

Jordan Journal of Dentistry

<https://jjd.just.edu.jo>

CBCT-Based Morphometric Assessment of Osseous Temporomandibular Joint Components in an Adult Jordanian Sample

Ghaida AlJamal ^{1*}, Dalal Shamiyah ², Lina Al-Qasem ³, Farah Alsadi ²

1 Department of Oral Medicine and Oral Surgery, Faculty of Dentistry, Jordan University of Science and Technology, Irbid, Jordan.

2 Faculty of Dentistry, Jordan University of Science and Technology, Irbid, Jordan.

3 Department of Conservative Dentistry, Faculty of Dentistry, Jordan University of Science and Technology, Irbid, Jordan.

ARTICLE INFO

Article History:

Received: 7/5/2026

Accepted: 1/6/2026

Correspondence:

Ghaida AlJamal
Department of Oral Medicine
and Oral Surgery
Faculty of Dentistry, Jordan
University of Science and
Technology, Irbid, Jordan.
ghaidaa@just.edu.jo

ABSTRACT

Objectives: Limited comprehensive morphometric data is available on osseous TMJ components using quantitative measurements, qualitative assessment, and demographic variables. The purpose of this study was to perform a morphometric assessment of the osseous TMJ components, mainly the mandibular condyle, glenoid fossa, articular eminence, and joint spaces, using cone-beam computed tomography (CBCT), and to study side-, sex-, and age-related associations in the mandibular condyles and glenoid fossae.

Materials and Methods: This retrospective cross-sectional study used CBCT images of 100 TMJs from 50 adults with no documented TMJ-related complaints. Corrected sagittal and coronal sections were assessed for articular eminence height, joint spaces, condylar dimensions, condylar shape, and glenoid fossa shape. Welch's t-test, Welch's ANOVA, and Fisher's exact test were used, with significance set at $p < 0.05$.

Results: No significant right-left differences were found in linear measurements or morphological variables (all $p > 0.05$). Males showed greater left articular eminence height and right condylar width than females. Left condylar shape distribution differed by sex ($p = 0.001$), with more round condyles in males and more convex condyles in females. The left glenoid fossa shape also differed by sex ($p = 0.002$). Age-group analysis showed lower left articular eminence height in the older age group ($p = 0.007$), while most other measurements showed no significant age-related differences.

Conclusions: CBCT-based osseous TMJ morphometry indicates general bilateral symmetry in this sample. Selective sex- and age-related differences were observed mainly on the left side; therefore, these findings should be interpreted as exploratory preliminary reference information for radiologic interpretation and treatment planning.

Keywords: TMJ, Cone-beam computed tomography, Temporomandibular joint, CBCT.

1. Introduction

The temporomandibular joint (TMJ) is a functional joint that is involved in essential functions, such as mastication, speech, swallowing, and respiration (1). This bilateral joint is formed by the mandibular condyles and the glenoid fossa of the temporal bone; it has certain unique biomechanical properties that enable both rotation and translation movements (2). The osseous components, articular disc, ligamentous structures, and

the musculature around the mandible interact in a highly complex manner to resist functional loads and maintain appropriate mandibular positioning (3). Clinical examination and appropriate imaging play a key role in the assessment of TMJ disorders (TMD), planning an effective treatment, and contributing to improved clinical outcomes of reconstruction procedures in the different dentistry disciplines. Baseline CBCT-based morphometrics, such as linear dimensions and shape

classification of osseous TMJ components in clinically asymptomatic cohorts, are still limited in the literature.

The TMJ is a dynamic structure in which morphological remodeling may occur as a result of functional requirements, biomechanical forces, and physiological variations (4). The morphology, size, and spatial relationships between mandibular condyles and glenoid fossae vary with age, sex, occlusal habits, masticatory activity, and parafunctional habits, resulting in large inter-individual variation, and may be linked to the adaptive remodeling of the joints (5,6). Sex-related differences in the craniofacial dimensions between males and females have been attributed in part to hormones, growth differences, differences in muscle mass, and different masticatory forces (7,8). Age has been associated with progressive alterations in the shape of the condyle, the inclination of the articular eminence, and the joint space dimensions (9).

The evaluation of osseous TMJ morphology necessitates imaging techniques with the ability to depict fine details of the osseous structures without distortion or superimposition. Two-dimensional radiographic methods, such as panoramic radiography and transcranial projections, have some inherent limitations, such as anatomical superimposition, magnification errors, and lack of three-dimensional information (10-12). CBCT has become widely used in dentomaxillofacial imaging by offering high-resolution multi-planar images of osseous component with a relatively lower radiation dose than conventional multi-detector computed tomography depending on the protocol, field of view and device (13). CBCT technology allows extensive analysis of morphometric measurements of the mandibular condyles, glenoid fossae, articular eminence height, and joint spaces in several planes (14). It is considered an imaging modality of choice for the evaluation of osseous degenerative changes (12,15). Magnetic resonance imaging is still the gold standard for the evaluation of internal derangement of the joint and other conditions that involve the soft tissue components (16).

