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Original Article

Condylar Morphology in Patients with Unilateral Maxillary Impacted Canines: A Panoramic Radiography Study

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Main Points

- The results of this study suggest that in individuals with a unilateral maxillary impacted canine, the absence of canine-protected occlusion alone may not be associated with side-dependent differences in mandibular condylar morphology.
- The symmetrical distribution of condylar shapes indicates that any adaptive morphological patterns are unlikely to be side-dependent in patients with unilateral canine impaction.
- These findings reinforce the multifactorial nature of temporomandibular joint adaptation, in which occlusion represents only one of several contributing factors.

ABSTRACT

Objective: The aim of this study was to evaluate the association between unilateral maxillary impacted canines (UMIC) and condylar morphology by comparing ipsilateral and contralateral condyles within affected individuals using panoramic radiography.

Methods: This retrospective cross-sectional study included 364 patients with UMIC (169 with impacted right canines and 195 with impacted left canines). Panoramic radiographs were used to evaluate mandibular condylar morphology. Condyles were classified into four categories (round, angled, flat, and pointed) and additionally dichotomized as round or non-round for binary comparisons. Paired ipsilateral and contralateral comparisons were performed using McNemar's test for binary outcomes with analyses stratified by age (<20 and ≥20 years). Statistical significance was set at $p<0.05$.

Results: Age-stratified McNemar analyses demonstrated no statistically significant side-related differences in binary condylar morphology (round vs. non-round) between ipsilateral and contralateral sides of the patients ($p>0.05$). Descriptive evaluations showed that round condylar morphology was less prevalent in patients aged ≥20 years, whereas angled and pointed morphologies were more frequently observed compared to those aged <20 years, on both the ipsilateral and contralateral sides.

Conclusion: Based on the present findings, UMIC alone does not appear to be associated with side-specific differences in condylar morphology. Further studies using advanced three-dimensional imaging techniques are needed to better characterize condylar morphology.

Keywords: Panoramic radiography, condylar morphology, impacted canines

INTRODUCTION

The impact of occlusal relationships on the temporomandibular joint (TMJ) remains a debated topic.[1] One of the key concepts in this discussion is canine-protected occlusion (CPO), which is believed to play a crucial role in minimizing adverse occlusal forces affecting the TMJ. In CPO, during lateral jaw movements, only the canines (and possibly the first premolars) come into contact, protecting the other teeth from harmful forces. This occlusal relationship is considered the ideal functional occlusion for natural dentition and is often the goal for restorative and orthodontic treatments.[2] Previous studies have shown that the electromyographic (EMG) activity of the temporalis and masseter muscles is lower during

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lateral excursions in patients with CPO, suggesting better muscle function. This finding contrasted with those with group function occlusion, in whom higher muscle activity was observed.[3] These results were further substantiated by research showing that CPOs do not result in significant alterations in muscle activity during mastication but notably decrease muscle activity during parafunctional clenching.[4] It was proposed that CPO, as opposed to group function, leads to minimal EMG activity and, consequently, to the least occlusal loading. Additionally, several studies have suggested that the canines may play a unique proprioceptive role, which helps reduce muscle activity and further minimize occlusal loading.[5] Given the central functional role attributed to the canines in occlusal guidance, alterations in canine position or in eruption patterns may influence occlusal dynamics. In cases of unilateral impacted maxillary canines, the question arises whether such occlusal asymmetry is associated with side-specific morphological patterns of the TMJ.

The TMJ is one of the most significant and distinctive joints in the body. It is a freely movable joint formed between the mandibular condyle and the squamous part of the temporal bone at the base of the skull.[6] The size and shape of the components of the TMJ, as well as their relationship to one another, can vary significantly. It is commonly believed that a normal, healthy condylar head should have a consistently convex, oval shape and that there should be symmetry between the contralateral sides of the same individual. Various studies have assessed the morphology of human mandibular condyles, noting differences in their shapes.[7]

