

**A Study to Assess the Temporomandibular Joint Variations in Digital Computed Tomography–A Cross-Sectional Study**

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**Abstract**

**Background:** The temporomandibular joint (TMJ) is a complex synovial articulation facilitating mastication, phonation, and deglutition. Understanding TMJ morphology and morphometry is essential to differentiate physiological remodeling from pathological changes. Cone Beam Computed Tomography (CBCT) provides precise three-dimensional evaluation of osseous

structures with minimal distortion and radiation exposure.

**Aim:** This study aimed to assess age- and gender-related morphological and morphometric variations of the TMJ using CBCT in an Indian population, establishing normative reference data.

**Materials and Methods:** A cross-sectional observational study was conducted on CBCT scans of participants divided into three age groups: 20–39, 40–59, and ≥60

years. Morphological features—condylar flattening, cortical sclerosis, erosion, and osteophyte formation—were recorded. Morphometric measurements included condylar height, width, volume, and anterior, superior, and posterior joint spaces bilaterally. Data were analyzed using descriptive and inferential statistics. Pearson correlation assessed age-morphometry relationships, while intra- and inter-observer reliability was evaluated using intraclass correlation coefficient (ICC).

**Results:** Condylar flattening (23%) and sclerosis (17.3%) were the most common morphological changes. Condylar height, width, and volume decreased significantly with age ( $p < 0.05$ ). Superior and posterior joint spaces narrowed with age, while anterior space remained stable. Condylar height showed the strongest negative correlation with age ( $r = -0.372$ ,  $p < 0.001$ ). Males had significantly larger condylar dimensions and fossa depth than females ( $p < 0.05$ ), with no significant gender difference in joint space. Intra- and inter-observer reliability was excellent ( $ICC > 0.90$ ).

**Conclusion:** TMJ morphology and morphometry vary with age and gender. CBCT provides reliable quantitative assessment, aiding in distinguishing adaptive remodeling from early pathology and offering essential normative data for clinical reference in diagnosis and treatment planning.

**Keywords:** Temporomandibular joint, CBCT, Morphology, Morphometry, Age, Gender, Remodeling, Joint Space, Condylar Height.

### Introduction

The temporomandibular joint (TMJ) is a complex synovial articulation connecting the mandibular condyles with the temporal bones, enabling mastication, deglutition, phonation, and facial expressions<sup>1</sup>. Its intricate anatomy, including a biconcave articular disc, dual compartments, and synchronized bilateral

movement, makes it susceptible to structural variations, degenerative changes, and functional disorders<sup>2</sup>. Standardized diagnostic protocols, such as RDC/TMD and DC/TMD, integrate clinical and psychosocial assessments to improve reliability across populations<sup>3,4</sup>. However, clinical evaluation alone may fail to detect subtle osseous changes, joint space variations, or early degeneration<sup>5,6</sup>.

Conventional two-dimensional imaging, including panoramic and lateral cephalometric radiographs, is limited by distortion and superimposition<sup>7,8</sup>. Digital CT and cone-beam CT (CBCT) provide high-resolution, three-dimensional visualization of condylar morphology, joint spaces, and articular eminence angulation with reproducible morphometric measurements<sup>9-11</sup>. TMJ morphology is influenced by age, sex, occlusal patterns, parafunctional habits, and genetics, with age-related condylar flattening, joint space narrowing, and cortical changes commonly observed<sup>12-15</sup>. Bilateral asymmetry, condylar shape variations, and altered joint spaces may reflect functional adaptation or predisposition to TMDs<sup>16,17</sup>.

This cross-sectional study aimed to assess TMJ morphological variations and bony changes using digital CT. The objectives were to evaluate TMJ differences across age groups, compare right-left joint variations, assess gender-related differences, and determine the diagnostic efficacy of digital CT. The study documented condylar morphology, articular eminence angulation, glenoid fossa dimensions, joint space widths, and bilateral symmetry to establish normative reference data for clinical and research use<sup>18-24</sup>.

