Original Article

ANATOLIAN CURRENT MEDICAL

DOI: 10.38053/acmj.1843391

Anatolian Curr Med J. 2026;8(3):417-423

Association between petrotympanic fissure and condylar morphology on CBCT: a retrospective pilot study

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Cite this article as: Naralan ME, Çakır B. Association between petrotympanic fissure and condylar morphology on CBCT: a retrospective pilot study. *Anatolian Curr Med J.* 2026;8(3):417-423. doi:10.38053/acmj.1843391

Received: 16.12.2025 ◆ **Accepted**: 25.03.2026 ◆ **Published**: 22.05.2026

ABSTRACT

Aims: This pilot study aimed to investigate the relationship between petrotympanic fissure (PTF) classification and mandibular condyle morphology using cone-beam computed tomography (CBCT), and to analyze the effects of age and sex on these anatomical characteristics.

Methods: A retrospective, cross-sectional analysis was conducted on 88 patients, yielding 176 temporomandibular joints (TMJs). PTF types were categorized on sagittal CBCT sections according to Sato's classification (Types 1-3), while condylar morphology was assessed on coronal sections using the Yale system (Types 1-4). To maintain statistical independence, right and left joints were evaluated separately. A supplementary analysis was performed on the pooled dataset. Associations were evaluated using Pearson's chi-square with permutation-derived p-values. A multinomial logistic regression model incorporating intra-patient clustering was applied for multivariate analysis.

Results: The cohort mean age was 36.0±13.2 years; 79.5% were female. No significant association between PTF type and condylar morphology was detected in side-specific analyses (Right: p=0.252; Left: p=0.244). A marginal association emerged only in the pooled analysis (χ^2=13.12, p=0.041), which is interpreted as a statistical artifact driven by duplicated TMJ counts and within-subject dependency, rather than a biologically meaningful correlation. Multivariate modelling demonstrated a weak inverse association between age and Type 4 condylar form (p=0.028). Sex did not exert a significant influence on morphology.

Conclusion: When analyzed under conditions that respect joint independence, PTF type is not correlated with condylar morphology. Observed pooled-data significance reflects sample inflation bias. PTF classification should therefore not be used as a clinical predictor of condylar shape.

Keywords: Temporomandibular joint, cone-beam computed tomography, mandibular condyle, petrotympanic fissure, glaserian fissure

INTRODUCTION

The temporomandibular joint (TMJ) plays a critical role in fundamental functions such as mastication and speech; variations in the joint's bony morphology can affect these functions and may be associated with temporomandibular disorders (TMD). The literature has reported links between condylar shape/morphology and symptoms and functional limitations; examples include differences in condylar volume and fossa dimensions with asymmetric movement patterns in mandibular asymmetry, condylar position/morphology changes associated with disc displacement, and associations between pain and radiographic findings in idiopathic condylar resorption.[1-8] These findings underscore the importance of addressing TMJ morphology systematically in clinical evaluation.

The petrotympanic fissure (PTF)-the Glaserian fissure-is a tunnel-like bony channel connecting the mandibular fossa to the tympanic cavity, through which the discomalleolar ligament (DML) is understood to course. On cone-beam computed tomography (CBCT), PTF geometry can be reliably categorized into tunnel configurations by the Sato classification (types 1-3).[9] Along the anatomy–function axis, reports of an association between PTF architecture and malleus head morphology and the co-occurrence of specific PTF features with TMD phenotypes suggest the clinical relevance of the linkage between the DML/ossicular chain and TMJ capsular/retrodiscal tissues.[9-11] Consistent with this, particular anatomic traits of the PTF have been reported in association with TMD, implying that PTF-DML variation may provide complementary information to guide diagnosis and treatment planning in selected patients.[11,12]

CBCT is particularly well suited to assessing the osseous structures of the TMJ: thanks to three-dimensional imaging,