The proper functioning and health of the TMJ are essential for daily life. The main roles of the TMJ are to allow smooth, efficient movement of the mandible during functions such as chewing, swallowing, and speaking; to ensure the stability of the mandibular position; and to prevent dislocation caused by external or unusual forces. The condyle plays a key role in mandibular growth.[8] The fundamental morphology of the mandibular condyle is believed to be established early and may undergo morphological adaptation throughout life in response to functional forces. Condylar remodeling is a natural process that adjusts the TMJ structure to accommodate functional needs. This process involves a dynamic interaction between the mechanical forces acting on the TMJ and the ability of the condyle to adapt. Even after growth is complete, TMJ components are believed to retain the capacity to remodel, thereby continually altering their structure and shape.[8]

Given the adaptive capacity of the TMJ and the potential influence of functional and occlusal factors on condylar morphology, TMJ-related considerations have gained increasing attention in orthodontic diagnosis and treatment planning. In their recent study, Kamar Alden et al.[9] emphasized the potential importance of early crossbite intervention in the context of temporomandibular disorder risk. A recent systematic review and meta-analysis highlighted the impact of temporomandibular disorders on orthodontic management and the importance of careful TMJ assessment in orthodontic patients.[10]

This study aims to evaluate condylar morphology in individuals with unilateral maxillary impacted canines (UMIC) by comparing ipsilateral and contralateral condyles on panoramic radiographs to determine whether side-specific morphological differences are present. The null hypothesis was that there would be no significant difference in condylar morphology between the ipsilateral and contralateral sides of individuals with UMIC.

METHODS

This retrospective cross-sectional study, including the radiographic evaluations of 364 patients, was approved by an institutional Marmara University Faculty of Dentistry Clinical Studies Ethics Committee (approval number: 2025-09-02/2025-64, date: 31.07.2025). All panoramic radiographs (orthopantomograms) included in this retrospective study were acquired using the same panoramic radiographic unit (Planmeca ProMax 2D, Planmeca, Helsinki, Finland) with exposure settings of 5 mA and 66 kV. Radiographs were obtained between 2015 and 2023, and the inherent manufacturer-stated magnification error of the device was accepted without additional correction. Radiographs were obtained with patients in an upright position, and head positioning was performed according to routine clinical practice, to align the Frankfort horizontal plane parallel to the floor. All images were selected from radiographs acquired under comparable projection and positioning conditions.

Panoramic radiographs were included if they provided clear, complete visualization of both mandibular condyles without projection errors and a UMIC was present. Radiographs demonstrating pathological conditions, fractures, developmental anomalies, craniofacial syndromes, fixation hardware, or other factors potentially affecting condylar morphology were excluded. A detailed description of the inclusion and exclusion process is presented in Figure 1.

A total of 364 panoramic radiographs meeting these criteria were randomly selected from the institutional archive. In the study sample, 239 patients (65.7%) were female and 125 (34.3%) were male. The mean age of the overall sample was 25.07±11.45 years. When patients were stratified by age, 175 were younger than 20 years, whereas 189 were 20 years or older (Table 1).

Condylar morphology was assessed by a single experienced orthodontist under standardized viewing conditions using a 24-inch medical-grade monitor (1920×1080 resolution) in a dimly lit environment. The examiner was blinded to the side of canine impaction during image evaluation. To assess reliability, a randomly selected subset of radiographs (20%) was re-evaluated after a two-month interval to assess intra-observer agreement and was independently evaluated by a second orthodontist to assess inter-observer agreement. Reliability was quantified using Cohen's kappa coefficient. According to the calculations, intra-observer agreement ranged from