### Material and method

This cross-sectional observational study evaluated morphological variations and bony changes of the temporomandibular joint (TMJ) using digital computed

tomography (CT). Ethical approval was obtained from the Institutional Ethics Committee, and all scans were anonymized. Only archival diagnostic CT images were used, ensuring no additional radiation exposure.

### Study Population

A total of 300 adult CT scans ( $\geq 18$  years) of both genders were included. Scans were selected based on: adequate image quality, complete bilateral TMJ visualization, standardized imaging parameters, and absence of systemic bone disorders. Exclusion criteria included motion artifacts, poor contrast, history of trauma or TMJ surgery, congenital anomalies, metallic artifacts, orthodontic appliances, or incomplete demographic data.<sup>25</sup>

Participants were stratified into three age groups:

- Group 1: 20–39 years (n=100)
- Group 2: 40–59 years (n=100)
- Group 3:  $\geq 60$  years (n=100)

### Imaging Protocol

All scans were obtained using the iCAT Classic CT machine with standardized settings: 120 kVp, 5 mA, isotropic voxel size 0.30 mm, 16×13 cm FOV, 0.5 mm slice thickness, and high-resolution bone reconstruction. Patients were positioned with the Frankfurt plane parallel and teeth in centric occlusion. Images were processed in DICOM format and evaluated in axial, coronal, and sagittal views.

### Morphometric and Morphological Analysis

Image assessment was performed using OsiriX MD software on calibrated high-resolution monitors. Qualitative parameters included condylar flattening, sclerosis, erosion, osteophytes, and subchondral cysts. Quantitative measurements included condylar height, width, depth, volume, and anterior, superior, and posterior joint spaces, along with glenoid fossa depth and

eminence angulation. Measurements were recorded bilaterally using standardized protocols.

### Statistical Analysis and Reliability

Data analysis was conducted using SPSS v29.0. Chi-square, ANOVA, Kruskal–Wallis, Pearson/Spearman correlation, and regression analyses were applied ( $p < 0.05$ ). Intra- and inter-observer reliability was evaluated on 60 scans using ICC and Dahlberg’s formula, with ICC  $\geq 0.90$  indicating excellent agreement.

#### SCHEMATIC DIAGRAM OF METHODOLOGY

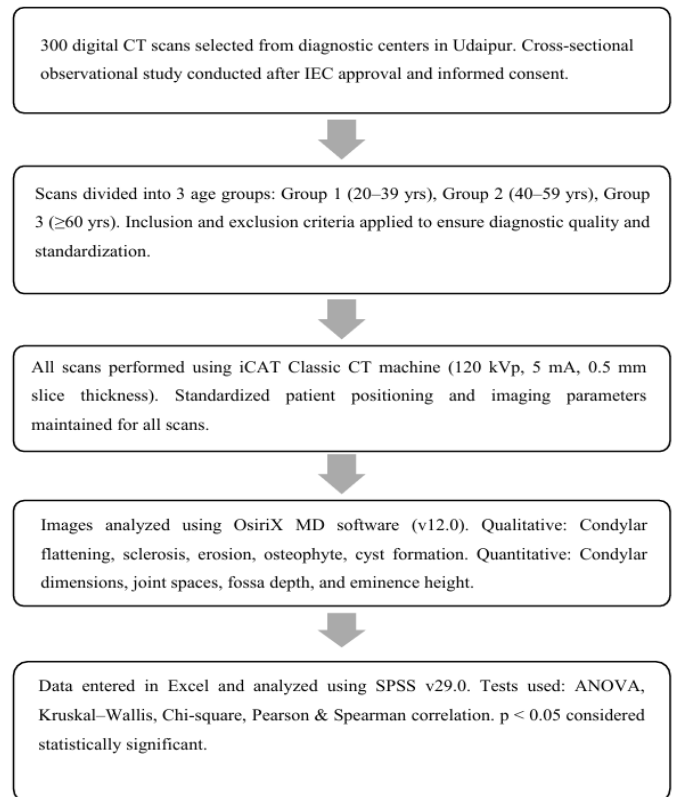


Figure 1: Schematic diagram of methodology.