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isotropic voxels, and multiplanar reformation, it depicts bony changes-such as condylar cortical contours, subchondral sclerosis, and erosion/osteophytes-at high spatial resolution and in volumetric detail.[12-14] With adjustable fields of view and short acquisition times, its suitability for routine clinical practice has increased; compared with multidetector CT, CBCT also offers lower radiation exposure and greater practical accessibility.[15,16] These technical strengths facilitate systematic reporting of condylar morphology using standard classifications and enable quantitative/qualitative comparisons at the joint level.[17] Nevertheless, CBCT is limited for soft-tissue assessment (disc, ligaments, effusion) and is sensitive to motion and metal artifacts; accordingly, it should be considered the primary modality for bone-focused questions, whereas MRI is complementary or preferred for soft-tissue questions.[12,13]

Craniofacial and mandibular morphology are influenced by age and sex; age-related shape changes, differences in joint space/morphology, and dimensional/configurational distinctions between sexes have been reported.[18-20] Moreover, data indicate that degenerative changes are more frequent in women even among younger individuals without disc displacement.[21] These factors should be considered, as they may affect classifications of the condyle and related structures.

That said, the provided literature indicates that studies examining the combined use and reliability of the DML/PTF and condylar classifications are limited.[10,11,22] Consistent CBCT-based characterization of DML/PTF variations and condylar morphology-and investigation of how these two structures align within the same patient-could be informative for diagnosis and treatment planning; for example, it may offer a more predictable framework for risk stratification, determining follow-up frequency, or prioritizing conservative approaches.[12,13,17] This pilot study seeks to explore potential patterns between these classifications, thereby generating hypotheses that could help shape future diagnostic algorithms and treatment strategies.

Importantly, this study was conducted in a general radiological archive population not pre-selected for TMD symptoms. Examining PTF-condylar morphology associations in such a population is intentional: establishing baseline morphological distributions and inter-structure relationships in individuals without known TMJ pathology is a necessary prerequisite for identifying what constitutes deviation from normal in future symptomatic cohorts. This approach is consistent with the pilot nature of the study, which aims to generate hypotheses and estimate effect sizes rather than to provide clinical diagnostic thresholds.

The aim of this pilot study is to evaluate, at the joint level on CBCT, whether an association exists between PTF type and condylar morphology, and to explore relationships of age and sex with these types. The findings are expected to deepen understanding of the clinical implications of TMJ morphology and to lay the groundwork for subsequent confirmatory studies.

METHODS

This retrospective study was approved by the Ethics Committee of the Dean's Office of the Faculty of Dentistry at Atatürk University (Date: 22.05.2025, Decision No. 50). All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki. Owing to the retrospective design and the use of fully anonymized archival data, the requirement for informed consent was waived by the ethics committee.

This retrospective study was conducted using CBCT images. The CBCT scans were retrieved from the archives of the Departments of Oral and Dentomaxillofacial Radiology at Atatürk University and Recep Tayyip Erdoğan University. All CBCT scans were acquired with patients in the upright (standing) position, which is an available acquisition mode of the NewTom VGI Evo device and represents the standard protocol at both participating institutions. The upright position was used as it more closely reflects the natural functional posture of the mandible and temporomandibular joint under physiological loading conditions. As this study focused exclusively on osseous morphological classification rather than condylar displacement or joint-space quantification, the influence of posture on the outcome variables is expected to be minimal; nonetheless, future studies comparing condylar position metrics should explicitly control for or report acquisition posture. Standardization was achieved using two light-beam markers: the vertical beam was aligned with the patient's mid-sagittal plane to ensure proper centring, and the lateral beam was aligned at the level of the mandibular condyle to determine the reconstruction centre. The patient's head was adjusted so that the hard palate was parallel to the floor and the sagittal plane perpendicular. Patients were identified from the radiological archives on the basis of available CBCT scans that met the imaging quality criteria. Clinical TMD assessment (e.g., Research Diagnostic Criteria for TMD [RDC/TMD] or DC/TMD) was not performed as part of this study, and clinical symptom data were not extracted from patient records. The exclusion criterion of 'known TMJ pathology and/or history of maxillofacial/TMJ surgery' was applied based on documented medical history available in the archive records; patients without such documented history were included regardless of whether a formal clinical TMD examination had been conducted. Therefore, this study should be understood as describing morphological associations in a general radiological population rather than in a clinically confirmed asymptomatic cohort. Patients with known TMJ pathology and/or a history of maxillofacial/TMJ surgery were excluded from the analysis; scans with severe artifacts that precluded reliable classification were also not included.