The morphometric analysis of osseous TMJ components has several radiologic and clinical applications. Reference data on TMJ dimensions and morphological patterns of populations may help radiologists and clinicians distinguish physiological anatomical variations from possible pathological changes. For instance, condylar flattening can be seen as

adaptive remodeling on imaging, not necessarily a disease process (17). In orthodontics, understanding osseous TMJ anatomy may help during treatment planning for patients who require functional appliance therapy or orthognathic surgery, because condylar stability is an important consideration in these cases (18).

Some CBCT-based imaging studies investigated TMJ morphology in different populations (19-23). Gaps remain regarding morphometric reference data in different populations, and the possible associations between demographic factors and morphological patterns. Many available data is based on patients with TMD or malocclusion, and this patient selection limits the generalization of results (21,22,24). Population-specific morphometric data is important in forensic anthropology for biological profiling (23), and in customized prosthetic design, where the anatomical reconstruction is required (20).

Given the limited number of studies providing comprehensive morphometric data and combining it with demographic factors, this study aimed to conduct an imaging-based analysis using CBCT images of osseous TMJ components to provide quantitative measurements and qualitative shape categorization of the mandibular condyles, articular eminence, and the glenoid fossa. Possible side, sex-, and age related differences in the morphological characteristics of the osseous TMJ components were also examined.

2. Materials and Methods

This retrospective cross-sectional study was conducted by evaluating CBCT images consecutively selected from our institution imaging database in compliance with the Helsinki Declaration. The study examined osseous TMJ morphology and dimensions in a sample of adult patients who had undergone CBCT imaging for implants or orthodontic indications, not for TMJ-related complaints. A total of 100 TMJs from 50 patients were included in the final analysis. All CBCT scans were acquired using a CS 9500 CBCT system (Carestream Dental, Atlanta, GA, USA) with either a medium field of view (15×9 cm) or a full head field of view (20×18 cm) and 0.2 mm voxel size. The scans were acquired at a tube voltage of 90kVp and a tube current of 10mA, and all revealed the TMJ region on both sides in the same scan. The sample size was based on the number of eligible CBCT scans available during the

study period that fulfilled the inclusion criteria and showed both TMJs in the same scan.

Patients were included based on the availability of CBCT scans with sufficient spatial resolution and sharpness, minimal motion or metallic artifacts affecting the TMJ region, obtained in maximum intercuspation without visible bite blocks or cotton rolls separating the arches, and showing no radiographic evidence of osseous pathology in the condyle or glenoid fossa. Only patients with no documented TMJ-related complaints based on clinical history and examination records, including TMJ pain, joint sounds, limitation of mouth opening, mandibular deviation, previous TMJ diagnosis, trauma, or inflammatory joint disease, were included. Images showing changes consistent with degenerative joint disease, inflammatory arthritis, tumors, or fractures were excluded from the study. Reconstruction and analysis of the images were performed using CS 3D imaging software (Carestream Dental LLC, Atlanta, GA, USA) and corrected sagittal and coronal reconstructions were used for the osseous TMJ analysis.

For each TMJ, corrected sagittal and coronal sections were selected after correction according to the horizontal angulation of the condyle. The corrected sagittal section was chosen at the plane where the mandibular condyle and the glenoid fossa were clearly visualized. This section was aligned through the point where the condyle showed its maximum anteroposterior dimension. The measurement of eminence height, joint spaces, and condyle length in the anteroposterior dimension was acquired on this section. A corrected coronal section parallel to the long axis of the condylar head was selected at the plane where the mediolateral dimension of the condylar section was maximum; this section was used to measure the condylar width. These standardized section-selection criteria were used for all scans before linear measurements and shape classification.

The measurements were performed by a single experienced oral and maxillofacial radiologist using the linear tool in measurement mode available in the CS 3D imaging software; this tool has a 0.1 mm measurement increment. Before formal data collection, the observer reviewed the measurement definitions and landmark locations to standardize the measurement process. To

ensure measurement consistency, each parameter was measured twice for every TMJ in two separate sessions, with a 4-week interval between the sessions.

The following measurements were recorded for each TMJ: Articular eminence height was obtained from the corrected sagittal section and was defined as the vertical dimension from the deepest point of the glenoid fossa to the tip of the articular eminence as shown in Figure 1. Joint spaces were assessed using three measurements from the corrected sagittal section. The distance between the posterior slope of the articular eminence and the anterior surface of the condyle was defined as the anterior joint space. The distance between the superior surface of the condyle and the deepest point of the glenoid fossa was defined as the superior joint space. The distance between the posterior wall of the glenoid fossa and the posterior surface of the condyle was defined as the posterior joint space.