### Results

The present cross-sectional study titled “A study to assess the morphometric and morphological changes of the temporomandibular joint (TMJ) with respect to age and gender using CBCT” included 300 subjects (157 males, 143 females). Table 1 and Graph 1 present the age–gender distribution, showing equal allocation into three age groups (20–39, 40–59,  $\geq 60$  years), ensuring balanced comparison across age categories.

Table 1 and Graph 1: Distribution of Study Participants by Age and Gender

Age Group (years)	Male (n)	Female (n)	Total (n)	Percentage (%)
20-39 (Group 1)	55	45	100	33.3
40-59 (Group 2)	50	50	100	33.3
≥60 (Group 3)	52	48	100	33.3
<b>Total</b>	<b>157</b>	<b>143</b>	<b>300</b>	<b>100.0</b>

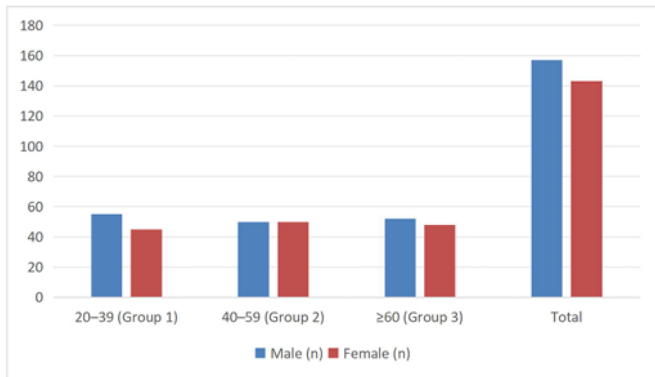


Table 2 and Graph 2 summarize TMJ morphological features, where condylar flattening (23%) was the most common finding, followed by cortical sclerosis (17.3%), osteophytes (11.3%), and erosions (9%). Subchondral cysts (4.6%) were least frequent. These patterns indicate early and progressive degenerative or adaptive remodeling changes. (Photograph 2)

Table 2 and Graph 2: Descriptive Statistics and Prevalence of TMJ Morphological Variations.

Parameter	Mean ± SD	Minimum	Maximum
Condylar width (mm)	18.41 ± 1.36	15.90	20.75
Condylar height (mm)	7.41 ± 0.68	6.02	8.90
Superior joint space (mm)	2.18 ± 0.32	1.65	2.95
Fossa depth (mm)	6.22 ± 0.71	4.80	7.80
Eminence height (mm)	8.94 ± 1.03	7.12	10.82

Test used: Descriptive statistics (Mean, SD, Minimum, Maximum).

