0.185	2.77	0.022
	Hypodivergent	Normodivergent	-1.035	0.532	-2.327	0.258	0.139
		Hyperdivergent	0.443	0.532	-0.85	1.735	0.685
	Hyperdivergent	Normodivergent	-1.477*	0.532	-2.77	-0.185	0.022
		Hypodivergent	-0.443	0.532	-1.735	0.85	0.685
Hypopharynx	Normodivergent	Hypodivergent	0.554	0.249	-0.05	1.158	0.078
		Hyperdivergent	.663*	0.249	0.059	1.268	0.029
	Hypodivergent	Normodivergent	-0.554	0.249	-1.158	0.05	0.078
		Hyperdivergent	0.109	0.249	-0.495	0.714	0.899
	Hyperdivergent	Normodivergent	-.663*	0.249	-1.268	-0.059	0.029
		Hypodivergent	-0.109	0.249	-0.714	0.495	0.899
Total	Normodivergent	Hypodivergent	1.265	0.666	-0.352	2.882	0.151
		Hyperdivergent	2.423*	0.666	0.806	4.04	0.002
	Hypodivergent	Normodivergent	-1.265	0.666	-2.882	0.352	0.151
		Hyperdivergent	1.157	0.666	-0.46	2.774	0.203
	Hyperdivergent	Normodivergent	-2.423*	0.666	-4.04	-0.806	0.002
		Hypodivergent	-1.157	0.666	-2.774	0.46	0.203

Table 5: Analysis of correlation between various variables of the study

		ANB	Sn Go Gn	Left Condyle Anterior	Left Condyle Posterior	Right Condyle Anterior	Right Condyle Posterior	Oropharynx	Hypopharynx	Total
ANB	Pearson Correlation	1	.581**	-.305*	.408**	-0.19	0.279	-0.169	-0.153	-.299*
	p-value		0	0.042	0.005	0.212	0.063	0.267	0.315	0.046
SnGoGn	Pearson Correlation	.581**	1	-0.18	.690**	-0.192	.477**	-0.199	-0.029	-.297*
	p-value	0		0.238	0	0.205	0.001	0.191	0.848	0.048
Left Condyle Anterior	Pearson Correlation	-.305*	-0.18	1	0.257	.667**	0.18	0.167	-0.064	0.186
	p-value	0.042	0.238		0.088	0	0.237	0.273	0.675	0.221
Left Condyle Posterior	Pearson Correlation	.408**	.690**	0.257	1	0.178	.716**	-0.123	-0.123	-0.173
	p-value	0.005	0	0.088		0.243	0	0.42	0.422	0.255
Right Condyle Anterior	Pearson Correlation	-0.19	-0.192	.667**	0.178	1	.427**	0.254	-0.067	0.182
	p-value	0.212	0.205	0	0.243		0.003	0.092	0.662	0.232
Right Condyle Posterior	Pearson Correlation	0.279	.477**	0.18	.716**	.427**	1	0.015	-0.169	-0.086
	p-value	0.063	0.001	0.237	0	0.003		0.924	0.268	0.576
Oropharynx	Pearson Correlation	-0.169	-0.199	0.167	-0.123	0.254	0.015	1	0.09	.897**
	p-value	0.267	0.191	0.273	0.42	0.092	0.924		0.557	0
Hypopharynx	Pearson Correlation	-0.153	-0.029	-0.064	-0.123	-0.067	-0.169	0.09	1	0.217
	p-value	0.315	0.848	0.675	0.422	0.662	0.268	0.557		0.152
Total	Pearson Correlation	-.299*	-.297*	0.186	-0.173	0.182	-0.086	.897**	0.217	1
	p-value	0.046	0.048	0.221	0.255	0.232	0.576	0	0.152	
**. Correlation is significant at the 0.01 level (2-tailed).										
*. Correlation is significant at the 0.05 level (2-tailed).										

Statistical Analysis:
All statistical analyses were performed using IBM SPSS statistical software (SPSS version 25; IBM, Armonk, NY, USA).

Descriptive Statistics:
Descriptive analysis includes expressions of all the explanatory and outcome variables in terms of frequency and proportions for categorical variables and in terms of mean and standard deviation for continuous variables.

Inferential Statistics:
Between group comparisons of various parameters between three groups was done using ANOVA. Pairwise comparison was done using Tuckey post hoc test. Pearson Correlation coefficient was derived to determine the corelations between all the continuous variables of the study.

The level of significance (p-value) was set at $p<0.05$.