CBCT imaging parameters included 110 kV and 10 mA, with a field of view (FOV) of 15×12 cm. Axial and sagittal sections were obtained with a slice thickness of 0.2 mm. Exposure was automatically adjusted during the 360° rotational acquisition, depending on the tissue density, through the system's automatic exposure control function.

PTF morphology was evaluated on sagittal CBCT sections according to the classification described by Sato et al.,[23] which categorizes PTFs into three types: Type 1 represents a wide,

tunnel-shaped structure; Type 2 describes a tunnel that is wide at the mandibular fossa and gradually narrows toward the tympanic cavity; and Type 3 features a wide mandibular fossa entrance, a flattened middle portion, and a narrow tympanic exit. Evaluations were performed at the midpoint of the sagittal plane, separately for each TMJ. (**Figure 1**)

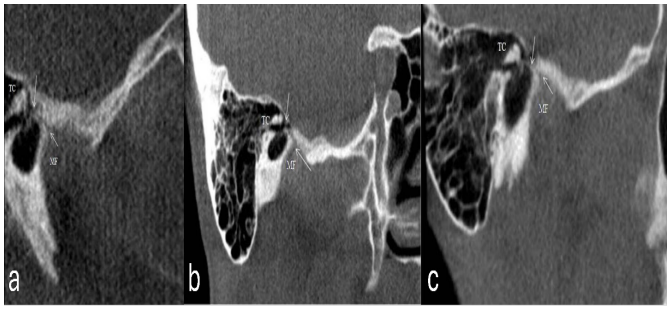


Figure 1. Sagittal CBCT sections demonstrating different petrotympanic fissure (PTF) configurations.

(a) Type 1 PTF: wide and tunnel-shaped; (b) Type 2 PTF: funnel-shaped narrowing toward the tympanic cavity; (c) Type 3 PTF: flattened midsection and narrow tympanic outlet. TC: Tympanic cavity; MF: Mandibular fossa

Mandibular condyle morphology was assessed using the Yale et al.[24] classification, which defines four main forms: Flattened, convex, angled, and rounded. All classifications were performed in consensus by two experienced oral and maxillofacial radiologists. Each TMJ was evaluated independently, and left and right joints were treated as separate data points during the statistical analysis (**Figure 2**).

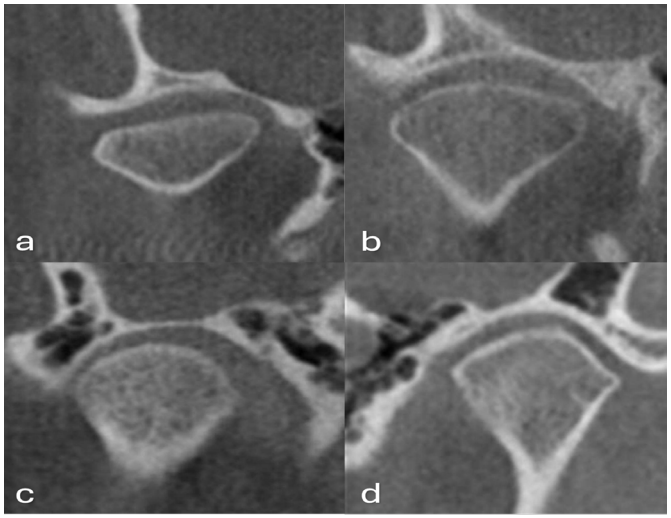


Figure 2. Coronal CBCT images illustrating four distinct mandibular condyle morphology types based on the Yale classification.

(a) Type 1: flattened; (b) Type 2: convex; (c) Type 3: angled; (d) Type 4: rounded

Statistical Analysis

All statistical analyses were performed at the joint level, treating right and left TMJs as separate observations. The primary aim was to evaluate the association between PTF type (1-3) and condylar morphology (1-4), with age and sex as secondary factors. Analyses used chi-square tests with permutation-based p-values and Cramér's V for effect size, and a multinomial logistic model with cluster-robust standard errors to account for within-patient dependence. Sensitivity analyses examined sides separately with Holm-Bonferroni correction. All computations were done in SPSS 29 and Python 3.11 at α=0.05; no missing data were present.

