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A THREE DIMENSIONAL EVALUATION OF MANDIBULAR CONDYLE IN ADULTS WITH VARIOUS GROWTH PATTERN USING CONE BEAM COMPUTED TOMOGRAPHY

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ABSTRACT
Introduction: Temporomandibular joint (TMJ) plays an important role in maintaining a balance between the oro-facial complex and the maxillo-mandibular system. The condyle can constantly reshape itself when exposed to various stimuli as it represents growth and the morphology it assumes has a fundamental role in the development and correction of the different types of malocclusions. **Aim:** Evaluation of the mandibular condylar shapes and width in adults with various growth patterns. **Methods:** The sample consisted of 96 patients were grouped into 3 growth patterns. On lateral cephlogram the hard tissue tracing is done on tracing sheet using 0.3 mm lead pencils and then the point were marked i.e., sella and nasion and the line is drawn (SN-PLANE) and gonion to ganathion the line is drawn (MP plane) then the angle was measured using protector manually. **Results** The findings indicate that the normodivergent group exhibits a greater average condylar width of 19.09 mm compared to the hypodivergent group at 18.84 mm and the hyperdivergent group at 16.64 mm. In the sagittal plane, normodivergent patients exhibit oval followed by crooked finger, diamond, bird beak, and angled shapes. Hypodivergent patients primarily display oval, diamond and bird beak shapes and no subjects were visualized with angled and crooked finger, while hyperdivergent group showed oval, bird beak, diamond, and crooked finger shapes no individuals with angled shape was observed. In the coronal plane, convex shapes, round shapes occurring, angled shapes in, concave shapes with and flattened with of normodivergent group, while in hypodivergent group convex shape followed by angled shapes occurring , round, concave and flattened and hyperdivergent group showed convex shape followed by angled shape, round shape, concave and flattened shapes. **Conclusion**: The present study concluded that mandibular condyle shapes and size vary significantly according to the growth pattern. Normodivergent have wider condyles followed by hypodivergent and hyperdivergent patients. In the sagittal plane, normodivergent patients exhibit oval followed by crooked finger, diamond, bird beak, and angled shapes.

KEYWORDS: Hypodivergent, Hyperdivergent, Normodivergent, Cone Beam Computed Tomography, Condylar Width, Condylar Shape.

INTRODUCTION
The temporomandibular joint (TMJ) is a highly specialized synovial articulation that plays a fundamental role in maintaining functional harmony between the craniofacial skeleton, masticatory muscles, and occlusion. The mandibular condyle, a principal component of the TMJ, undergoes continuous adaptive remodeling throughout life in response to functional

loading, occlusal changes, and masticatory muscle activity. This adaptive capacity enables the condyle to influence mandibular growth, craniofacial morphology, and the development of various malocclusions. Consequently, evaluation of condylar morphology has become an important component of orthodontic diagnosis and treatment planning, particularly in patients with altered skeletal growth patterns.[1-6]

Variations in mandibular condylar morphology have been associated with age, sex, functional loading, facial type, occlusal characteristics, and skeletal growth pattern. Previous investigations have demonstrated that differences in condylar size and shape may reflect adaptive responses to biomechanical demands and may influence mandibular development and long-term occlusal stability. Hyperdivergent individuals generally exhibit reduced masticatory muscle function and lower bite forces, whereas hypodivergent individuals demonstrate greater functional loading, potentially resulting in differences in condylar morphology. These morphological adaptations may have important implications for orthodontic diagnosis, treatment mechanics, and long-term stability.[6-12]

Cone-beam computed tomography (CBCT) has become the imaging modality of choice for three-dimensional assessment of the temporomandibular joint because it provides accurate visualization of osseous structures with relatively low radiation exposure compared with conventional computed tomography. CBCT enables precise evaluation of condylar morphology and linear dimensions without the superimposition and distortion associated with two-dimensional radiographic techniques, thereby improving the reliability of morphologic assessment in orthodontic patients.[13-15]

Although several CBCT studies have investigated condylar morphology in relation to skeletal malocclusion and facial divergence, the available evidence remains inconsistent regarding the influence of vertical skeletal growth patterns on condylar shape and dimensions. Furthermore, limited studies have simultaneously evaluated both qualitative condylar morphology and quantitative condylar width among normodivergent, hypodivergent, and hyperdivergent adults using standardized CBCT assessment protocols. Therefore, further investigation is warranted to improve the understanding of condylar adaptations associated with different vertical skeletal patterns.