Condylar length was measured from the most anterior point to the most posterior point of the condyle based on the corrected sagittal section. Condylar width was the maximum mediolateral distance of the condyle and was measured as the distance between the lateral pole and the medial pole based on corrected coronal sections.

In addition to linear measurements, morphological assessment was conducted to describe the anatomical variations in the osseous TMJ components. The morphology of the mandibular condyle was assessed from the corrected coronal sections based on a previously published classification scheme and classified into five morphological shapes: round, convex, flattened, angled, or other, including irregular surfaces, multiple convexities, or unusual shapes (25).

The glenoid fossa shape was assessed from the corrected sagittal section and categorized into five morphological classes: oval, triangular, angled, trapezoidal, or other. The other category included irregular or mixed morphology fossae that did not fall in the defined categories (Figure 2). The observer used representative images from the aforementioned study as reference during the classification (25). The same classification criteria were applied consistently for all cases.

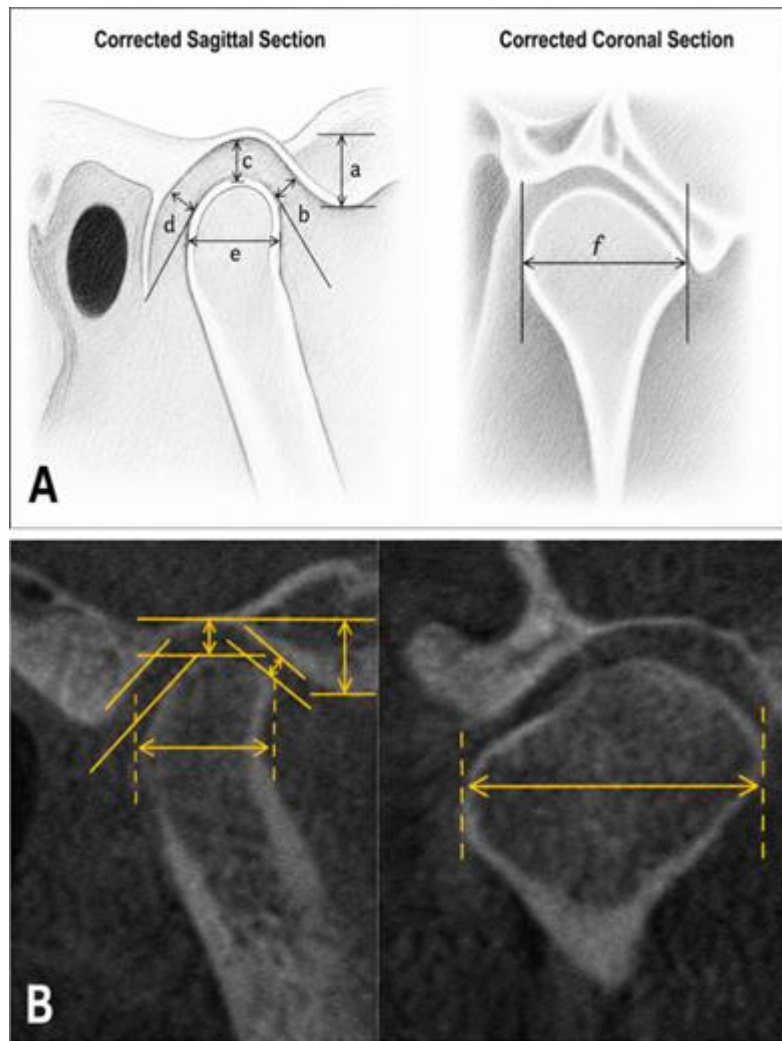


Figure 1: CBCT-based illustration of TMJ measurements. **A.** Schematic illustration showing the measurement definitions used in this study. **B.** Representative corrected sagittal and coronal CBCT sections demonstrating the corresponding measurements on a clinical case. In panel A: a, articular eminence height; b, anterior joint space; c, superior joint space; d, posterior joint space; e, condylar length; and f, condylar width

2.1. Statistical Analysis

All data was compiled into a standardized database and analyzed using SPSS Statistics, version 26.0 (IBM Corporation, Armonk, NY, USA). All continuous variables were summarized using descriptive statistics and presented as mean and standard deviation (SD), whereas categorical variables were presented as frequencies and percentages. Welch's two-sample t-test was used to compare the measurements of both sides (left and right) in each sex. To compare continuous measurements among three age groups, one-way analysis of means without the assumption of equal variances (Welch's ANOVA) was used, as the possibility of heterogeneity of variance between the age

groups was expected. Fisher's exact test was used to compare morphological shape distributions between groups. Cross-tabulation analysis was conducted to investigate the association between categorical variables (sex, side, age group) and morphological classifications. A two-tailed p-value < 0.05 was considered statistically significant. Intra-observer reliability for the linear measurements was assessed using intraclass correlation coefficients (ICCs). Reliability for morphological variables was evaluated using Cohen's kappa statistics. The strength of agreement was interpreted according to established criteria. No formal sample-size calculation was performed because of the retrospective exploratory design and the limited number of eligible CBCT scans

available. Therefore, subgroup analyses by age and sex were considered exploratory and hypothesis-generating rather than confirmatory.