As this investigation is explicitly designed as a pilot study, no a priori power calculation was performed. Post hoc, using the observed effect size (Cramér's V=0.19, equivalent to w≈0.19 for a 3×4 contingency table, df=6) and α=0.05, the achieved power for the pooled chi-square test (n=176) was approximately 0.52, indicating that the study was underpowered to detect an effect of this magnitude with conventional 80% power. To achieve 80% power for a comparable effect size in a confirmatory study, a minimum of approximately 340 joints (170 patients, assuming bilateral inclusion) would be required. These estimates are provided to guide the design of subsequent investigations rather than to draw definitive conclusions from the present data.

RESULTS

Descriptive Statistics

A total of 88 patients (176 joints) were included in the analysis. The mean age was 36.0±13.2 years (median 35.0; IQR 20.5). The cohort was predominantly female (70/88, 79.5%; male: 18/88, 20.5%).

At the joint level, PTF type distribution was as follows: Type 1: 118/176 (67.0%), Type 2: 11/176 (6.3%), and Type 3: 47/176 (26.7%). Condylar morphology distribution was: Type 1 (flattened): 70/176 (39.8%), Type 2 (convex): 72/176 (40.9%), Type 3 (angled): 12/176 (6.8%), and Type 4 (rounded): 22/176 (12.5%) (**Table 1**).

Table 1. Petrotympanic fissure type×condyle type contingency table (n=176)

PTF type\condyle type	1	2	3	4	Total
Type-1	52	44	9	13	118
Type-2	6	3	2	0	11
Type-3	12	25	1	9	47
Total	70	72	12	22	176

PTF: Petrotympanic fissure

Primary Association Analysis (Pooled Data)

In the pooled analysis combining right and left joints (n=176), a marginal association was observed between PTF type and condylar morphology ($\chi^2(6)=13.12$; p=0.041; permutation p≈0.046; Cramér's V=0.19) (**Figure 3**). However, this association should be interpreted with caution for two reasons: first, no cell-level deviation exceeded the conventional threshold (max |standardized residual|=1.55, below |1.96|) (**Figure 4**); and second, 41.7% of cells had expected frequencies below 5, which limits the reliability of the chi-square approximation.

Side-Specific Sensitivity Analyses

To address the potential violation of the independence assumption inherent in using both joints from the same patient, right and left TMJs were analyzed separately. No statistically significant association between PTF type and condylar morphology was detected on either side (Right: $\chi^2(6)=7.817$, p=0.252; Left: $\chi^2(6)=7.917$, p=0.244) (**Table 2**). These results

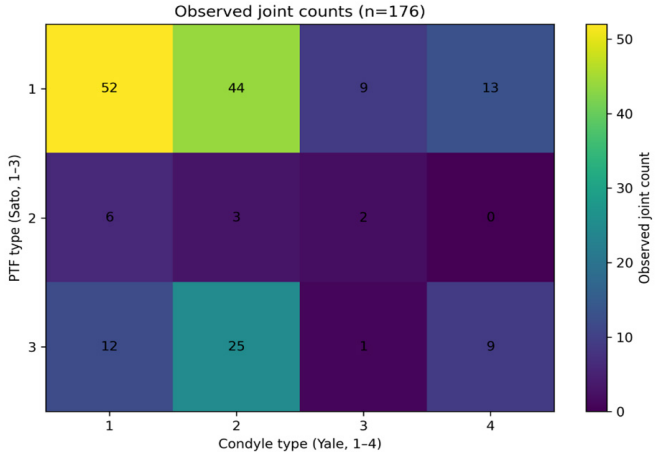


Figure 3. PTF×Condyle type: Observed frequencies (heat map)

Rows show PTF types (1-3) and columns show condyle types (1-4). Colour intensity represents the observed number of joints. The analysis included 88 patients and 176 joints (right and left combined). $\chi^2(6)=13.12$, p=0.041; permutation p≈0.046; Cramér's V=0.19. PTF, petrotympanic fissure; condyle types, condylar morphology classification