Accordingly, the present study aimed to evaluate and compare the mandibular condylar morphology and condylar width among normodivergent, hypodivergent, and hyperdivergent adults using cone-beam computed tomography. It was hypothesized that significant differences in condylar morphology and width exist among different vertical skeletal growth patterns.

MATERIALS AND METHODS

Study Design and Participants

This cross-sectional observational study included 96 adult participants (20–30 years of age) who were selected from patients seeking orthodontic treatment at the Department of Orthodontics and Dentofacial Orthopaedics. The study protocol was approved by the Institutional Ethics Committee, and written informed consent was obtained from all participants before enrollment.

Eligibility Criteria

Participants were included if they were between 20 and 30 years of age, had no history of previous orthodontic treatment, and were free from systemic diseases or medical conditions that could influence craniofacial growth.

Participants were excluded if they presented with congenital craniofacial anomalies, temporomandibular joint (TMJ) disorders, previous condylar fractures, internal derangement of the TMJ, TMJ pain or joint sounds, degenerative condylar changes, previous TMJ surgery, coronoid hyperplasia, neuromuscular disorders, or other conditions affecting mandibular morphology.

Skeletal Growth Pattern Classification

The vertical skeletal growth pattern was determined using the mandibular plane angle (SN–MP) according to Steiner's cephalometric analysis. Lateral cephalograms were traced, and the SN–MP angle was measured for each participant. Based on this measurement, participants were equally allocated into three groups (n = 32 each):

- **Normodivergent group:** SN–MP angle between 30° and 32°
- **Hypodivergent group:** SN–MP angle <30°
- **Hyperdivergent group:** SN–MP angle >32°

CBCT Evaluation

Cone-beam computed tomography (CBCT) images of the bilateral temporomandibular joints were obtained for all participants and analyzed using IRYS software (MyRay, Cefla, Italy). Condylar morphology was assessed independently in both the sagittal and coronal planes.

In the sagittal view, condylar morphology was classified according to the criteria described by **Koyama et al.** into five categories: oval, bird beak, diamond, crooked finger, and angled. In the coronal view, condylar morphology was classified according to the **Yale et al.** classification as convex, concave, round, flattened, or angled.

Fig. 1: Lateral cephalogram tracing.

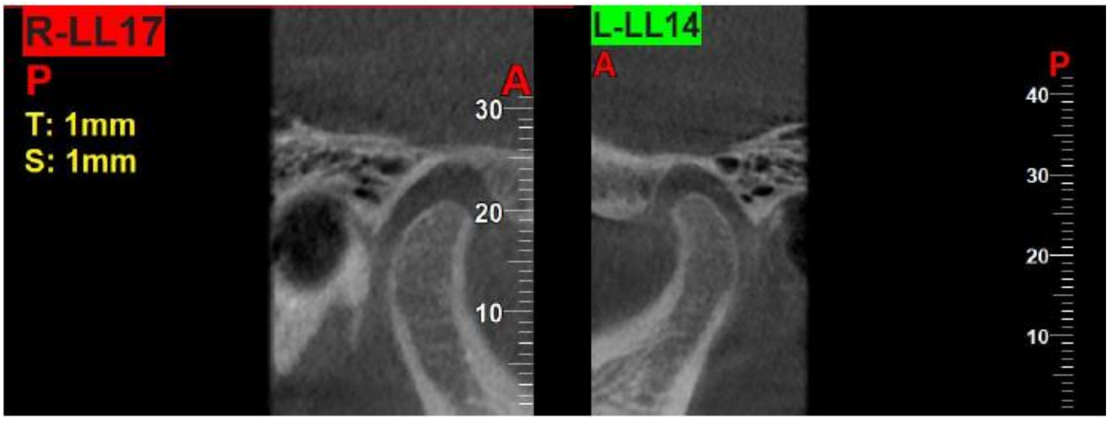

Fig. 2: Condylar shapes in sagittal view appeared as crooked finger on both right and left side of condyle in normodivergent patients.

