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Assessment of Mandibular Condylar Morphological Variations Using Cone-Beam Computed Tomography: A Retrospective Cross-Sectional Study

Mandibular Kondil Morfolojisindeki Varyasyonların Konik-Işınlı Bilgisayarlı Tomografi ile Değerlendirilmesi: Retrospektif Kesitsel Araştırma

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ABSTRACT Objectives: The mandibular condyle is a key of the temporomandibular joint component and the mandible's primary growth center. Although individual variations in condylar shapes are well recognized, the application of existing morphological classifications to clinical relationships remains limited. This study aims to determine the prevalence of mandibular condyle morphologies based on existing classifications using cone-beam computed tomography (CBCT) and to evaluate their relationships with sex, malocclusion, orthognathic surgery, and edentulism. **Material and Methods:** This retrospective study was conducted with a total of 182 patients (122 females, 60 males), with an average age of 26.31±4.61 years. The relationships between condylar morphology and factors such as gender, edentulism, malocclusion (skeletal Class I, II, III), and a history of orthognathic surgery were investigated. Condylar morphology and edentulism were evaluated using CBCT. The skeletal status of the jaws was determined using lateral cephalometric images analyzed with Steiner analysis through the WebCeph program. Statistical analyses were performed using IBM SPSS Statistics Version 28.0 software. **Results:** The most commonly observed condyle morphology was convex, found in 35.6% on the right side and 42.9% on the left. This was followed by the angled type, observed in 29.1% on the right and 22.5% on the left. No statistically significant relationship was found between condyle morphology and gender, edentulism, or malocclusion (p>0.05). However, a statistically significant relationship was found between condyle morphology and history of orthognathic surgery (p<0.05). **Conclusions:** This study evaluated the distribution of mandibular condyle morphologies based on existing classifications using CBCT and demonstrated that a history of orthognathic surgery may influence condylar morphology.

Keywords: Temporomandibular joint; mandibular condyle; cone-beam computed tomography; cephalometry; orthognathic surgery

ÖZET Amaç: Mandibular kondil, temporomandibular eklemin önemli bir bileşeni ve mandibulanın birincil büyüme merkezidir. Kondil şekillerindeki bireysel farklılıklar bilinse de, mevcut morfolojik sınıflandırmaların klinik ilişkilere yönelik kullanımı sınırlıdır. Bu çalışma, konik ışınlı bilgisayarlı tomografi (KIBT) kullanarak mandibular kondil morfolojilerinin mevcut sınıflandırmaya göre rastlanma sıklığını belirlemeyi ve bunların cinsiyet, maloklüzyon, ortognatik cerrahi ve dişsizlik ile ilişkisini değerlendirmeyi amaçlamaktadır. **Gereç ve Yöntemler:** Bu retrospektif çalışma, yaş ortalaması 26,31±4,61 yıl olan toplam 182 hasta (122 kadın, 60 erkek) ile gerçekleştirilmiştir. Çalışmada, kondil morfolojisi ile cinsiyet, dişsizlik, maloklüzyon (iskeletsel Sınıf I, II, III) ve ortognatik cerrahi geçmişi arasındaki ilişkiler incelenmiştir. Kondil morfolojisi ve dişsizlik, KIBT ile değerlendirilmiştir. Çene iskeletinin durumu, WebCeph programı kullanılarak yapılan Steiner analiziyle lateral sefalometrik görüntüler üzerinden belirlenmiştir. İstatistiksel analizler, IBM SPSS Statistics Sürüm 28.0 yazılımı kullanılarak gerçekleştirilmiştir. **Bulgular:** En yaygın gözlemlenen kondil morfolojisi konveks tip olup, sağda %35,6, solda ise %42,9 oranında bulunmuştur. Bunu açılı tip izlemekte olup, sağda %29,1, solda ise %22,5 oranında gözlemlenmiştir. Cinsiyet, dişsizlik durumu ve maloklüzyon ile kondil morfolojisi arasında istatistiksel olarak anlamlı bir ilişki bulunmamıştır (p>0,05). Ancak, ortognatik cerrahi geçmişi olan hastalar ile olmayanlar arasındaki kondil morfolojisi farkları istatistiksel olarak anlamlı bulunmuştur (p<0,05). **Sonuç:** Bu çalışma, KIBT kullanarak mandibular kondil morfolojilerinin mevcut sınıflandırmalara göre dağılımını değerlendirmiş ve ortognatik cerrahi öyküsünün kondil morfolojisi üzerinde etkili olabileceğini göstermiştir.