This retrospective study involved the use of the

existing CBCT images in the institutional database. The study protocol received approval from the Institutional Review Board (IRB).

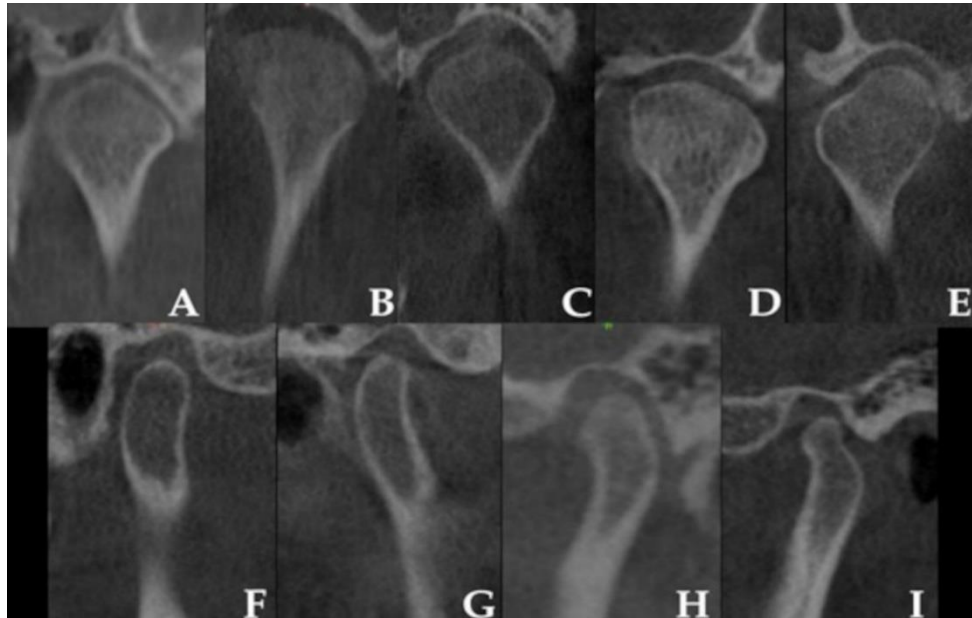


Figure 2: Representative CBCT examples of mandibular condyle and glenoid fossa morphological categories. A-E, mandibular condyle shapes on corrected coronal CBCT sections: A, angled; B, flattened; C, convex; D, round; and E, other morphology. F-I, glenoid fossa shapes on corrected sagittal CBCT sections: F, angled; G, triangular; H, oval; and I, trapezoidal

3. Results

A total of 100 TMJs from 50 patients (27 females and 23 males) were analyzed in this study. Intra-observer agreement for the linear osseous TMJ measurements exceeded 0.90 for condylar width, condylar length, articular eminence height, and the anterior, superior, and posterior joint spaces. Cohen's

kappa values for morphological variables were 0.86 for condyle shape and 0.82 for glenoid fossa morphology.

Comparative analysis revealed that males had greater left articular eminence height and greater right condylar width than females. Other linear measurements including joint spaces showed no statistically significant differences (Table 1).

Table 1: Comparison of males and females within sides

Characteristic	Left Side			Right Side		
	Female N = 27 ¹	Male N = 23 ¹	p-value ²	Female N = 27 ¹	Male N = 23 ¹	p-value ²
Eminence height	5.93 (1.03)	7.15 (1.43)	0.011	6.08 (1.16)	6.48 (1.09)	0.2
Condyle length	7.94 (1.14)	8.06 (1.02)	0.7	7.72 (1.15)	7.98 (1.11)	0.4
Condyle width	19.09 (1.95)	19.55 (2.22)	0.4	18.91 (2.10)	20.41 (2.62)	0.03
Anterior joint space	2.22 (0.52)	2.13 (0.38)	0.5	2.06 (0.46)	2.17 (0.54)	0.5
Superior joint space	3.39 (0.90)	3.89 (0.92)	0.11	3.50 (0.88)	3.71 (0.85)	0.4
Posterior joint space	2.35 (0.73)	2.37 (0.40)	0.9	2.18 (0.46)	2.47 (0.64)	0.1

¹ Mean (SD).

² Welch's two-sample t-test.

Right and left comparisons within each sex revealed no significant differences in any of the measured parameters (Table 2). This pattern was observed for articular eminence height, condylar length, and condylar width in both females and males. Bilateral symmetry was also observed for joint-space measurements in both sexes (anterior, superior, and posterior) ($p > 0.05$). For morphological variables, right-left comparisons across

the study sample showed no significant difference in the distribution of condylar or glenoid fossa shapes between the left and right sides (Table 3). Females showed no significant bilateral difference in condyle shape ($p = 0.3$) or glenoid fossa shape ($p = 0.13$). Similarly, among males, no significant bilateral difference was observed in condyle shape ($p = 0.6$) or glenoid fossa shape ($p = 0.4$).