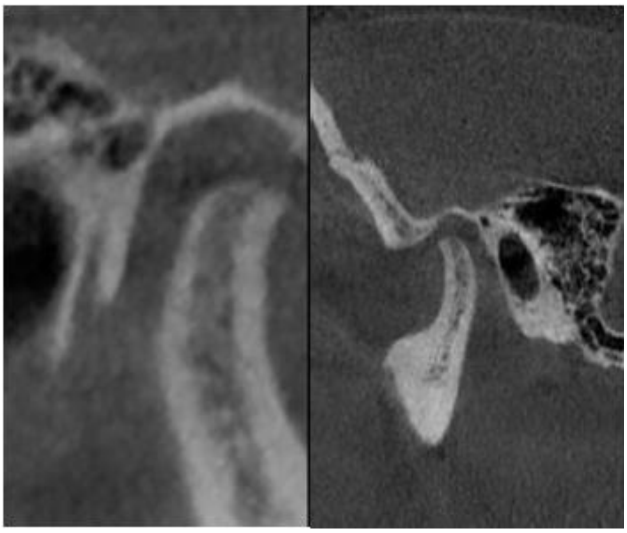

Fig. 3: Condylar shapes in sagittal view appeared as bird beak on Both right and left side of condyle in hypodivergent patients.

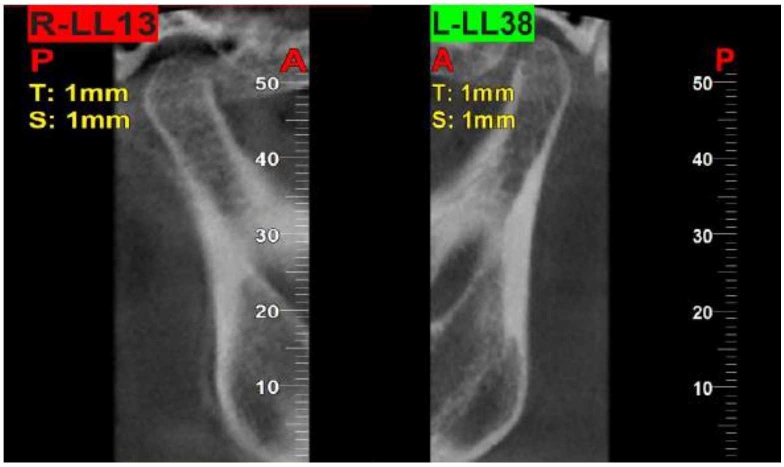

Fig. 4: Condylar shapes in sagittal view appeared as oval on both right and left side of condyle in hyperdivergent.

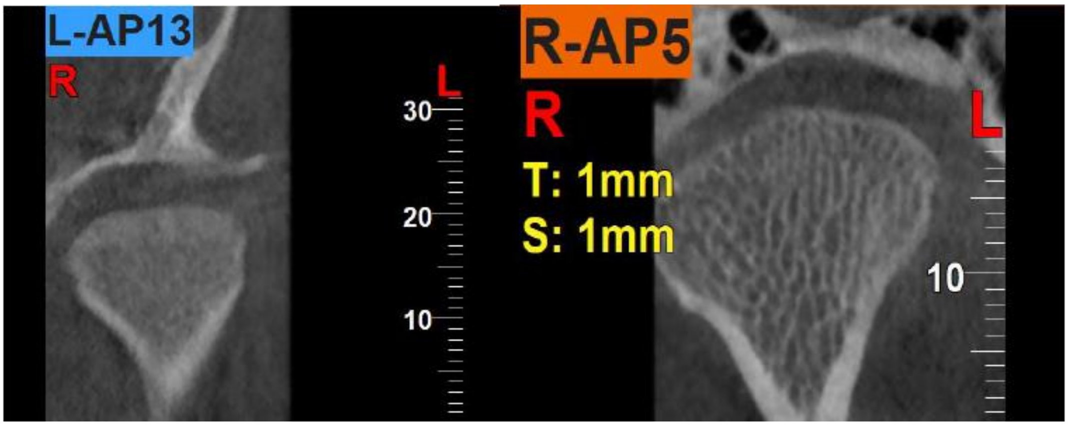

Fig. 5: condylar shapes in coronal view appeared as convex on both right and left side of condyle in normodivergent patients.