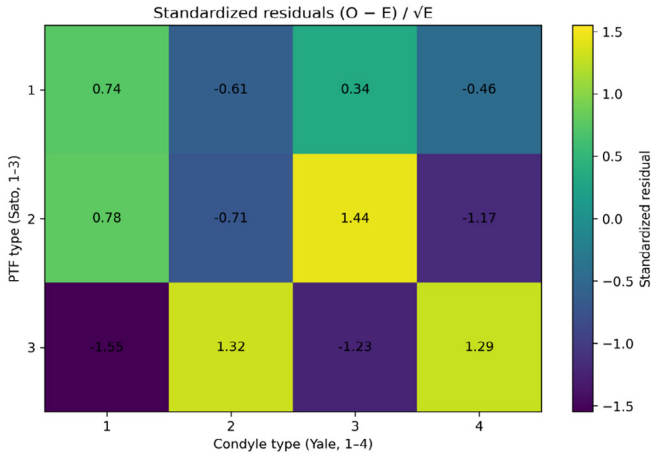


Figure 4. PTF×Condyle type: Standardized residuals (heat map)

Rows show PTF types (1-3) and columns show condyle types (1-4). Each cell displays (Observed-Expected)/√Expected; positive values indicate more frequent than expected and negative values indicate less frequent than expected. Max |standardized residual|=1.55, and no cell exceeded |1.96|. Expected counts were sometimes low (58.3% ≥5; minimum expected =0.75), so p-values should be interpreted cautiously. PTF, petrotympanic fissure; condyle types, condylar morphology classification

Table 2. Association of Petrotympanic fissure type×Condyle Type in side-specific analyses: separate Pearson χ^2 results for right and left joints, with classical and permutation p-values and Holm-Bonferroni adjustment

Side	Chi-square (χ^2)	df	p (classic)	p (permutation)	p (holm-adjusted)
Right	7.817	6	0.252	0.240	0.240
Left	7.917	6	0.244	0.233	0.466

Analyses were performed separately for right and left sides to ensure independence of observations. No statistically significant association was found in either side-specific analysis (p>0.05). Holm-Bonferroni adjustment did not alter the interpretation of non-significance

remained non-significant after Holm–Bonferroni correction. Accordingly, the marginal association observed in the pooled dataset is interpreted as a statistical artifact attributable to sample inflation and within-patient dependency, rather than a biologically meaningful correlation.

Multivariate Analysis

A multinomial logistic regression model was fitted with condyle type as the outcome (reference: Type 1) and PTF type, age, and sex as predictors; cluster-robust standard errors were applied to account for within-patient dependence. The overall pattern was consistent with the primary analysis: no PTF type demonstrated a statistically significant or clinically meaningful association with condylar morphology across all comparisons. Age showed a weak inverse association with Type 4 versus Type 1 condylar morphology (RRR=0.936; 95% CI: 0.882-0.993; p=0.028), suggesting a small, pattern-specific age effect. Sex did not significantly influence condylar morphology in any comparison (all p>0.10). The near-zero coefficient for PTF Type 2 in the Type 4 versus Type 1 comparison reflects quasi-separation due to an empty cell (zero observed joint count) and is a numerical artifact; this finding should not be interpreted clinically (**Table 3**).

DISCUSSION

In this pilot study, the association between PTF type and condylar morphology was examined on CBCT at the joint level, and a marginally significant relationship of small magnitude was identified ($\chi^2(6)=13.12$; p=0.041; permutation p≈0.046; Cramér's V=0.19). The absence of any pronounced cell-wise focus (max |standardized residual|=1.55) and the presence of expected frequencies <5 in some cells suggest limited statistical power and warrant cautious interpretation of p-values. Although the independence assumption is debatable because two joints per patient were included, side-specific sensitivity analyses showed similar trends (which, however, did not persist after Holm adjustment). In the covariate-adjusted multinomial model, age exhibited only a weak inverse effect for the condyle type 4 vs 1 comparison (RRR=0.936; p=0.028), implying that age effects on morphology are small and pattern-specific; extreme coefficients observed for rare PTF-2 combinations point to possible quasi-separation.[25]