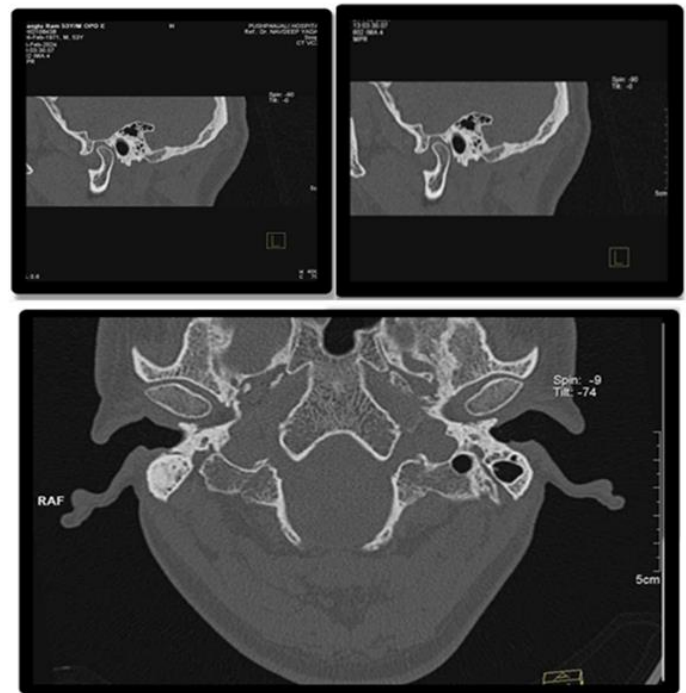
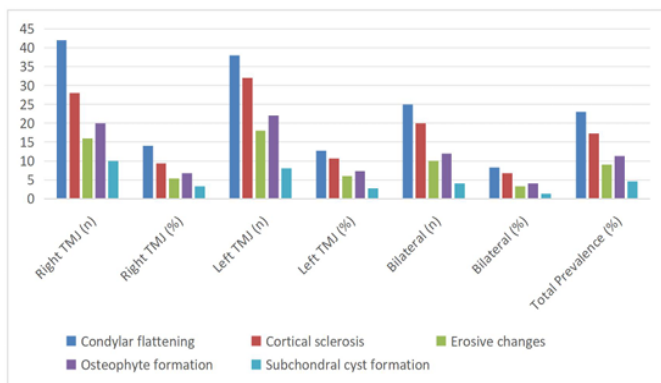


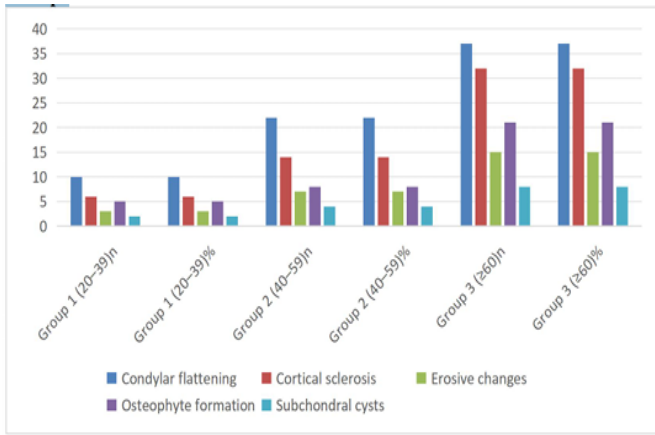
Figure 2: Morphological Variations of TMJ: Sagittal and axial with Flattening and Cortical Sclerosis, Axial Showing Osteophyte.

Age-wise evaluation (Table 3 and Graph 3) showed a significant increase in degenerative features with age ( $p \leq 0.01$ ). Cortical sclerosis exhibited the strongest age association ( $\chi^2 = 26.87$ ,  $p < 0.001$ ), while subchondral cysts showed no significant age trend.

Table 3 and Graph 3: Comparison of TMJ Morphological Variations Across Age Groups.

Morphological Change	Group 1 (20-39)	Group 2 (40-59)	Group 3 (≥60)	$\chi^2$ value	p-value	Significance
Condylar flattening	10 (10%)	22 (22%)	37 (37%)	22.41	0.001*	Significant ↑ with age
Cortical sclerosis	6 (6%)	14 (14%)	32 (32%)	26.87	<0.001*	Significant ↑ with age
Erosive changes	3 (3%)	7 (7%)	15 (15%)	9.45	0.009*	Significant
Osteophyte formation	5 (5%)	8 (8%)	21 (21%)	13.32	0.001*	Significant
Subchondral cysts	2 (2%)	4 (4%)	8 (8%)	3.85	0.146	Not significant

Test used: Chi-square test for association between morphological changes and age group. \*p-value significant at 0.05 levels