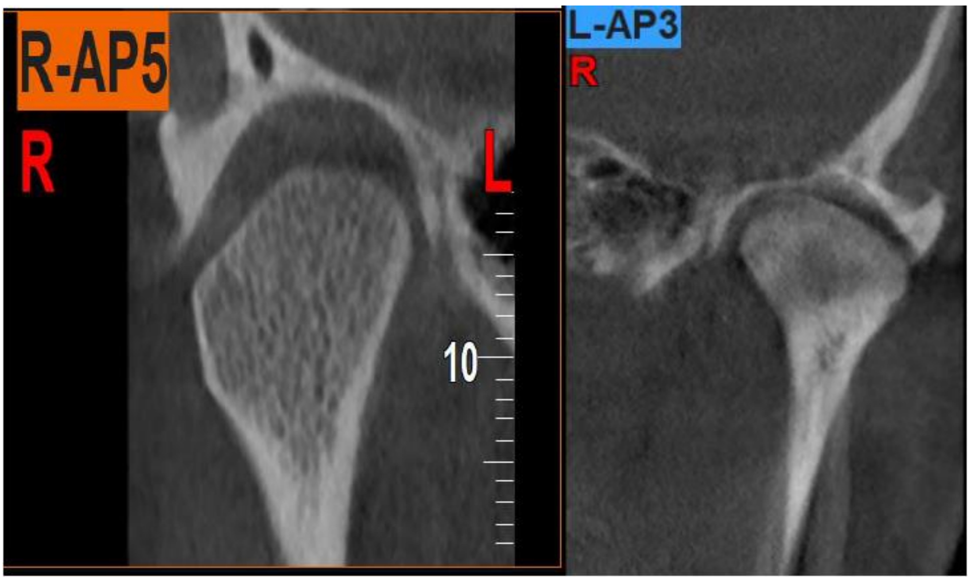

Fig. 6: Condylar shapes in coronal view appeared as angled on right side and left side of condyle in hypodivergent patients.

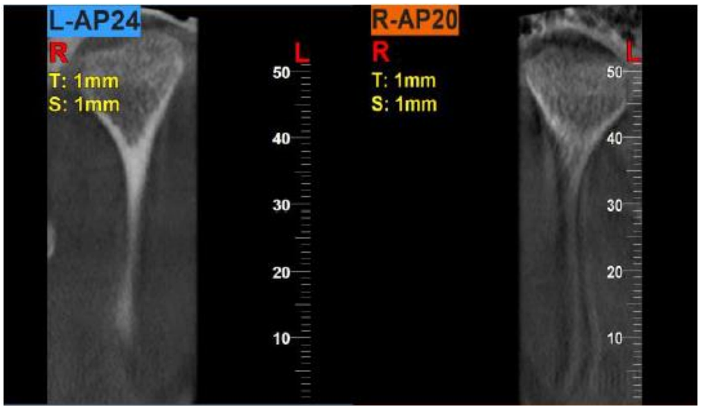

Fig. 7: condylar shapes in coronal view appeared as Angled on right side and left side of condyle in Hyperdivergent patients.

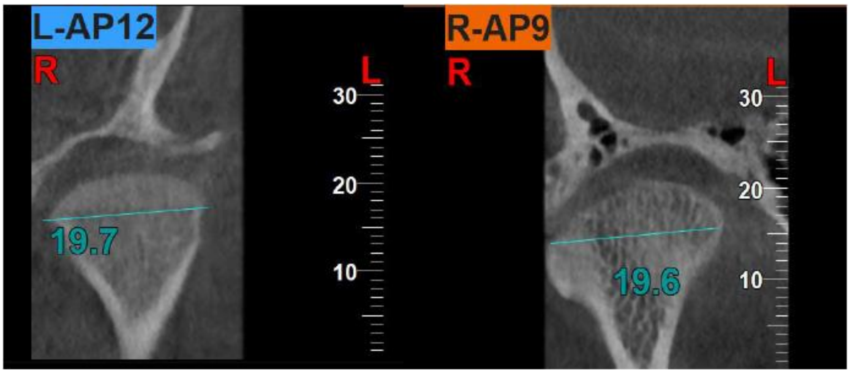

Fig. 8: Condylarwidth on right side (19.6 mm) and left Side of condyle (19.7 mm) in normodivergent patients.

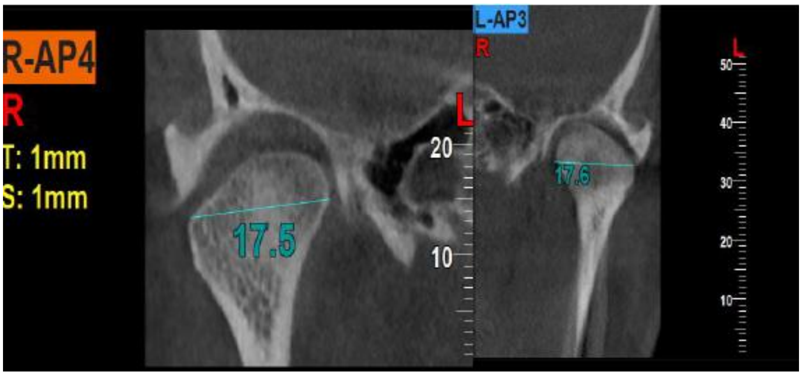

Fig. 9: Condylar width on right side (17.5 mm) and left Side (17.6 mm) of condyle in hypodivergent patients.