Anahtar Kelimeler: Temporomandibular eklem; mandibular kondil; konik ışınlı bilgisayarlı tomografi; sefalometri; ortognatik cerrahi

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The temporomandibular joint (TMJ) is one of the most unique joints in the human body, coordinating complex movements across different orthogonal planes and multiple axes of rotation. It consists of the articular eminence of the temporal bone and the condylar process of the mandible, and integrates five major ligaments, retrodiscal tissues, nerves, and blood and lymphatic systems to facilitate its function. The cooperation between the right and left TMJs, along with the masticatory muscles, is essential for coordinated dynamic functions. During mouth opening, the TMJ exhibits a hinge movement, followed by gliding.[1] The structures that form the TMJ include bones, ligaments, the disc, muscle groups, and the joint capsule.[2]

The condyle is a significant component of the TMJ and serves as the primary growth center of the mandible.[3] It forms the joint between the mandible and the cranium, attaching to the mandibular ramus via a thin neck.[4] The condyle is a crescent-shaped structure with decreasing thickness from front to back along its neck. In adults, condylar dimensions are approximately 15-20 mm in mediolateral length and 8-10 mm in anteroposterior length.[5] The upper and anterior surfaces of the condylar head form the articulation surface.[6]

Cone-beam computed tomography (CBCT) has emerged as a crucial imaging modality for the detailed evaluation of the TMJ, providing high-resolution visualization of its bony components while minimizing radiation exposure.[7] Additionally, CBCT is an effective tool for assessing the morphology and pathologies of the bony structures of the TMJ, including fractures, condylar bony changes, ankylosis, developmental anomalies, subchondral bone sclerosis, pathological changes, and condylar position.[7-9] However, CBCT has limitations in evaluating soft tissues. Therefore, it may not be sufficient alone to evaluate soft tissue components of the TMJ, such as disk position, perforation, and displacements.[10,11]

This study aims to determine the prevalence of mandibular condylar morphologies according to the current classification using CBCT and evaluate their relationship with gender, malocclusion, orthognathic surgery, and edentulism.

MATERIAL AND METHODS

Approval for our study was obtained from the Non-Interventional Ethics Committee of Bezmialem Vakıf University, with document number December 27, 2022-2022/372 of the Non-Interventional Research Ethics Committee.

This retrospective study included a total of 182 patients, comprising 60 males (33%) and 122 females (67%), with a mean age of 26,31±4,61 who presented to the Oral, and Maxillofacial Radiology Clinic of Bezmialem Vakıf University Faculty of Dentistry between January 2017-October 2022 for reasons such as orthodontic treatment, orthognathic surgery planning, and examination of pathologies in the maxillofacial region. All patients had CBCT images and lateral cephalometric images of the craniofacial area. Patients were excluded if they were under 18 years of age, had artifacts in their CBCT images that could affect evaluations, had incomplete imaging of the joint region in CBCT images, lacked lateral cephalometric images, or had undergone condylectomy.

TMJ condyle morphologies and edentulism status were evaluated using CBCT images, while skeletal class differentiation was performed using lateral cephalometry. All CBCT images were obtained with high resolution using a Planmeca ProMax 3D Mid ProFace (Planmeca Oy, Helsinki, Finland) with the following imaging parameters: 90 kVp, 10 mA, and a scan time of 36 seconds. The isotropic voxel size was set to 0.2 mm³, as provided by the manufacturer.The images were processed using Romexis software version 3.8.3.R (Planmeca Oy, Helsinki, Finland).

Condyle morphology was analyzed by taking sections from the axial slices of the mandibular condyles at their longest anteroposterior regions, creating paracoronal and parasagittal sections. Condylar morphology was categorized as convex, round, flat, or angled according to the classification provided by Yale et al.[12] In addition to this classification, an atypical type was added in the presence of osteophytes or osteodegenerative changes (Figure 1).