Multiple lines of evidence support the clinical relevance of TMJ bony morphology. Reported findings include associations between variations in condylar shape and symptoms/function, differences in condylar volume and fossa dimensions in asymmetry, condylar position/morphology changes

Table 3. Multicategory (multinomial) logit-covariate-adjusted results (outcome: condyle type; reference= type 1)

Variable	2 vs 1 RRR (95% CI), p	3 vs 1 RRR (95% CI), p	4 vs 1 RRR (95% CI), p
PTF type 2 (ref: 1)	0.492 (0.090-2.672), p=0.411	1.683 (0.139-20.335), p=0.682	<0.001 (N/A) †
PTF type 3 (ref: 1)	2.421 (0.940-6.232), p=0.067	0.455 (0.041-5.051), p=0.522	3.519 (0.876-14.140), p=0.076
Age (years)	1.001 (0.965-1.034), p=0.945	1.014 (0.967-1.062), p=0.567	0.936 (0.882-0.993), p=0.028*
Sex (male)	1.449 (0.438-4.801), p=0.544	1.271 (0.105-15.404), p=0.851	3.769 (0.769-18.480), p=0.102

* p<0.05. † PTF Type 2 → Condyle type 4 vs 1: quasi-separation is likely due to sparse cells; coefficients should be interpreted with caution. Condyle type ~ PTF type (ref: 1) + Age (years) + Sex (male vs female). Relative risk ratio (95% CI), p. Cluster-robust SEs at the patient level were used. RRR: Relative risk ratio, CI: Confidence interval, PTF: Petrotympanic fissure

accompanying disc displacement, and pain-radiographic relationships in idiopathic condylar resorption.[1-3,6,21] The weak association between PTF and condyle type in our sample suggests that PTF is unlikely to be the sole determinant of morphology; individual variation, adaptive remodelling, and occlusal/biomechanical loading may contribute. This interpretation accords with the broader literature indicating that complex clinical pictures cannot be explained by a single anatomic marker.[6]

These observations align with the general trajectory of CBCT-based morphology studies: while condylar shape and surface features can be systematically classified and reported on CBCT, reported associations are often small to moderate and heterogeneous.[17,26,27] Publications that type DML/PTF variations on CBCT and present their distributions underscore marked anatomic diversity, which, in turn, suggests that any relationship with condylar morphology may remain weak and pattern-specific.[10,11] Moreover, the practical strengths and methodological limitations of CBCT in three-dimensional osseous assessment of the TMJ-particularly its insensitivity to soft tissues and susceptibility to artifacts-have been emphasized previously, consistent with the small effects and need for caution in our study.[12,13] Taken together with the provided literature, any association between PTF types and condylar morphology-if present-appears weak and context-dependent; basic demographic factors such as age and sex seem to exert limited effects confined to selected comparisons.[13]

Anatomic variation in PTF/DML is well characterized, and radiologic descriptions demonstrate the diversity of fissure configurations.[22] However, consistent evidence that these variations determine condylar morphology in a stable and predictable manner is lacking. Our findings support the view that PTF alone may not "drive" condylar type; any relationship, if present, remains at a small-effect level.

Craniofacial/mandibular structures are sensitive to age and sex; age-related shape changes and sex-based dimensional/configurational differences have been demonstrated across series.[28,29] The fact that our model identified only a weak age association for the condyle type 4 vs 1 contrast suggests that age effects may be local rather than global, influencing specific morphological transitions. The absence of a significant, consistent sex pattern may reflect imbalanced group sizes and sparse cells.,[21] and thus requires confirmation in larger studies.

CBCT is valuable for depicting TMJ bony morphology in three dimensions with high spatial resolution; nevertheless, it is limited for soft-tissue assessment and is sensitive to motion/metal artifacts.[14,15,30] This technical context necessitates attention to tissue-specific constraints when interpreting bone-based classifications. The reliability of condyle type and PTF typing (intra-/inter-observer agreement) is critical in study design and can contribute to outcome variability; future work should therefore report reliability metrics systematically.