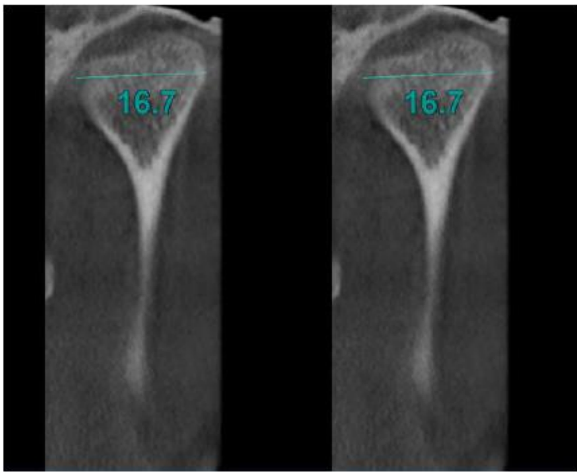

Fig. 10: Condylar width on right side (16.7 mm) and left side of Condyle (16.7 mm) in hyperdivergent patients.

most lateral ar condyle Condylar width was measured in the coronal section as the linear distance between the using the measurement tools incorporated within the IRYS software.

Statistical Analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS, version XX.0; IBM Corp., Armonk, NY, USA). Descriptive statistics were calculated for all variables. The distribution of condylar morphology among the three skeletal growth patterns was compared using the chi-square test, whereas differences in condylar width were analyzed using one-way analysis of variance (ANOVA). A value of $P < 0.05$ was considered statistically significant.

RESULTS

A total of **96 participants** (20–30 years) were included and equally distributed among the normodivergent, hypodivergent, and hyperdivergent groups (n = 32 each).

Table 1: Demographic characteristics of the study participants.

Characteristic	Normodivergent	Hypodivergent	Hyperdivergent	Total
Number of subjects	32	32	32	96
Age (years)	20–30	20–30	20–30	20–30
Skeletal pattern (SN-MP)	30–32°	<30°	>32°	—

Result text

Ninety-six adult participants aged between 20 and 30 years were included in the study. Based on the SN–MP angle, participants were equally allocated into normodivergent, hypodivergent, and hyperdivergent groups (32 participants each).

Table 2. Distribution of sagittal condylar morphology

Shape	Normodivergent n (%)	Hypodivergent n (%)	Hyperdivergent n (%)
Oval	15 (46.9)	15 (46.9)	12 (37.5)
Bird beak	3 (9.4)	9 (28.1)	10 (31.3)
Diamond	6 (18.8)	6 (18.8)	9 (28.1)
Crooked finger	7 (21.9)	0	1 (3.1)
Angled	1 (3.1)	0	0
P value	0.066	0.122	**0.033***

Result text

Oval morphology was the predominant sagittal condylar shape in all three skeletal growth patterns. Normodivergent subjects demonstrated a greater prevalence of crooked-finger morphology, whereas bird-beak morphology was more frequently observed in hyperdivergent subjects. No angled or crooked-finger condyles were identified in the hypodivergent group. A statistically significant difference in sagittal condylar morphology was observed only in the hyperdivergent group ($P = 0.033$).

Table 3. Distribution of coronal condylar morphology

Shape	Normodivergent n (%)	Hypodivergent n (%)	Hyperdivergent n (%)
Convex	15 (46.9)	10 (31.3)	11 (34.4)
Round	10 (31.3)	7 (21.9)	7 (21.9)
Angled	4 (12.5)	8 (25.0)	8 (25.0)
Concave	2 (6.3)	4 (12.5)	4 (12.5)
Flattened	1 (3.1)	3 (9.4)	2 (6.3)
P value	**<0.001***	0.136	0.240

Result text

Convex morphology was the most prevalent coronal condylar configuration in all three skeletal growth patterns. Round morphology represented the second most common configuration. Flattened condyles were the least frequently observed in every group. A statistically significant difference in coronal morphology was observed only in the normodivergent group ($P < 0.001$).