Table 2: Comparison of left and right sides within each sex

Characteristic	Female			Male		
	Left Side N = 27 ¹	Right Side N = 27 ¹	p-value ²	Left Side N = 23 ¹	Right Side N = 23 ¹	p-value ²
Eminence height	5.93 (1.03)	6.08 (1.16)	0.6	7.15 (1.43)	6.48 (1.09)	0.2
Condyle length	7.94 (1.14)	7.72 (1.15)	0.5	8.06 (1.02)	7.98 (1.11)	0.8
Condyle width	19.09 (1.95)	18.91 (2.10)	0.7	19.55 (2.22)	20.41 (2.62)	0.2
Anterior joint space	2.22 (0.52)	2.06 (0.46)	0.3	2.13 (0.38)	2.17 (0.54)	0.8
Superior joint space	3.39 (0.90)	3.50 (0.88)	0.7	3.89 (0.92)	3.71 (0.85)	0.6
Posterior joint space	2.35 (0.73)	2.18 (0.46)	0.3	2.37 (0.40)	2.47 (0.64)	0.6

¹ Mean (SD).

² Welch's two-sample t-test.

Table 3: Distribution of condyle and glenoid fossa shapes by side within each sex

Characteristic	Female			Male		
	Left Side N = 27 ¹	Right Side N = 27 ¹	p-value ²	Left Side N = 23 ¹	Right Side N = 23 ¹	p-value ²
Condyle Shape			0.3			0.6
Round	3 (11%)	4 (15%)		8 (35%)	6 (26%)	
Convex	14 (52%)	9 (33%)		2 (8.7%)	4 (17%)	
Flat	6 (22%)	10 (37%)		4 (17%)	5 (22%)	
Angled	4 (15%)	2 (7.4%)		4 (17%)	6 (26%)	
Other	0 (0%)	2 (7.4%)		5 (22%)	2 (8.7%)	
Glenoid Fossa Shape			0.13			0.4
Oval	15 (56%)	21 (78%)		10 (43%)	13 (57%)	
Triangular	5 (19%)	5 (19%)		1 (4.3%)	4 (17%)	
Angled	0 (0%)	0 (0%)		2 (8.7%)	1 (4.3%)	
Trapezoidal	6 (22%)	1 (3.7%)		1 (4.3%)	1 (4.3%)	
Other	1 (3.7%)	0 (0%)		9 (39%)	4 (17%)	

¹n (%).

²Fisher's exact test.

Qualitative morphological examination showed sex-related variations in shape distribution (Table 4). The condylar shape distribution on the left side differed significantly by sex ($p = 0.001$). Males showed a higher proportion of round condyles (35%), whereas females showed a higher proportion of convex condyles (52%).

Morphological heterogeneity was greater in males, with 22% classified in the "other" category, while none of the females were classified in this category. In contrast, no significant sex differences were found for the right condyle ($p = 0.2$).

Analysis of glenoid fossa shape showed a significant

sex-related difference on the left side ($p=0.002$). Males exhibited greater morphological heterogeneity, including a high proportion (39%) of the “other” category. Females, however, had more homogeneous distribution, with the oval shape as the predominant morphology (56%). There were no significant sex differences in the distribution of glenoid fossa shape on the right side ($p = 0.10$), where the oval shape was the most common in both sexes (78% in

females, 57% in males).

Age-group comparison of linear measurements showed a significant difference in left articular eminence height ($p = 0.007$), with lower values in the older age group. No statistically significant age-group differences were observed for right articular eminence height, condylar length, condylar width, or joint-space measurements on either side (Table 5).

Table 4: Distribution of condyle and glenoid fossa shapes by sex within each side

Characteristic	Left Side		p-value ²	Right Side		p-value ²
	Female N = 27 ¹	Male N = 23 ¹		Female N = 27 ¹	Male N = 23 ¹	
Condyle Shape			0.001			0.2
Round	3 (11%)	8 (35%)		4 (15%)	6 (26%)	
Convex	14 (52%)	2 (8.7%)		9 (33%)	4 (17%)	
Flat	6 (22%)	4 (17%)		10 (37%)	5 (22%)	
Angled	4 (15%)	4 (17%)		2 (7.4%)	6 (26%)	
Other	0 (0%)	5 (22%)		2 (7.4%)	2 (8.7%)	
Glenoid Fossa Shape			0.002			0.1
Oval	15 (56%)	10 (43%)		21 (78%)	13 (57%)	
Triangular	5 (19%)	1 (4.3%)		5 (19%)	4 (17%)	
Angled	0 (0%)	2 (8.7%)		0 (0%)	1 (4.3%)	
Trapezoidal	6 (22%)	1 (4.3%)		1 (3.7%)	1 (4.3%)	
Other	1 (3.7%)	9 (39%)		0 (0%)	4 (17%)	

¹n (%).