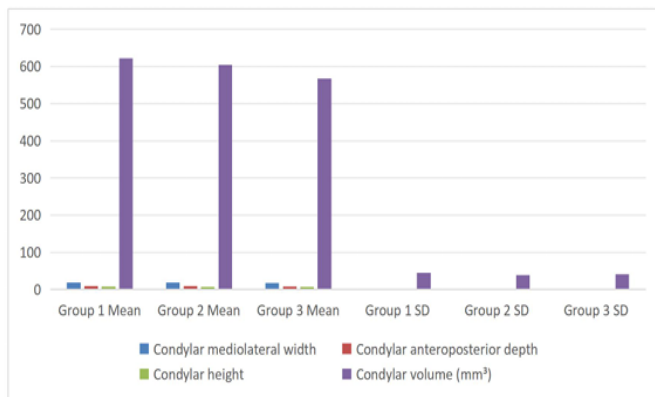


Morphometric assessment (Table 4 and Graph 4) revealed a gradual reduction in condylar width, height, and volume with increasing age ( $p < 0.01$ ).

Table 4 and Graph 4: Age-wise Comparison of Mean Condylar Morphometric Parameters.

Parameter (mm)	Group 1 (Mean ± SD)	Group 2 (Mean ± SD)	Group 3 (Mean ± SD)	p-value (ANOVA)	Significance
Condylar mediolateral width	18.92 ± 1.41	18.45 ± 1.35	17.86 ± 1.22	0.004*	Significant ↓ with age
Condylar anteroposterior depth	9.42 ± 0.87	8.95 ± 0.83	8.34 ± 0.76	<0.001*	Significant
Condylar height	7.85 ± 0.72	7.42 ± 0.69	6.98 ± 0.58	<0.001*	Significant
Condylar volume (mm <sup>3</sup> )	621.5 ± 45.3	603.8 ± 39.2	567.9 ± 41.6	0.002*	Significant

Test used: One-way ANOVA followed by Tukey's post-hoc test. \*p-value significant at 0.05 levels

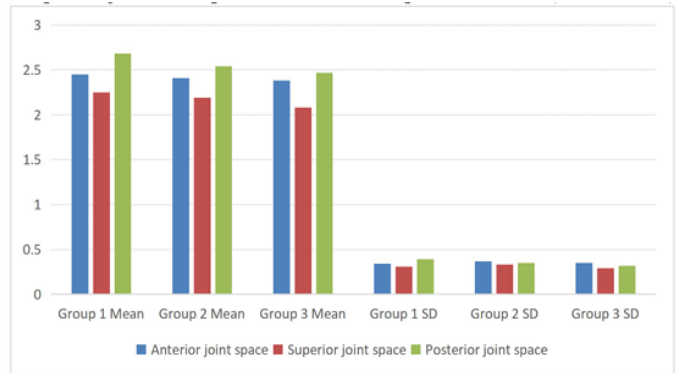


Joint space measurements (Table 5 and Graph 5) showed significant narrowing of superior and posterior joint spaces ( $p = 0.012$ ,  $p = 0.027$ ), whereas anterior joint space remained unaffected.

Table 5 and Graph 5: Age-wise Comparison of TMJ Joint Space Measurements.

Joint Space (mm)	Group 1	Group 2	Group 3	p-value (ANOVA)	Significance
Anterior joint space	2.45 ± 0.34	2.41 ± 0.37	2.38 ± 0.35	0.321	NS
Superior joint space	2.25 ± 0.31	2.19 ± 0.33	2.08 ± 0.29	0.012*	Significant ↓ with age
Posterior joint space	2.68 ± 0.39	2.54 ± 0.35	2.47 ± 0.32	0.027*	Significant

Test used: One-way ANOVA followed by Tukey's post-hoc test. \*p-value significant at 0.05 levels