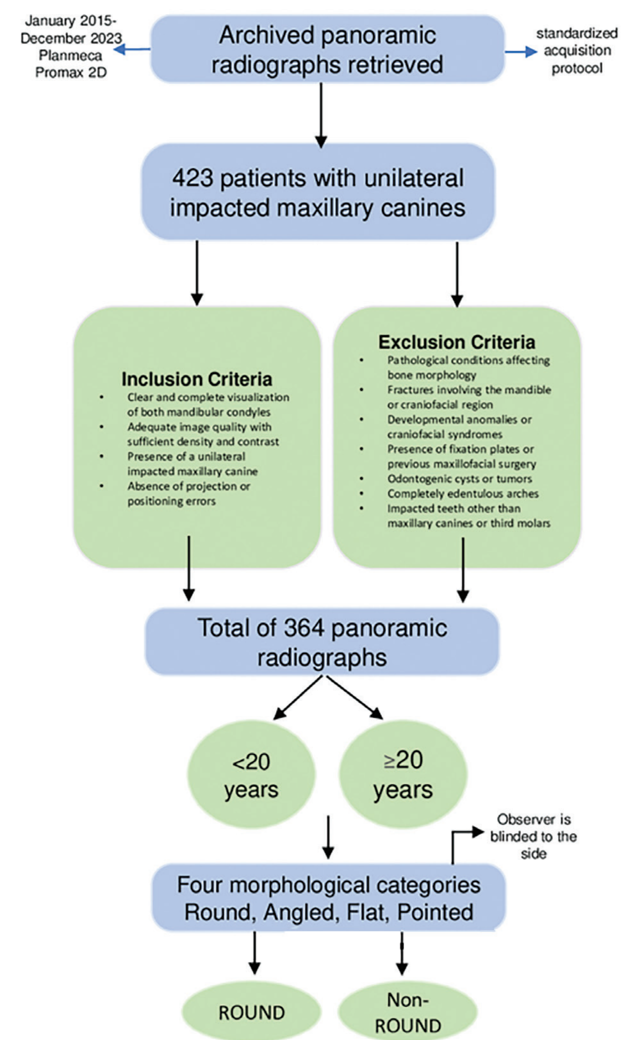

Figure 1. Flow diagram of sample selection and exclusion process.

substantial to excellent (Cohen's κ=0.74-0.82), while inter-observer agreement was substantial (κ=0.72-0.78).

The final sample consisted of 728 condyles from 364 individuals, including 169 patients with impacted right canines and 195 with impacted left canines. Each patient contributed two condyles, which were categorized as ipsilateral or contralateral relative to the side of canine impaction.

For descriptive analysis, condylar shapes were visually categorized as round, angled, flat, or pointed according to previously published morphological criteria.[11] For analytical purposes, this four-category classification of condylar morphology was dichotomized into round and non-round categories to enable paired statistical comparisons. Round morphology was defined as a smooth, convex condylar outline, whereas the non-round category included flat, angled, and pointed morphologies (Figure 2).

Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics version 22.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to summarize the demographic variables, including age and sex.

For the binary classification of condylar morphology (round vs. non-round), side-related differences between ipsilateral and contralateral condyles were evaluated using McNemar's test for paired categorical comparisons. All tests were two-tailed, and statistical significance was set at $p<0.05$.

Age-related differences in the distribution of ipsilateral and contralateral condylar morphology across four shape categories were evaluated using the Pearson chi-squared test.

Based on the differences in the distribution of condylar morphology across age groups reported in a previous study, an a priori power analysis was conducted using the G*Power software (version 3.1.9.6; Heinrich-Heine-Universität, Düsseldorf, Germany). A sample size of 251 individuals was required to achieve 95% power at $\alpha=0.05$ for an effect size of 0.272.[12]

RESULTS

In patients under 20 years of age, paired comparisons of ipsilateral and contralateral condylar morphology showed no statistically significant side-related difference. As presented in Table 2, discordant pairs were observed in equal numbers in the ipsilateral round/contralateral non-round and ipsilateral non-round/contralateral round categories (25 vs. 25). McNemar's test revealed no significant difference between sides ($p=0.89$), with a matched odds ratio of 1.00 [95% confidence interval (CI): 0.57-1.74].

Among patients aged 20 years and older, paired analyses similarly demonstrated no statistically significant difference between ipsilateral and contralateral condylar morphologies (Table 3). Although discordant pairs were numerically higher in the ipsilateral non-round/contralateral round category than in the opposite category (30 vs. 22), this difference was not

Table 1. Demographic characteristics of the study population

Age group	Female (n, mean±SD)	Male (n, mean±SD)	Total (n, mean±SD)
<20 years	120 (15.97±2.01)	55 (16.08±1.84)	175 (16.01±1.95)
≥20 years	119 (32.05±9.75)	70 (35.85±10.37)	189(33.46±10.13)
Total	239 (23.98±10.68)	125 (27.15±12.59)	364 (25.07±11.45)

Values are presented as n (mean ± standard deviation).
SD, standard deviation.