Visualization based on standardized residuals from r×c tables is a powerful approach for interpreting patterns of over-/under-representation at the cell level.[31] In our study, residuals remained below the |1.96| threshold, indicating small-scale, diffuse deviations. In multinomial models, rare combinations can induce quasi-separation, manifesting as extreme coefficients and narrow confidence intervals; this phenomenon is well described in the literature and should be handled using modelling choices and sensitivity analyses.[25] In our results, the extreme findings for the PTF-2×Condyle type-4 combination were interpreted cautiously in this light. Given the pilot context, the findings are useful for hypothesis generation and for parameter/variance estimation; for confirmatory studies, the observed effect size (Cramér's V≈0.19) can inform sample-size planning.[32,33]

In practice, predicting condylar morphology from PTF type alone (or vice versa) does not appear reliable based on these data. Morphological classifications can standardize reporting and play a complementary role in clinical decision support; however, diagnostic and therapeutic processes should be framed within a multiparametric context that incorporates symptomatology and functional measures.[1,6]

Strengths include standardized CBCT-based classification, use of permutation p-values to address sparse cells, and cluster-robust multinomial modelling to mitigate within-patient dependence. Limitations comprise the retrospective, single-centre design; low expected counts in some PTF×Condyle type cells; potential independence violations due to inclusion of two joints per patient; and the possibility of quasi-separation in rare combinations. Image quality and classification reliability may also have contributed to variance in outcomes.[14,30]

Limitations

Confirmatory studies should preferably be prospective and multicentre; pre-specified, justified category-collapsing strategies (e.g., 1-2 vs 3-4; PTF 1 vs 2-3) should be evaluated; within-patient dependence should be modelled explicitly using generalized estimating equations (GEE)/mixed-effects frameworks; and observer-agreement metrics (kappa/ICC) should be reported. Presenting visual analytics (mosaic/heat maps) alongside standardized residuals will render the distribution of small effects across cells more transparent.[31] By virtue of its pilot nature, this study provides effect-size and variance estimates that can directly inform the design of larger subsequent studies.[32,33]

A significant limitation is the absence of clinical TMD assessment data. Because patients were not screened using standardized clinical protocols (e.g., DC/TMD), it cannot be confirmed that the study population was truly asymptomatic; subclinical or undiagnosed TMD may have been present in some individuals. This limits the clinical interpretability of the morphological associations observed: it is not possible to determine whether the identified patterns are specific to healthy joints, represent early adaptive changes, or are incidentally present alongside undiagnosed dysfunction. Future studies should prospectively incorporate standardized clinical TMD evaluation alongside CBCT-based morphological classification to enable meaningful structure-symptom correlations.

The study was underpowered for the observed small effect size (post hoc power≈52%), which precludes definitive conclusions and reinforces its pilot characterization. Sample size calculations for confirmatory studies should be based on the Cramér's V≈0.19 reported here.

CONCLUSION

Overall, a weak association-if any-was observed between PTF and condylar morphology; age and sex effects were limited and pattern-specific. The findings suggest that TMJ morphology alone may not be a sufficiently strong marker to guide clinical decision-making, but it can have complementary value as part of a multiparametric assessment. Larger, better-balanced samples are needed to clarify the clinical significance of these early signals.

ETHICAL DECLARATIONS

Ethics Committee Approval

This study was approved by the Ethics Committee of the Dean's Office of the Faculty of Dentistry at Atatürk University (Date: 22.05.2025, Decision No. 50).

Informed Consent

As this was a retrospective study, formal written informed consent was not required and was therefore not obtained.

Peer Review Process

This manuscript was subject to external peer review.

Conflict of Interest

The authors declare no conflicts of interest related to this study.

Financial Disclosure

The authors received no financial support for the conduct or publication of this research.

Author Contributions

Concept: MEN, BÇ; Design: MEN, BÇ; Control: BÇ; Data Collection and/or Processing: MEN, BÇ; Analysis and/or Interpretation: MEN, BÇ; Literature Review: MEN; Article Writing: MEN; Critical Review: All Authors.

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