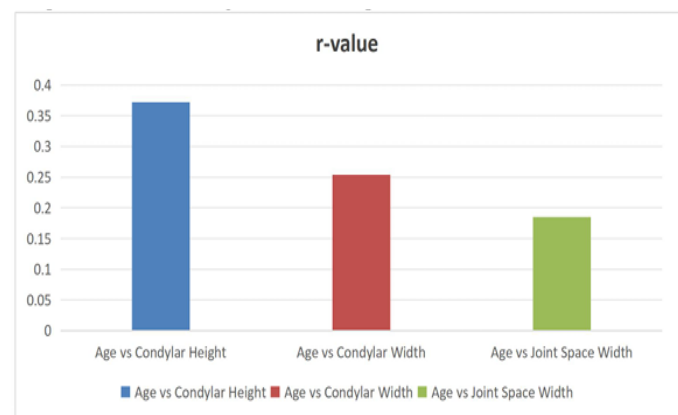


Correlation analysis (Table 6 and Graph 6) demonstrated significant negative correlations between age and condylar height ( $r = -0.372$ ), width ( $r = -0.254$ ), and joint space ( $r = -0.185$ ), suggesting age-related structural decline.

Table 6 and Graph 6: Correlation Between Age and TMJ Morphometric Parameters.

Variable	r-value	p-value	Interpretation
Age vs Condylar Height	-0.372	<0.001	Moderate negative correlation
Age vs Condylar Width	-0.254	0.004*	Weak negative correlation
Age vs Joint Space Width	-0.185	0.028*	Weak negative correlation

Test used: Pearson's correlation coefficient. \*P-value significant at 0.05 levels

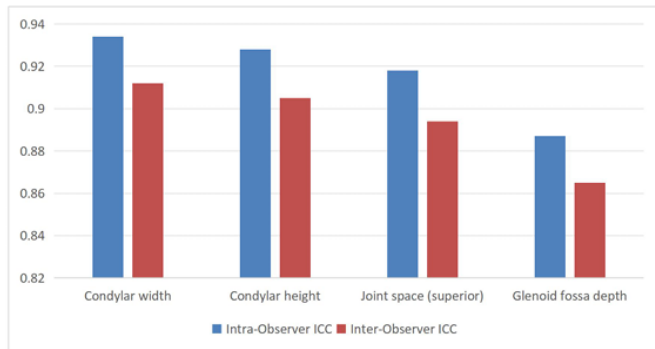


Reliability testing (Table 7 and Graph 7) showed excellent intra- and inter-observer agreement (ICC > 0.90), confirming measurement accuracy.

Table 7 and Graph 7: Intra- and Inter-Observer Reliability of TMJ Morphometric Measurements.

Measurement Parameter	Intra-Observer ICC	Inter-Observer ICC	Method Error (mm)	Interpretation
Condylar width	0.934	0.912	0.22	Excellent reliability
Condylar height	0.928	0.905	0.18	Excellent reliability
Joint space (superior)	0.918	0.894	0.20	Excellent reliability
Glenoid fossa depth	0.887	0.865	0.26	Good reliability

**Test used:** Intraclass Correlation Coefficient (ICC) and Dahlberg's formula for measurement error.

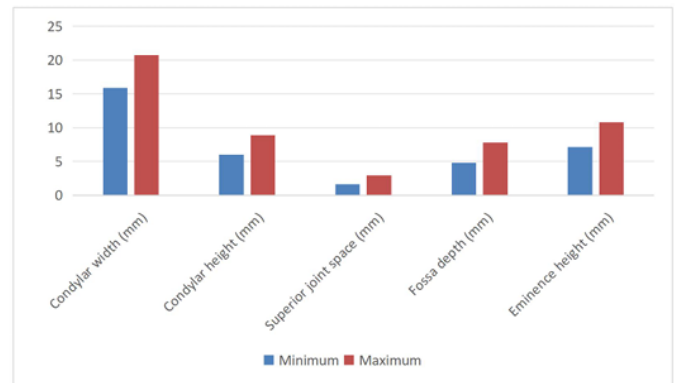


Descriptive statistics (Table 8 and Graph 8) provided baseline TMJ dimensions, showing minimal intra-sample variability.