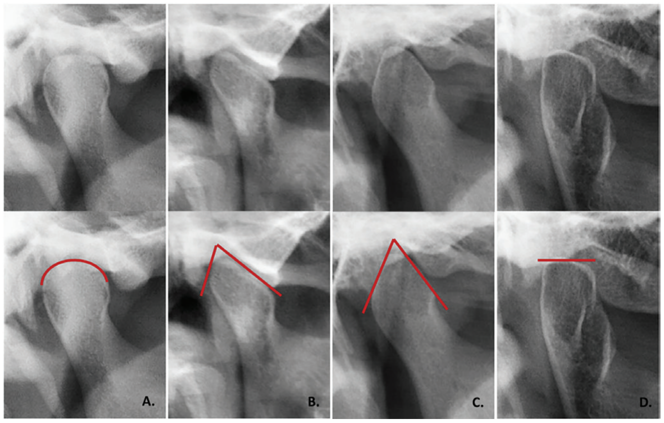

Figure 2. The condyle morphology classification[11] (A) Round: symmetrical condylar outline with smooth, continuous, and convex anterior, superior, and posterior surfaces; (B) Angled: asymmetrical, with an acute angle at the posterior surface; (C) Pointed: symmetrical, with an acute angle at the midpoint of the superior surface (D) Flat: Flattened superior surface extending from the anterior to the posterior aspect of the condylar head.

statistically significant (McNemar's test, p=0.33). The matched odds ratio was 1.36 (95% CI: 0.79-2.36).

Accordingly, no statistically significant side-specific differences in condylar morphology were observed in either age group, and the null hypothesis could not be rejected.

The distribution of condylar shape classifications (round, angled, flat, and pointed) according to age groups (<20 years and ≥20 years) on the ipsilateral and contralateral sides is presented in Tables 4 and 5. The Pearson chi-squared test demonstrated a significant association between age group and condylar shape distribution on both the ipsilateral (p<0.001) and contralateral sides (p<0.001).

In patients aged <20 years, round condylar morphology was the most frequently observed category on both sides.

Table 2. Paired ipsilateral-contralateral condylar morphology in patients under 20 years

	Contralateral round	Contralateral non-round	p
Ipsilateral round	74	25	0.89
Ipsilateral non-round	25	51	

Paired comparisons were performed using McNemar's test. Statistical significance was set at p<0.05.

Table 3. Paired ipsilateral-contralateral condylar morphology in patients aged 20 years and older

	Contralateral round	Contralateral non-round	p
Ipsilateral round	26	22	0.33
Ipsilateral non-round	30	111	

Paired comparisons were performed using McNemar's test. Statistical significance was set at p<0.05.

In contrast, among patients aged ≥20 years, the relative frequency of round morphology was reduced, whereas angled morphology became the most prevalent category on both the ipsilateral and contralateral sides. Pointed condylar morphology was observed more frequently in the ≥20 years group on the ipsilateral side, whereas its distribution on the contralateral side showed a similar trend without a distinct predominance.

DISCUSSION

Condyle remodeling is influenced by more than occlusal loading alone; therefore, CPO cannot be singled out as the sole cause. Factors such as age, sex, and genetics also play a role in this complex process.[13] As with TMJ disorders, pinpointing a single cause is challenging, these conditions are multifactorial.[14] The interplay of these elements makes it difficult to eliminate one factor without considering the broader context of the individual's health and predispositions.