²Fisher's exact test.

Table 5: Characteristics comparison by age group

Characteristic	Left Side			p-value ²	Right Side			p-value ²
	< 35 Years N = 17 ¹	35-50 Years N = 20 ¹	> 50 Years N = 13 ¹		< 35 Years N = 17 ¹	35-50 Years N = 20 ¹	> 50 Years N = 13 ¹	
Eminence height	6.84 (1.30)	6.47 (1.33)	5.41 (0.80)	0.007	6.33 (1.04)	6.15 (1.14)	6.29 (1.35)	0.9
Condyle length	7.56 (1.21)	8.34 (0.93)	8.00 (0.99)	0.13	7.85 (1.12)	8.05 (1.08)	7.50 (1.20)	0.4
Condyle width	18.55 (2.37)	19.94 (1.94)	19.22 (1.62)	0.2	19.01 (2.60)	20.36 (2.43)	19.21 (2.15)	0.2
Anterior joint space	2.29 (0.49)	2.12 (0.38)	2.14 (0.62)	0.6	2.06 (0.49)	2.12 (0.52)	2.15 (0.48)	0.9
Superior joint space	3.50 (1.04)	3.56 (1.05)	3.68 (0.47)	0.8	3.31 (0.87)	3.62 (0.88)	3.91 (0.76)	0.2
Posterior joint space	2.28 (0.86)	2.41 (0.48)	2.39 (0.49)	0.9	2.34 (0.64)	2.34 (0.54)	2.17 (0.48)	0.6

¹Mean (SD).

²One-way analysis of means (not assuming equal variances).

Descriptive analysis of condylar and glenoid fossa shapes across age groups showed heterogeneous distribution, with no clear age-related pattern. These

comparisons should be interpreted cautiously because of the limited number of patients in each subgroup and the small frequencies in several shape categories.

4. Discussion

Although the linear measurements remained similar between males and females, differences were observed in morphological shapes. The statistically significant findings were limited to the left side. Both condylar and glenoid fossa shapes in males showed a more varied distribution on the left side and differed significantly from females. Manoj et al. also reported significant condyle shape differences on the left side, although their finding was related to age group rather than sex (26). This unilateral pattern should be interpreted cautiously because of the sample size and subgroup distribution.

Since the decrease in eminence height occurred only on the left, this finding may reflect local functional or anatomical factors rather than a uniform systemic age-related effect. Gürorgöz et al. reported similar degenerative changes in one side greater than the other, suggesting a possible role for asymmetric functional loading in unilateral osseous changes (22). She et al. related sex-related differences to craniofacial size and muscular anatomy (7). The observed sex-specific quantitative differences, including left-sided eminence height in males and right-sided condyle width, are selective and not uniform. This asymmetry, where various parameters are influenced on either side, may reflect a complex relationship between functional factors and sex-related anatomical variation. The greater percentage of males having morphological heterogeneity compared to females may suggest greater variability among males. To a certain extent, these findings are consistent with those of Yalcin and Ararat (19) and Daneshmehr et al. (21), but with population-specific variations that may be related to population differences, genetic backgrounds, or masticatory habits.

While this sex-related variation has potential implications for forensic anthropology, the practical application of sex determination is limited. Hu et al. indicated that the extent of sex overlap and differences, along with population-specific differences, restrict the certainty of sex determination (24). However, these explanations remain speculative, because chewing preference, occlusal status, and muscle function were not assessed.

Age analysis revealed selective dimensional differences. For instance, the height of the left eminence was lower in the older age group, from an average of 6.84 ± 1.30 mm in the youngest group to 5.41 ± 0.80 mm in the oldest group ($p = 0.007$). Other morphometric

parameters showed no statistically significant differences across age groups. Age-stratified analysis showed no statistically significant association between age group and fossa or condylar shape, although this should be interpreted cautiously because of the small frequencies in several shape categories. Our finding of age-related decrease in eminence height on the left side is consistent with Görurgoz et al. who considered increasing age as a risk factor for degenerative changes in left TMJs in the Turkish population (22). Of relevance, Görurgoz et al. focused on degenerative pathology, whereas our study showed a similar lateral predilection for dimensional change in a cohort with no documented TMJ-related complaints. The stability of most other parameters in our sample contrasts with the results of Hu et al., who reported significant age-related differences, which may be partly related to their population being patients with symptomatic TMJ disorder, in whom degenerative changes may be more frequent (24). Therefore, the stability found in our study may not be generalizable to symptomatic TMJ populations.

The bilateral symmetry seen across all parameters may have implications for radiologic assessment of unilateral osseous TMJ findings. This symmetry is consistent with findings reported in asymptomatic individuals and may support the practice of using the contralateral joint features as an internal reference during imaging evaluation of unilateral TMJ findings. This approach should not be interpreted as a validated clinical guideline, and further studies with larger samples and standardized clinical assessment are needed before routine clinical adoption. Together, these findings support the value of bilateral CBCT review when assessing unilateral osseous TMJ findings.