Intergroup comparison (ANOVA findings)

1) Skeletal parameters
2) ANB angle differed significantly among groups ($p < 0.001$):
   - Highest in the hyperdivergent group
   - Lowest in the hypodivergent group
3) SN-GoGn angle showed a highly significant difference ($p < 0.001$), validating the vertical skeletal classification:
   - o Hypodivergent < Normodivergent < Hyperdivergent
4) Condylar position parameters
   - Left condyle (anterior and posterior spaces) showed statistically significant differences among groups:
   - Hyperdivergent subjects demonstrated reduced anterior joint space and increased posterior joint space, suggesting a posteriorly positioned condyle.
   - Right condyle posterior space also showed significant intergroup differences ($p < 0.001$).

- Right condyle anterior space, however, did not show a statistically significant difference (p = 0.213).

5) Overall, condylar positional changes were more pronounced in hyperdivergent individuals, with mild asymmetry noted between left and right sides.
6) Airway dimensions
   - Oropharyngeal, hypopharyngeal, and total airway dimensions differed significantly among groups:
     § Normodivergent group had the largest airway dimensions
     § Hyperdivergent group had the smallest airway dimensions
     § These differences were statistically significant for:
   - Oropharynx (p = 0.024)
   - Hypopharynx (p = 0.024)
   - Total airway (p = 0.003)

This indicates a progressive reduction in airway space with increasing vertical divergence.

7) Post hoc (Tukey) analysis

Hyperdivergent group differed significantly from both normodivergent and hypodivergent groups for:

§ ANB

1) § SN-GoGn
2) § Left and right posterior condylar spaces
3) § Oropharyngeal, hypopharyngeal, and total airway dimensions

a) Differences between normodivergent and hypodivergent groups were less consistent and often non-significant for airway variables.
   - Correlation analysis
   - Skeletal-airway relationship
   - NB and SN-GoGn showed:
b) Negative correlation with total airway dimension ($p < 0.05$)
c) Higher skeletal divergence was associated with reduced airway size
   - Condylar relationships
   - Strong positive correlations were observed between:
   § Left and right anterior spaces
   § Left and right posterior spaces
   § ($p < 0.01$), indicating bilateral symmetry in condylar positioning trends
d) Airway components
   - Oropharynx strongly correlated with total airway dimension ($r = 0.897$, $p < 0.001$), making it the major contributor to total airway size.
   - Hypopharynx showed weak and non-significant correlations, suggesting a less dominant role.
e) Overall interpretation
   - Hyperdivergent skeletal pattern is associated with:
   - Posteriorly positioned condyles
   - Significantly reduced oropharyngeal and total airway dimensions
   - Vertical skeletal parameters (SN-GoGn) demonstrate a stronger association with airway reduction than sagittal parameters alone.
   - The oropharynx plays a key role in determining total airway size.

4. Discussion

The spatial configuration of the temporomandibular joint (TMJ) and the patency of the upper airway are intimately linked to the overarching craniofacial skeleton. In skeletal Class II malocclusions, variations in vertical growth patterns introduce unique biomechanical and structural adaptations. While conventional 2D cephalometrics historically limited evaluations due to magnification errors and structural superimposition, the advent of Cone Beam Computed Tomography (CBCT) permits an accurate 3D assessment of both hard tissue morphology and complex airway geometry. This study evaluated the specific correlation between condylar position within the glenoid fossa and upper airway dimensions across hyperdivergent, hypodivergent, and normodivergent skeletal Class II individuals within a South Indian population.

The results of this investigation demonstrate that vertical skeletal morphology heavily influences condylar position. The hyperdivergent group () exhibited a significantly smaller mean joint space in the anterior region (on the left side) compared to the posterior region (on the left side). Applying the Pullinger and Hollender linear ratio formula, this distinct discrepancy signifies a pronounced posterior condylar displacement within the glenoid fossa. This finding aligns with the biological mechanisms of high-angle patterns, where the mandible undergoes backward rotatory growth, carrying the condyle into a more retruded position. Conversely, the hypodivergent group exhibited highly concentric, well-balanced joint spaces (anteriorly vs. posteriorly on the left). Notably, intergroup comparisons confirmed no statistically significant differences between the right and left sides for anterior spaces (), suggesting that despite sagittal and vertical discrepancy trends, general bilateral condylar symmetry remains intact.

Concurrently, vertical divergence demonstrated a profound, progressive impact on pharyngeal dimensions. The hyperdivergent cohort presented with the smallest upper airway spaces across all measured subregions, with total airway dimensions dropping significantly down to a mean of (). The normodivergent group maintained the largest dimensions (). This systematic reduction is clinically critical; the posterior rotation of the mandible in hyperdivergent individuals physically relocates the hyoid bone, tongue posture, and surrounding soft tissues posteriorly, narrowing the pharyngeal lumen.