Table 4: Comparison of mean condylar width among different skeletal growth patterns GroupMean (mm) SD

Normodivergent	**19.09**	0.46
Hypodivergent	18.84	0.51
Hyperdivergent	**16.96†**	0.97

Result text

The normodivergent group exhibited the greatest mean condylar width, followed by the hypodivergent and hyperdivergent groups. Hyperdivergent participants demonstrated the smallest mean condylar width, indicating reduced mediolateral condylar dimensions compared with the other skeletal growth patterns.

DISCUSSION

The present study evaluated mandibular condylar morphology and condylar width among adults with different vertical skeletal growth patterns using cone-beam computed tomography. The principal findings demonstrated that oval morphology was the predominant sagittal condylar configuration across all groups, whereas convex morphology was the most frequent coronal configuration.

Furthermore, normodivergent individuals exhibited the greatest mean condylar width, followed by hypodivergent and hyperdivergent subjects, indicating that vertical skeletal pattern is associated with variations in condylar morphology and dimensions.

The predominance of oval morphology in the sagittal plane and convex morphology in the coronal plane observed in the present study is consistent with the findings of **Mohsen et al.**, who also reported oval condyles as the most common sagittal morphology irrespective of skeletal growth pattern.

Likewise, convex morphology was the predominant coronal configuration in all facial types, suggesting that these morphologic patterns represent the normal adaptive anatomy of the mandibular condyle. Minor variations in the frequency of bird-beak, diamond, and crooked-finger morphologies among different skeletal patterns may reflect functional remodeling in response to differences in masticatory loading and mandibular growth.

Our findings partially agree with those of **Park et al.**, who reported that hypodivergent individuals predominantly exhibited oval condyles in the sagittal plane but observed a greater prevalence of round morphology in hyperdivergent subjects in the coronal plane. These differences may be attributed to variations in ethnicity, sample characteristics, imaging protocols, and skeletal classification methods. In contrast, **Rajesh et al.** reported different distributions of condylar morphology across vertical skeletal patterns, highlighting the absence of a universally accepted morphologic pattern and emphasizing the influence of population-specific characteristics.

A notable finding of the present study was that normodivergent individuals demonstrated the greatest mean condylar width, whereas hyperdivergent individuals exhibited the smallest condylar dimensions. These observations are consistent with the studies by **Chae et al.**, **Santander et al.**, **Choi et al.**, **Zhou et al.**, and **Diwakar et al.**, who also reported reduced condylar dimensions in hyperdivergent subjects. Reduced masticatory muscle activity and lower occlusal loading in hyperdivergent individuals may contribute to decreased functional stimulation of the condyle, resulting in smaller mediolateral condylar dimensions.

Conversely, **Jeon et al.**, **Lin et al.**, **Noh et al.**, and **Otsuka et al.** reported greater condylar width in hypodivergent individuals. These conflicting findings may be explained by differences in study populations, CBCT acquisition protocols, age distribution, sample size, and cephalometric criteria used to classify vertical skeletal patterns.

From a clinical perspective, the observed association between vertical skeletal pattern and condylar morphology highlights the importance of comprehensive TMJ assessment during orthodontic diagnosis and treatment planning. Three-dimensional CBCT evaluation provides valuable information regarding condylar morphology that may assist clinicians in understanding mandibular adaptation, predicting treatment response, and improving long-term stability, particularly in patients with vertical skeletal discrepancies.

The strengths of the present study include the use of CBCT for three-dimensional evaluation and equal distribution of participants among the three skeletal growth patterns. However, several limitations should be acknowledged. Gender-based differences were not evaluated, the study employed a cross-sectional design, and only condylar shape and width were assessed without volumetric analysis. Future longitudinal studies with larger multicenter samples and comprehensive three-dimensional assessment of condylar morphology are recommended to further elucidate the relationship between temporomandibular joint morphology and craniofacial growth patterns.

CONCLUSIONS

1. Mandibular condylar morphology varies according to vertical skeletal growth pattern.
2. Oval morphology in the sagittal plane and convex morphology in the coronal plane were the most frequently observed condylar configurations.
3. Normodivergent individuals exhibited the greatest mean condylar width, whereas hyperdivergent individuals demonstrated the smallest condylar dimensions.
4. Cone-beam computed tomography provides reliable three-dimensional assessment of condylar morphology and should be considered a valuable adjunct in orthodontic diagnosis and treatment planning.

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