Regarding shape distribution, the predominance of oval glenoid fossae in our sample matches what Hu et al. reported in their controls, but differs from the more triangular shapes in their study group of patients with TMD (24). The more prevalent convex condyles (29% total) in our study align with the results of Yalcin and Ararat, in which convex condyle was the most frequent form (40.5%) (19). Görurgoz et al. reported high rates of flattened condyles. However, their study focused on cohorts with degenerative changes (22). These differences may be related to differences in study population, particularly degenerative or TMD cohorts compared with asymptomatic cohorts.

The use of CBCT imaging in this study provided high-resolution, three-dimensional visualization of the osseous TMJ components with sub-millimeter spatial resolution. The systematic selection of patients with no documented TMJ-related complaints allowed for evaluation and measurements that reflected morphological variations and contributed to providing preliminary reference data, which are limited in TMJ CBCT-based studies in clinically asymptomatic cohorts. The analysis also employed comprehensive quantitative measurements and qualitative classifications of the mandibular condyle and the glenoid fossa. Additionally, the bilateral assessment allowed side-to-side comparison within the same patient, and the age stratification allowed identification of exploratory age-related trends.

This retrospective cross-sectional design does not allow longitudinal evaluation or establish causal relationships. The differences noted with age may be related to a cohort effect instead of true aging, because the older group was exposed to different environmental conditions. No formal sample-size calculation was performed, and the small sample size ($n = 50$) limited the detection of small associations, especially in stratified subgroup analysis. The key sex- and age-related findings were observed mainly on the left side, including left condylar shape, left glenoid fossa shape, and left articular eminence height with age; therefore, these results should be interpreted as exploratory. Unequal sex distribution may also have impacted the detection of sex-related differences. Age-stratified shape analysis was limited by small cell frequencies within several morphological categories; therefore, these findings should be interpreted as descriptive rather than confirmatory. The lack of data on masticatory preferences, parafunctional habits, and occlusal characteristics limits the interpretation of the observed morphological differences. This study adds descriptive data for the Jordanian population combining key TMJ

parameters with demographic variables. Within the limits of its design, the results indicate that sex-related variations in TMJ morphology appear to be selective, and age-related differences were selective.

5. Conclusions

In conclusion, this CBCT-based morphometric analysis showed general bilateral symmetry of the osseous TMJ components in adults with no documented TMJ-related complaints. Sex-related analysis revealed selective differences in morphological shape distribution, while age-group analysis showed lower left articular eminence height in the older age group, with no significant differences in most other parameters. Because several significant findings were limited to the left side and no formal sample-size calculation was performed, these results should be considered exploratory. These findings may provide preliminary reference data for radiologic interpretation of osseous TMJ variation and treatment planning, but they should not be interpreted as validated clinical guidelines. However, the results should be interpreted cautiously because of the retrospective design, limited sample size, and the inability of CBCT to assess the articular disc or other soft-tissue components. Future longitudinal studies with larger samples, standardized clinical TMJ assessment, functional data, multi-population comparisons, and bilateral assessment of sagittal condylar guidance-related angles are recommended.

Conflicts of Interests

The authors declare no conflict of interests.

Funding Information

No funding or financial support was received for this study. Therefore, there was no role of any funding body in study design, data collection, analysis, interpretation, manuscript preparation, or publication decision.

References

1. Roberts WE, Goodacre CJ. The temporomandibular joint: A critical review of life-support functions, development, articular surfaces, biomechanics and degeneration. *J Prosthodont.* 2020;29:772-779.
2. Genovesi W, Comenale IC, Genovesi Filho W, Fernandes MV. Biomechanical comparative analysis of temporomandibular joint, glenoid fossa and head of the condyle of conventional models prosthesis with new PEEK design. *J Oral Biol Craniofac Res.* 2022;12:529-541.
3. Iturriaga V, Bornhardt T, Velasquez N. Temporomandibular joint. *Dent Clin North Am.* 2023;67:199-209.
4. Shu J, Ma H, Liu Y, Zheng T, Shao B, et al. In vivo biomechanical effects of maximal mouth opening on the temporomandibular joints and their relationship