Correlation analysis further solidified this interconnected complex. Both sagittal () and vertical () parameters demonstrated a statistically significant negative correlation with total airway dimensions (). Interestingly, vertical skeletal divergence () showed a more robust association with airway narrowing than sagittal discrepancy alone, reinforcing that vertical growth management is paramount during treatment planning. Furthermore, the oropharynx demonstrated an exceptionally strong positive correlation with total airway dimension (,), identifying it as the principal anatomical zone determining global upper airway patency.

From a clinical standpoint, these findings highlight that South Indian Class II patients presenting with hyperdivergent features carry a dual anatomical predisposition: posteriorly displaced condyles-which are frequently linked to centric relation interferences and an increased risk of temporomandibular disorders (TMDs)-and constricted oropharyngeal dimensions that elevate the risk for obstructive sleep apnea (OSA). Orthodontic and orthognathic treatment plans for these patients must therefore look beyond dental alignment, focusing heavily on vertical control, mandibular advancement mechanics, or surgical interventions designed to simultaneously stabilize the TMJ and expand the pharyngeal airway.

5. Conclusions

Vertical skeletal morphology exerts a significant influence on condylar positioning and upper airway patency in skeletal Class II individuals.

Hyperdivergent Class II patients demonstrate a distinct non-concentric, posterior displacement of the condyle within the glenoid fossa, whereas hypodivergent patients present with more stable, concentric condylar positions.

Upper airway dimensions undergo progressive structural narrowing as vertical divergence increases. The oropharynx serves as the primary anatomical determinant of total pharyngeal airway space.

Statistically significant negative correlations exist between vertical skeletal parameters (SN-GoGn) and total airway volume, emphasizing the heightened risk of airway compromise and OSA susceptibility in high-angle Class II individuals.

3D CBCT diagnostic imaging provides essential qualitative and quantitative data, enabling clinicians to properly integrate TMJ health and airway preservation into orthodontic treatment planning

References

[1] Paknahad M, shahidi S: Paknahad M, Shahidi S. Association between condylar position and vertical skeletal craniofacial morphology: A cone beam computed tomography study. International orthodontics. 2017 Dec 1;15(4):740-51.. Diagnostics. 2024, 13:96-105. Oğuz. 10.1016/j.ortho.2017.09.007

[2] Pop SI, Procopciuc A, Arsintescu B, Mițariu M, Mițariu L, Pop RV, Cerghizan D, Jánosi KM: Three-dimensional assessment of upper airway volume and morphology in patients with different sagittal skeletal patterns. Diagnostics. 2024, 13:96-105. Oğuz. 10.3390/diagnostics14090903

[3] Lenza MG, Lenza MD, Dalstra M, Melsen B, Cattaneo PM: An analysis of different approaches to the assessment of upper airway morphology: a CBCT study. Orthodontics & craniofacial research. 2010, 13:96-105. 10.1111/j.1601-6343.2010.01482.x

[4] Oğuz F, Bor S, Khanmohammadi A, Kıranşal M: Evaluation of condylar and airway volume in skeletal Class I patients with different vertical growth patterns. Applied Sciences. 2025, 5:2794. 10.3390/app15052794

[5] Anthwal N, Tucker AS: Evolution and development of the mammalian jaw joint: Making a novel structure. Evolution & Development. 2023, 25:3-14. 10.1111/ede.12426

[6] Alomar X, Medrano J, Cabratosa J, Clavero JA, Lorente M, Serra I, Monill JM, Salvador A: Anatomy of the temporomandibular joint. InSeminars in Ultrasound, CT and MRI. 20071, 28:170-183. 10.1053/j.sult.2007.02.002

[7] Dargaud J, Vinkka-Puhakka H: L'articulation temporo-mandibulaire. Morphologie. 20041, 88:3-12. 10.1016/S1286-0115(04)97991-X

[8] Pullinger AG, Hollender L, Solberg WK: Petersson A. A tomographic study of mandibular condyle position in an asymptomatic population. The. Journal of prosthetic dentistry. 19851, 53:706-13. 10.1016/0022-3913(85)90029-0

[9] Pullinger AG, Solberg WK, Hollender L, Guichet D: Tomographic analysis of mandibular condyle position in diagnostic subgroups of temporomandibular disorders. The. Journal of Prosthetic Dentistry. 1986, 1:723-9. 10.1016/0022-3913(86)90450-6

[10] Cholasueksa P, Warita H, Soma K: Alterations of the rat temporomandibular joint in functional posterior displacement of the mandible. The Angle. Orthodontist. 2004, 1:677-83. 10.1043/0003-3219(2004)074%3C0677: AOTRTJ%3E2.0.CO;2

[11] Santander P, Quast A, Olbrisch C, Rose M, Moser N, Schliephake H, Meyer-Marcotty P: Comprehensive 3D analysis of condylar morphology in adults with different skeletal patterns-a cross-sectional study. Head & Face Medicine. 2020, 16:1-0. 10.1186/s13005-020-00245-z