To the best of our knowledge, there are no previous studies specifically investigating the relationship between impacted canines and condylar morphology. Although some studies have examined condylar alterations associated with general occlusal disturbances, none have focused exclusively on impacted canines.[15,16] While panoramic radiography has been considered sufficient for certain morphological assessments in previous studies,[17] these investigations have largely relied on two-dimensional imaging techniques and therefore provide limited information regarding three-dimensional osseous structures. Supporting this limitation, a recent comparative study that evaluated panoramic radiographs and cone-beam computed tomography (CBCT) for condylar morphology assessment showed that flat, pointed, and round condylar morphologies identified on panoramic radiographs were

Table 4. Distribution of condylar shape categories on the ipsilateral side according to age group

Ipsilateral	<20 years	≥20 years	p
Round	**99 (56.6%)****	**48 (25.4%)****	p<0.001
Angled	**44 (25.1%)****	**90 (47.6%)****	
Flat	11 (6.3%)	11 (5.8%)	
Pointed	**21 (12.0%)***	**40 (21.2%)***	

Chi-square test *p<0.05 **p<0.001. Bold letters mean statistically significant differences.

Table 5. Distribution of condylar shape categories on the contralateral side according to age group

Contralateral	<20 years	≥20 years	p
Round	**99 (56.6%)***	**56 (29.6%)***	p<0.001
Angled	**47 (26.9%)***	**88 (46.6%)***	
Flat	8 (4.6%)	9 (4.8%)	
Pointed	21 (12.0%)	38 (19.0%)	

Chi-square test *p<0.001. Bold letters mean statistically significant differences.

confirmed by CBCT, whereas the angled morphology did not appear to correspond to a true anatomical condylar shape.[11] In this context, the study offers descriptive insights into condylar morphology in patients with impacted canines. However, given the inherent limitations of panoramic radiographs in capturing three-dimensional morphology, further studies using advanced imaging modalities, such as CBCT, are warranted to validate these observations and to enable more detailed morphological assessment, as supported by recent CBCT-based orthodontic imaging studies.[18]

The popularity of CPO has led many to treat it as an established fact, despite the lack of conclusive evidence supporting it as the ideal functional occlusion. Clark and Evans[19] emphasized that the criteria for an "ideal" occlusion remain undefined, and the validity of CPO, alongside group function and balanced occlusion, remains questionable, as not all individuals function in the extreme border positions that CPO represents. Accordingly, it is difficult to attribute non-round condylar morphologies observed in some patients to a single occlusal factor. Rather, such morphological variations are more likely to reflect the combined influence of functional loading, age-related adaptation, and individual biological variability. Further research is required to clarify the relationship between occlusal characteristics and condylar remodeling.

According to our results, there were no statistically significant side-related differences between ipsilateral and contralateral condyles in either age group. In patients younger than 20 years, discordant pairs were equally distributed between the left and right sides, indicating symmetrical condylar morphology. Similarly, among patients aged 20 years and older, a numerically higher frequency of ipsilateral non-round morphology was observed; however, this difference was not statistically significant. Based on these outcomes, unilateral maxillary canine impaction alone does not appear to result in consistent side-dependent alterations in condylar morphology detectable on panoramic radiographs. The absence of significant asymmetry across age groups supports the concept that condylar morphology reflects adaptive or anatomical variation rather than localized occlusal imbalance associated with the side of canine impaction.

Analysis of the age-stratified distribution of condylar morphology revealed distinct patterns between younger and older patients, with comparable distribution trends observed on the ipsilateral and contralateral sides. In patients younger than 20 years, round condylar morphology predominated bilaterally, followed by angled, pointed, and flat forms. In contrast, among patients aged 20 years and older, the relative frequency of round condyles was lower, angled morphology became the most prevalent category, and pointed morphology was observed more frequently in these patients, particularly on the ipsilateral side. Notably, flat morphology remained the least common shape in both age groups. The similar distribution patterns observed on ipsilateral and contralateral sides within each age group indicate that these variations are more likely related to age-associated adaptive or maturational changes rather than to side-specific functional or occlusal asymmetry associated with unilateral canine impaction.