Table 8 and Graph 8: Prevalence and Distribution of TMJ Morphological and Morphometric Parameters.

Morphological Feature	Right TMJ n (%)	Left TMJ n (%)	Bilateral n (%)	Total Prevalence (%)
Condylar flattening	42 (14.0)	38 (12.7)	25 (8.3)	23.0
Cortical sclerosis	28 (9.3)	32 (10.7)	20 (6.7)	17.3
Erosive changes	16 (5.3)	18 (6.0)	10 (3.3)	9.0
Osteophyte formation	20 (6.7)	22 (7.3)	12 (4.0)	11.3
Subchondral cyst formation	10 (3.3)	8 (2.7)	4 (1.3)	4.6

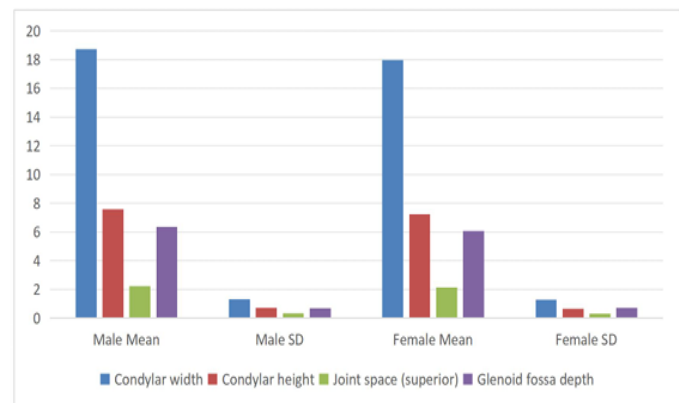
**Test used:** One-way ANOVA followed by Tukey's post-hoc test. \*p-value significant at 0.05 levels



Gender comparison (Table 9 and Graph 9) revealed significantly higher condylar dimensions in males (p < 0.05), while joint spaces showed no major sex differences.

Table 9 and Graph 9: Gender-wise Comparison of TMJ Morphometric Parameters.

Parameter (mm)	Male (Mean ± SD)	Female (Mean ± SD)	p-value (t-test)	Significance
Condylar width	18.74 ± 1.32	17.96 ± 1.29	0.005	Significant
Condylar height	7.58 ± 0.71	7.23 ± 0.65	0.014	Significant
Joint space (superior)	2.23 ± 0.35	2.14 ± 0.30	0.061	NS
Glenoid fossa depth	6.34 ± 0.68	6.08 ± 0.72	0.037*	Significant



Overall statistical associations (Table 10) confirmed that TMJ morphology and morphometry exhibit significant age-related structural and degenerative changes, supported by highly reliable CBCT measurements.

Table 10: Summary of Significant Findings

Parameter	Statistical Test	p-value	Result
Condylar flattening vs Age	Chi-square	0.001*	Significant association
Condylar height vs Age	ANOVA	<0.001*	Significant difference
Superior joint space vs Age	ANOVA	0.012*	Significant difference
Osteophyte formation vs Age	Chi-square	0.001*	Significant association
Reliability (ICC)	ICC analysis	>0.90	Excellent reproducibility

## Discussion

The present study comprehensively evaluated the morphological and morphometric features of the temporomandibular joint (TMJ) using digital computed tomography in an adult population. The findings demonstrated considerable variability in condylar shape, joint space dimensions, and degenerative changes, consistent with previously reported anatomical diversity of the TMJ<sup>25</sup>. Age-related differences were evident, with older individuals exhibiting a higher prevalence of flattening, erosion, and reduced joint space measurements, reflecting physiological remodeling and early degenerative transformations associated with functional loading over time<sup>26</sup>.

Gender-based comparisons revealed that males generally exhibited larger condylar dimensions compared with females<sup>4</sup>, which aligns with broader craniofacial structural differences reported in anthropometric research. However, qualitative morphological variations such as osteophytes, subcortical sclerosis, and condylar asymmetry did not show a marked gender predilection, suggesting that degenerative patterns may be more closely associated with biomechanical factors rather than sex-specific predisposition<sup>27-28</sup>.