All cephalometric images were taken with Planmeca (ProMax 2D S2, Finland) using parameters of 66 kVp, 10 mA, and 10.5 seconds. The images were processed with Romexis software version 3.8.3.R by

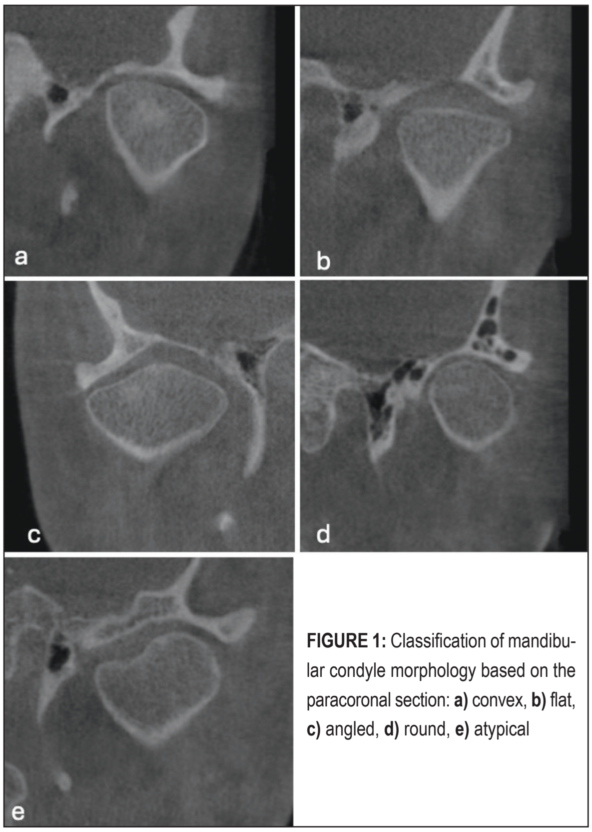

FIGURE 1: Classification of mandibular condyle morphology based on the paracoronal section: **a)** convex, **b)** flat, **c)** angled, **d)** round, **e)** atypical

Planmeca. Evaluations of the lateral cephalometric radiographs were performed using Steiner analysis, considering the A Point-Nasion-B Point value, via the free WebCeph program at https://webceph.com/en/. WebCeph is a fully automated digital cephalometric analysis program developed by AssembleCircle (Seoul, South Korea). The program uses artificial intelligence algorithms to automatically identify selected anatomical points and perform the necessary measurements and calculations on the digital cephalometric radiograph (Figure 2, Figure 3).

Evaluations of condylar morphologies using CBCT were independently analyzed by a dentomaxillofacial radiologist with 6 years of experience (EA), a research assistant with 2 years of experience (ERS), and a fifth-year undergraduate student (KG). In cases of disagreement among observers, consensus was reached through discussion.

Malocclusion assessments based on lateral cephalometry were performed using the WebCeph software by an orthodontist with 6 years of experience (ŞŞ), a dentomaxillofacial radiologist with 2 years of experience (ERS), and a 5th-year undergraduate student (KG), with all evaluations conducted through consensus.

Correlations between condylar morphologies and sex, edentulism* (*In our study, partial edentulism was defined as the absence of one or more teeth in the mouth, excluding third molars and premolar teeth extracted at the beginning of orthodontic treatment if needed), malocclusion (skeletal class I, class II, class III), and orthognathic surgery (whether or not it had been performed) were evaluated.

STATISTICAL ANALYSIS

All statistical analyses were performed using IBM SPSS Statistics version 28.0 (IBM, Chicago, IL). Fre-

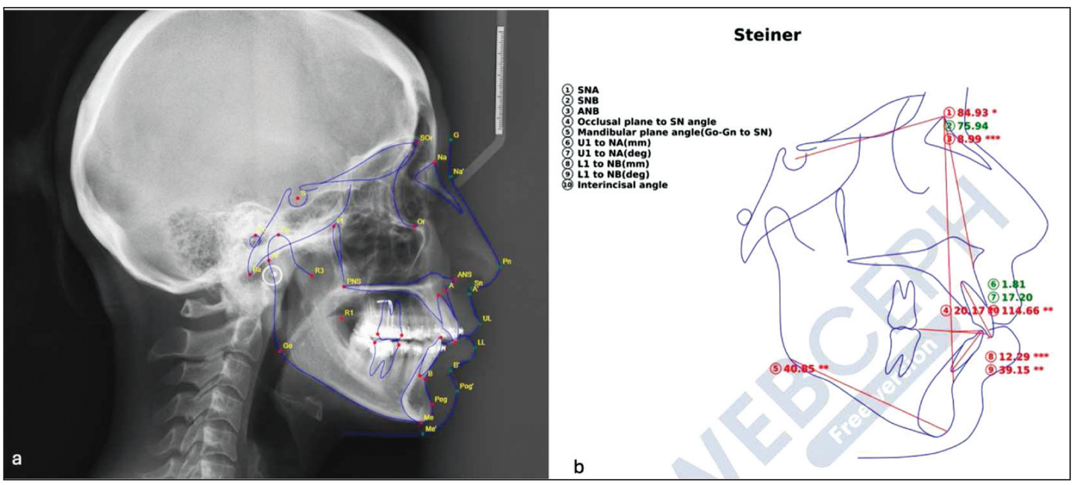

FIGURE 2: a) Automatic marking by the WebCeph program **b)** Steiner analysis, SNA: Sella-Nasion-A Point; SNB: Sella-Nasion-B Point; ANB: Nasion-A Point; SN: Sella-Nasion
*: Mild deviation from the normal value; **: Moderate deviation from the normal value; ***: Severe deviation from the normal value