- to morphology and kinematics. *J Biomech.* 2022;141:111175.
5. Serindere G, Aktuna Belgin C, Serindere M. Volumetric and morphological analysis of condyle and glenoid fossa on computed tomography. *Eur Arch Otorhinolaryngol.* 2020;277:2581-2587.
6. Almashraqi AA. Dimensional and positional associations between the mandibular condyle and glenoid fossa: A three-dimensional cone-beam computed tomography-based study. *J Contemp Dent Pract.* 2020;21:1075-1083.
7. She X, Sun S, Damon BJ, Hill CN, Coombs MC, Wei F, Lecholop MK, Steed MB, Bacro TH, Slate EH, Zheng N, Lee JS, Yao H. Sexual dimorphisms in three-dimensional masticatory muscle attachment morphometry regulates temporomandibular joint mechanics. *J Biomech.* 2021 Sep 20;126:110623.
8. Taner L, Gursoy GM, Uzuner FD. Does gender have an effect on craniofacial measurements? *Turk J Orthod.* 2019;32:59-64.
9. Sa SC, Melo SLS, de Melo DP, Freitas DQ, Campos PSF. Relationship between articular eminence inclination and alterations of the mandibular condyle: A CBCT study. *Braz Oral Res.* 2017;31:e25.
10. Lindvall AM, Helkimo E, Hollender L, Carlsson GE. Radiographic examination of the temporomandibular joint. *Dentomaxillofac Radiol.* 1976;5:24-32.
11. Fallon SD, Fritz GW, Laskin DM. Panoramic imaging of the temporomandibular joint: An experimental study using cadaveric skulls. *J Oral Maxillofac Surg.* 2006;64:223-229.
12. Mallya SM, Ahmad M, Cohen JR, Kaspo G, Ramesh A. Recommendations for imaging of the temporomandibular joint. Position statement from the American Academy of Oral and Maxillofacial Radiology and the American Academy of Orofacial Pain. *J Oral Facial Pain Headache.* 2023;37:7-15.
13. Dhabale GS, Bhowate RR. Cone-beam computed tomography for temporomandibular joint imaging. *Cureus.* 2022;14:e31515.
14. Nithin, Ahmed J, Sujir N, Shenoy N, Binnal A, et al. Morphological assessment of TMJ spaces, mandibular condyle, and glenoid fossa using cone beam computed tomography (CBCT): A retrospective analysis. *Indian J Radiol Imaging.* 2021;31:78-85.
15. Dygas S, Szarmach I, Radej I. Assessment of the morphology and degenerative changes in the temporomandibular joint using CBCT according to the orthodontic approach: A scoping review. *Biomed Res Int.* 2022;2022:6863014.
16. Peroz I, Seidel A, Griethe M, Lemke AJ. MRI of the TMJ: Morphometric comparison of asymptomatic volunteers and symptomatic patients. *Quintessence Int.* 2011;42:659-667.
17. de Melo DP, Silva DFB, Campos PSF, Dantas JA. The morphometric measurements of the temporomandibular joint. *Front Oral Maxillofac Med.* 2021;3:14.
18. Lee GH, Lee SM, Park JH. The role of mandibular stabilization in orthognathic surgery. *Semin Orthod.* 2019;25:188-204.
19. Yalcin ED, Ararat E. Cone-beam computed tomography study of mandibular condylar morphology. *J Craniofac Surg.* 2019;30:2621-2624.
20. Yun JM, Choi YJ, Woo SH, Lee UL. Temporomandibular joint morphology in Korea using cone-beam computed tomography: Influence of age and gender. *Maxillofac Plast Reconstr Surg.* 2021;43:21.
21. Daneshmehr S, Razi T, Razi S. Relationship between the condyle morphology and clinical findings in terms of gender, age, and remaining teeth on cone beam computed tomography images. *Braz J Oral Sci.* 2022;21:e2266611.
22. Görürgöz C, İçen M, Kurt MH, Aksoy S, Bakırarar B, et al. Degenerative changes of the mandibular condyle in relation to the temporomandibular joint space, gender and age: A multicenter CBCT study. *Dent Med Probl.* 2023;60:127-135.
23. Christopher VS, Patil K, Jogigowda SC, Basavarajappa R. Morphometric analysis of temporomandibular joint using cone beam computed tomography. *Eur J Anat.* 2025;29:825-834.
24. Hu X, Sujanamulk B, Lakshmi CR, Li C. Age-and gender-related morphometric assessment and degenerative changes of temporomandibular joint in symptomatic subjects and controls using cone beam computed tomography (CBCT): A comparative analysis. *Curr Med Imaging.* 2024;20:e15734056248617.
25. Yasa Y, Akgül HM. Comparative cone-beam computed tomography evaluation of the osseous morphology of the temporomandibular joint in temporomandibular dysfunction patients and asymptomatic individuals. *Oral Radiol.* 2018;34:31-39.
26. Manoj M, Mathew L, Natarajan S, Yellapurkar S, Shetty S, et al. Morphometric analysis of mandibular

- coronoid, condyle and sigmoid shape using panoramic view for personal identification in South Indian population. J Clin Imaging Sci. 2022;12:25.
27. Pradhan A, Bhattacharya P, Singh S, Chandna AK, Gupta A, et al. Comparative analysis of craniofacial asymmetry in subjects with and without symptoms of temporomandibular joint disorders: A cross-sectional study. J Korean Assoc Oral Maxillofac Surg. 2023;49:125-134.