Correlation analysis demonstrated a significant association between age and morphometric parameters, particularly condylar height reduction and joint space narrowing. These radiological indicators may serve as early predictors of temporomandibular disorders (TMD), especially in individuals with parafunctional habits, malocclusion, or a history of recurrent subluxation<sup>29,30</sup>.

Reliability testing showed excellent intra- and inter-observer agreement, confirming that CT-based evaluation is a robust method for studying subtle osseous changes in the TMJ. The detailed visualization provided by CT enables accurate assessment of condylar morphology and

degenerative alterations, enhancing diagnostic confidence and supporting clinical decision-making<sup>31-33</sup>.

Overall, the findings highlight the significance of imaging in understanding normal anatomical variations, diagnosing early degenerative changes, and aiding clinicians in appropriate management of TMJ-related conditions<sup>34,35,36</sup>.

This study had several limitations. First, its cross-sectional design prevented evaluation of temporal or progressive changes in TMJ morphology. A longitudinal approach would provide stronger evidence regarding the natural course of remodeling and degeneration. Second, clinical and functional parameters—such as occlusal characteristics, parafunctional habits, and symptom severity—were not analyzed alongside radiological findings, which may have limited clinico-radiological correlation<sup>37-40</sup>. Third, although CT is excellent for assessing bony structures, it does not capture soft tissue details such as disc position, capsule integrity, or retrodiscal tissue status<sup>14</sup>. The study sample was also limited to a specific geographic region, which may restrict generalizability of the results<sup>41</sup>.

Future research should focus on longitudinal studies to track progressive TMJ changes across different age groups<sup>42</sup>. Integrating CT with MRI would allow comprehensive evaluation of both osseous and soft tissue structures, improving diagnostic accuracy<sup>43</sup>. Further work should incorporate functional assessments—occlusal analysis, muscle activity studies, and clinical symptom scoring—to strengthen clinico-radiological associations<sup>44</sup>. Expanding the sample size to include diverse ethnic and demographic groups may help establish normative reference data for TMJ morphometry<sup>45</sup>. Additionally, emerging technologies such as 3D reconstruction, AI-based morphometric analysis, and automated segmentation hold potential for

early detection of subtle TMJ abnormalities<sup>46</sup>. Such advancements may support personalized treatment planning and improved outcomes for patients with TMJ disorders<sup>47-50</sup>.

### Conclusion

The temporomandibular joint (TMJ) is a complex, functionally adaptive articulation that remodels continuously in response to mechanical loading and age-related changes. This CBCT-based study systematically evaluated TMJ morphology and morphometry in an Indian population, focusing on condylar height, width, volume, and joint space dimensions across different age and gender groups. CBCT provided high-resolution, three-dimensional imaging with excellent reproducibility (ICC > 0.90), enabling accurate quantification of structural variations. Morphological assessment revealed condylar flattening (23%) as the most prevalent feature, followed by cortical sclerosis (17.3%) and osteophyte formation (11.3%), indicating ongoing adaptive remodeling rather than pathological degeneration. Morphometric analysis demonstrated a significant age-related reduction in condylar dimensions, with condylar height showing the strongest negative correlation with age ( $r = -0.372$ ,  $p < 0.001$ ). Superior and posterior joint spaces also decreased with age, reflecting remodeling of the articular surfaces and cartilage thinning. Gender-based comparisons showed that males exhibited larger condylar dimensions and fossa depth, while joint space symmetry was preserved across sexes, highlighting sexual dimorphism in craniofacial anatomy. These findings reinforce that TMJ remodeling is a physiological, dynamic process that maintains joint function under mechanical stress. The study provides normative reference values for the Indian population and underscores the clinical utility of CBCT in diagnosing, planning, and managing TMJ-related conditions.

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