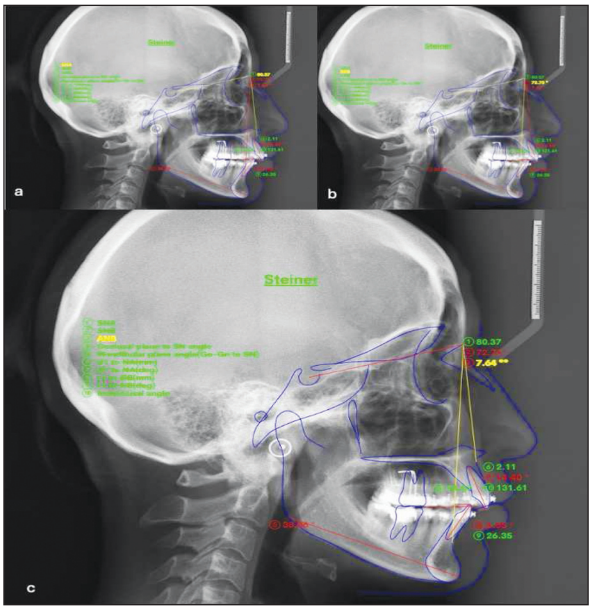

FIGURE 3: **a**) SNA angle (Sella-Nasion-A Point), **b)** SNB angle (Sella-Nasion-B Point), **c)** A Point-Nasion-B Point angle (A Point-Nasion-B Point)

quency analysis was conducted to display the observational frequencies and percentage distributions of the data. The Pearson chi-square test with cross-tabulation was employed to assess the statistical significance of comparisons between independent variables. Statistical significance was defined as p<0.05.

POWER ANALYSIS

In this study, a power analysis conducted with a 0.8 power and a 0.05 significance level indicated that the minimum required sample size to detect the smallest effect size (Cohen's d=0.21) is 178.

RESULTS

Regarding skeletal jaw relationships, of the 182 patients, 44 (24.2%) were classified as Class I, 44 (24.2%) as Class II, and 94 (51.6%) as Class III, indicating that Class III is the most common skeletal jaw relationship. In terms of dentition status, 107 patients (58.8%) had full dentition, 75 patients (41.2%) had partial dentition, and none were completely edentulous. Regarding orthognathic surgery, 99 patients (54.4%) had undergone surgery, while 83 patients (45.6%) had not (Table 1).

The morphology of the condyles of the 182 patients included in the study was analyzed separately for the right and left sides (Table 1).

Cohen's Kappa was used to assess intraobserver agreement in classifying the mandibular condyle into "convex", "flat", "angular", "round", and "atypical" categories. The results showed that the Kappa value for the first observer was calculated as 0.989, indicating excellent agreement (p<0.001), the Kappa value for the second observer was calculated as 0.955, indicating excellent agreement (p<0.001), and the Kappa value for the third observer was calculated as 0.933, indicating excellent agreement (p<0.001).

There was no significant difference between malocclusion types and condyle morphology for both right and left condyles (p>0.05), indicating that malocclusion type does not affect condyle morphology (Table 2).

There is a statistically significant difference in the distribution of condyle morphology types between patients who underwent orthognathic surgery and those who did not (p<0.05), (p<0.024), (p<0.005). The angled condyle type is more common in patients who underwent surgery on the right condyle, while both angled and flat condyle types are

TABLE 1: Distribution of skeletal jaw relationships, dentition status, orthognathic surgery status, and condyle morphology

		Frequency	Percentile
Skeletal jaw relationships	Class I	44	24.2
	Class II	44	24.2
	Class III	94	51.6
Dentition status	Full dentition	107	58.8
	Partial dentition	75	41.2
	Total edentulism	0	0
Orthognathic surgery application status	No	83	45.6
	Yes	99	54.4
Right condyle	Convex	65	35.7
	Flat	32	17.6
	Angled	53	29.1
	Round	22	12.1
	Atypical	10	5.5
	Total	182	100.0
Left condyle	Convex	78	42.9
	Flat	27	14.8
	Angled	41	22.5
	Round	23	12.6
	Atypical	13	7.1
	Total	182	100.0