The observed distribution of condylar shape categories showed that round and angled morphologies were encountered more frequently than flat and pointed forms, consistent with previous studies reporting these shapes as common anatomical variations in healthy populations. For example, in their assessment of mandibular landmarks in a North Indian population, Bains et al.[20] also reported that oval and angled condyles were the two most frequently observed morphologies, indicating that these shapes likely represent common anatomical variants rather than pathological alterations. The distribution of condylar morphology appeared similar on the ipsilateral and contralateral sides among the patients included in this study. This observation suggests that the occurrence of different morphological variants may reflect natural variation within the population rather than being related to the side of canine impaction. Comparisons to previous studies provide additional context for the observed variability in condylar shape distribution. In their radiographic survey evaluating condylar morphology, Singh et al.[21] reported oval (round) condyles as the most common morphology, similar to the results of this study. Nevertheless, differences in the relative frequency of secondary morphological categories were noted: pointed condyles were reported as the second most prevalent form in their study, whereas angled morphology was more frequently observed in the sample of this study. Such variations may be attributed to population characteristics.

The symmetrical distribution observed in this study implies that condylar morphology in individuals with impacted canines may reflect inherent morphological variation within the studied population rather than a consistent side-related pattern. However, given the cross-sectional design of this study, potential remodeling processes could not be attributed to a single factor and are likely influenced by multiple contributing mechanisms.

Age is an important factor to consider in the evaluation of condylar morphology and potential remodeling processes. As age increases, the impact of occlusal loading on the condyle becomes more pronounced due to prolonged mechanical stress, leading to more noticeable changes in the bone structure,[22,23] which can be more easily observed on panoramic radiographs. In this study, age-stratified analyses revealed distinct distribution patterns of condylar morphology in younger versus older patients, suggesting that the observed variations may reflect maturational or adaptive changes over time. These findings emphasize the importance of accounting for age when interpreting radiographic assessments of condylar morphology and support the need for longitudinal studies to further clarify age-related remodeling processes.

From a clinical perspective, the findings of this study indicate that UMIC alone should not be interpreted as an indicator of side-specific condylar morphological alteration on panoramic radiographs. This may help clinicians avoid the overinterpretation of routine radiographic findings and unnecessary concern regarding TMJ morphology in asymptomatic patients. Nevertheless, a comprehensive clinical evaluation of the TMJ remains appropriate in patients with impacted canines, particularly when clinical signs or symptoms are present.

Study Limitations

The limitations of this study include its cross-sectional design and reliance on panoramic radiographs, which may not have captured condylar morphology as accurately as CBCT. Panoramic radiographs are subject to inherent, non-uniform magnification related to projection geometry and patient positioning, which may represent a source of measurement or classification bias. However, because this study relied on descriptive morphological categorization rather than absolute linear measurements, the impact of this limitation is expected to be minimal.

Another limitation is the absence of a matched non-impacted control group, which prevents direct comparison of morphological distributions and limits interpretation of relative prevalence. Furthermore, clinical TMJ variables, such as pain, joint sounds, functional limitations and standardized DC/TMD-based clinical assessments, were not evaluated, thereby restricting the interpretation of the findings to radiographic morphology. Although age-stratified analyses were performed, the cross-sectional design limits the interpretation of age-related differences in condylar morphology. Future studies should utilize advanced imaging modalities, standardized clinical TMJ assessments, and longitudinal designs to better clarify the potential relationships between impacted canines and TMJ morphology.

CONCLUSION

In patients with UMIC, condylar morphology was largely symmetrical between the ipsilateral and contralateral sides. These findings indicate that unilateral canine impaction alone is unlikely to be associated with side-specific condylar morphological patterns on panoramic radiographs. Differences in morphological distribution across age groups suggest that condylar shape variability may be influenced by age-related factors rather than by localized occlusal asymmetry. Further longitudinal studies using three-dimensional imaging modalities and matched control groups are needed to clarify the clinical relevance of these observations.

Ethics

Ethics Committee Approval: The study was approved by Marmara University Faculty of Dentistry Clinical Studies Ethics Committee (approval number: 2025-09-02/2025-64, date: 31.07.2025).

Informed Consent: Informed consent was waived due to the retrospective nature of the study.

Footnotes

Presented in: This study was presented at the 19th International Turkish Orthodontic Society Symposium.

Author Contributions: Concept - B.T.M.; Design - B.T.M.; Data Collection and/or Processing - A.Y.A.; Analysis and/or Interpretation - A.Y.A.; Literature Search - B.T.M., A.Y.A.; Writing - B.T.M.

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