TABLE 2: Comparison of condylar morphologies with malocclusion, orthognathic surgery, gender, and dentition status

		Convex	Flat	Angled	Round	Atypical	Total	p value
Malocclusion	Class I	15	9	15	3	2	44	
Type (right)	Class II	15	11	11	3	4	44	0.353
	Class III	35	12	27	16	4	94	
	Total	65	32	53	22	10	182	
Malocclusion	Class I	18	10	10	4	2	44	
Type (left)	Class II	17	9	7	6	5	44	0.332
	Class III	43	8	24	13	6	94	
	Total	78	27	41	23	13	182	
Orthognathic	No	31	22	17	9	4	83	
Surgery	Yes	34	10	36	13	6	99	0.024*
Right	Total	65	32	53	22	10	182	
Orthognathic	No	40	19	14	7	3	83	
Surgery	Yes	38	8	27	16	10	99	0.005*
Left	Total	78	27	41	23	13	182	
Gender	Male	17	10	21	11	1	60	
Right condyle	Female	48	22	32	11	9	122	0.101
	Total	65	32	53	22	10	182	
Gender	Male	28	7	14	9	2	60	
Left condyle	Female	50	20	27	14	11	122	0.533
	Total	78	27	41	23	13	182	
Dentition	Full	36	17	30	16	8	107	
Status	Partial	29	15	23	6	2	75	0.347
Right	Total	65	32	53	22	10	182	
Dentition	Full	43	18	24	14	8	107	
Status	Partial	35	9	17	9	5	75	0.877
Left	Total	78	27	41	23	13	182	

*p<0.05: Pearson chi-square

more prevalent in the left condyle of patients who underwent orthognathic surgery (Table 2).

Gender had no significant effect on right or left condyle morphology (p>0.05), meaning there was no notable difference between males and females in terms of condyle morphology. Additionally, there is no statistically significant difference in right and left condyle morphology between patients with full dentition and those with partial dentition (p>0.05) (Table 2).

DISCUSSION

There are various studies in the literature concerning condylar morphologies. In a study conducted by Yalcin et al., consisting of 50.3% females and 49.7% males, with 910 patients, they found condylar morphologies of the right condyle to be 42.1% convex, 33.6% angled, 12.7% flat, and 11.5% round, while for the left condyle, these percentages were 39% convex, 35.1% angled, 18.2% flat, and 7.7% round.[13] Shubhasini et al., in a study evaluating mandibular condylar morphologies on CBCT in 32 patients aged 18-22, found in coronal sections: angled (37.5%), convex (31.3%), round (15.6%), concave (9.4%), and flat (6.3%).[14] In a study by Yale et al. looking at the Terry collection and pre-hispanic groups and classifying mandibular condylar morphologies, in the Terry group, out of 502 condyles, 232 (46.3%) were convex, 133 (26.5%) flat, 67 (13.4%) angled, 59 (11.8%) round, and 10 (2%) other, while in the pre-hispanic group, out of 352 condyles, 150 (43%) were angled, 140 (40.1%) convex, 41 (11.8%) flat, 13 (3.7%) other, and 5 (1.4%) round.[12,15] In our study, similar to the study by Yalcin et al. and paralleling the Terry group by Yale et al. the highest rate of convex morphology was observed in the right (35.7%) and left (42.9%) condyles, followed by the angled type.[12,13,15] The difference between the literature and the current study findings could be due to sample size, population, and different ethnic groups.

In a study by Merigue et al. where they evaluated condylar morphology and position in malocclusion patients using CBCT on 49 patients, they reported no significant difference in condylar shapes between Class I and Class II patients.[16] Rodrigues et al. in a study evaluating the relationship between changes in mandibular condylar morphology and tooth loss and craniofacial factors, examined condylar changes in 123 patients using panoramic radiographs.[17] They reported no significant relationship between condylar changes and Angle's molar relationship. Similarly, in our study, there is no significant correlation between condylar morphology and skeletal relationship of the jaws. These findings indicate that establishing a direct relationship between malocclusion class and condylar morphology is difficult and that other factors need to be considered. Therefore, clinicians should take into account individual patient characteristics and various etiological factors that may influence condylar morphology beyond malocclusion class, tooth loss, and gender.

In a study by Scolozzi et al. where they evaluated changes in condylar morphology post-orthognathic surgery using panoramic radiographs, they reported no significant change in condylar morphology during the 1-year follow-up after surgery.[18] However, they noted that the surgical methodology used could affect the changes in condylar morphology. Hoppenreijs et al. in a study evaluating condylar remodeling and resorption after bimaxillary osteotomy and Le Fort I osteotomies in patients with anterior open bite, reported morphological changes in condyles post-surgery.[19] De Clercq et al. in a study examining the relationship between orthognathic surgery and condylar atrophy, stated that surgery was associated with condylar resorption.[20] In our study, similar to Hoppenreijs et al. and De Clercq et al. a statistically significant bilateral relationship was found between patients who underwent orthognathic surgery and condylar shapes.[19,20] This could be explained by changes in occlusal forces in condyles, which are growth centers, post-surgery, leading to a new balance and subsequent changes in condyles, which are growth centers. Additionally, the findings indicate that condylar morphology is an important factor in cases requiring orthognathic surgery and that surgical intervention can have significant effects on condylar morphology. In a study by Lee et al. evaluating postoperative changes in condylar positions using a balanced orthognathic surgery system, they reported significant changes in condylar positions following surgery, suggesting that these changes could directly impact treatment outcomes and long-term stability.[21] These findings align with our research, emphasizing the relationship between orthognathic surgery and variations in condylar morphology. The study highlights the necessity of carefully assessing condylar shape and position to be integrated into surgical planning. When evaluating these results, clinicians should consider condylar morphology in orthognathic surgery planning. This may lead to better management of pre- and post-surgical processes and improvement in treatment outcomes.

In studies regarding gender, Yalcin et al. found a significant relationship between gender and morphological changes on the right side, while no significant relationship was found on the left side.[13] Similarly, Yale et al. found no significance between gender and condylar shape.[15] Widmalm et al. in their study evaluating TMJ pathologies according to age, gender, and edentulism status, reported no significant relationship between morphological changes in the TMJ and gender.[22] Similarly, in our study, no significant relationship was found between condylar shape and gender, consistent with the literature. This could be due to the non-homogeneous distribution of our groups, consisting of 60 male and 122 female patients.

In a study by Rodrigues et al. a statistically significant change was found in condylar morphology associated with tooth loss.[17] Similarly, Yalcin et al. found a statistically significant difference between edentulism and condylar morphology, whereas in our study, no statistically significant relationship was found between dentition status and condylar morphology.[13] This difference may be attributed to the distribution of patients in our study, with a higher proportion in the 20-29 age range, as well as the smaller sample size and the absence of an edentulous patient group.

This study has several limitations. First, the retrospective design may introduce biases and affect the data collection methods. Additionally, while factors such as malocclusion class, tooth loss, and gender were evaluated, the impact of individual patient characteristics and other etiological factors on condylar morphology was not comprehensively assessed. Furthermore, the sample size and demographic diversity are limited, as the study focused on a specific age range and gender distribution.

CONCLUSION

This study determined the prevalence of mandibular condylar morphologies according to the current classification using CBCT and examined their relationship with gender, malocclusion, orthognathic surgery, and edentulism. The findings suggest that condylar morphology may differ in individuals with a history of orthognathic surgery, and these differences should be considered in clinical assessments. This study highlights how variations in condylar morphology can contribute to clinical evaluations and treatment planning. A better understanding of these individual variations could aid in optimizing clinical and surgical approaches. Future studies with larger populations will provide a more detailed understanding of how these relationships translate into clinical and surgical practice, further enhancing the clinical significance of the findings.

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

***Idea/Concept:** Elifhan Alagöz, Kardelen Gülenç; **Design:** Elifhan Alagöz, Emine Rana Sarıkaya; **Control/Supervision:** Elifhan Alagöz, Şerife Şahin; **Data Collection and/or Processing:** Elifhan Alagöz, Kardelen Gülenç, Emine Rana Sarıkaya, Şerife Şahin; **Analysis and/or Interpretation:** Elifhan Alagöz, Kardelen Gülenç, Emine Rana Sarıkaya, Şerife Şahin; **Literature Review:** Elifhan Alagöz, Kardelen Gülenç; **Writing the Article:** Elifhan Alagöz, Kardelen Gülenç; **Critical Review:** Elifhan Alagöz, Şerife Şahin.*

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