REVIEW ARTICLE

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Morphological variations of the mandibular condyle as assessed from panoramic radiographic images: a literature review

Nurul Masyrifah[1*], Barunawaty Yunus[2]

ABSTRACT

Objectives: This literature review aims to analyze the morphological variations of the mandibular condyle as observed in panoramic radiographic images. It investigates recent findings on the correlation between condylar morphology and clinical factors, highlights the clinical relevance of these variations in diagnosis and treatment planning, and underscores the importance of early identification of structural abnormalities in dental practice.

Review: A comprehensive literature search was conducted using databases including PubMed, ScienceDirect, and Google Scholar. Keywords used were: mandibular condyle, morphological variation, panoramic radiograph, and TMJ. Inclusion criteria comprised peer-reviewed studies published in English from 2015 to 2023 focusing on human panoramic radiographic evaluations of condylar morphology. Exclusion criteria included studies using only CBCT without panoramic comparisons, case reports, and studies on animal subjects. The review synthesized retrospective, cross-sectional, and observational studies with sample sizes ranging from children to older adults to identify common condylar morphologies and their clinical implications.

Conclusion: Panoramic radiographs can effectively identify morphological variations of the mandibular condyle, such as round, flat, angled, convex, and rare bifid shapes. These variations are associated with factors like age, gender, dentition status, and occlusion. Understanding these differences is crucial for early diagnosis and proper management of temporomandibular disorders.

Keywords: *Morphological variations, mandibular condyle, panoramic radiography, temporomandibular joint, TMJ disorders*

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INTRODUCTION

The mandible is the strongest and heaviest bone of the human face, playing a crucial role in essential functions such as mastication, speech, and swallowing. Among its anatomical structures, the mandibular condyle holds significant clinical and anatomical relevance, as it forms a key component of the temporomandibular joint (TMJ). The condyle acts as a secondary growth center and is a highly dynamic structure, undergoing morphological changes from embryonic development through adulthood.[1,2,3] Anatomically, the mandibular condyle presents in a variety of shapes, including round, flat, convex, concave, and, in rare cases, bifid.[4] These morphological variations may be influenced by age, sex, dental status, functional load, malocclusion, and genetic factors.[5,6,7] Previous studies have indicated a correlation between condylar morphology and temporomandibular joint (TMJ) dysfunction, as well as its contribution to facial asymmetry and malocclusion.[8,9,10] Although various studies have examined condylar morphology, most of them employed three-dimensional imaging modalities such as cone-beam computed tomography (CBCT) or computed tomography (CT), which, while accurate, are not always widely accessible due to cost and limited availability. In contrast, panoramic radiography (orthopantomogram/OPG) remains a widely used and cost-effective two-dimensional modality in routine dental practice.[11,12,13] Therefore, understanding the potential of OPG in identifying condylar morphological variations is essential, particularly for early detection of TMJ abnormalities and for improved clinical treatment planning.

One of the most commonly used diagnostic tools by dental practitioners is panoramic radiography, or orthopantomogram (OPG), which provides critical information about the teeth,

[1]Department of Oral and Maxillofacial Radiography, Faculty of Dentistry, Hasanuddin University, Makassar 90245, Indonesia

[2]Department of Oral and Maxillofacial Radiography, Faculty of Dentistry, Hasanuddin University, Makassar 90245, Indonesia

*Correspondence to:
Nurul Masyrifah
Nurulmasyrifah31@gmail.com

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mandible, and other jaw structures. This tool helps us understand anatomical variations in the maxilla and mandible, as well as bone changes or adaptations that occur over time.[13,14,15] For TMJ screening, when clinical examinations indicate.

Certain joint pathologies and noticeable bone changes in the condyle can be evaluated easily and affordably with digital panoramic radiography, which dentists and dental specialists often use to assess TMJ bone structures. Furthermore, studies have shown that digital radiography of the condyle area provides good accuracy and consistency.[15]

Radiography is essential in dental diagnosis. Panoramic radiography is a reliable type of imaging that provides a comprehensive view of the jaw, including the mandibular condyle. Consequently, panoramic radiography can be used to diagnose structural issues or abnormalities in the mandibular condyle or jaw.[16] Two-dimensional (2D) or 3D radiographic examinations can be used to evaluate the dimensions and morphology of the mandibular condyle and ramus. However, there remains a gap in the literature regarding the accuracy and reliability of identifying mandibular condyle morphology using two-dimensional imaging, such as panoramic radiography (OPG), particularly in larger and more diverse populations. Several studies have evaluated condylar shapes without correlating them with key clinical factors such as age, gender, or dental status. In addition, there is currently no standardized classification system for condylar morphology based on panoramic radiography, which limits diagnostic consistency and comparability across studies.

Therefore, this literature review aims to: 1. Analyze the various morphological variations of the mandibular condyle identified through panoramic imaging; 2. Illustrate the clinical significance of these variations in the context of diagnosis and treatment planning, and ; 3. Highlight the need for standardization and further research, especially within diverse populations and resource-limited clinical settings.

REVIEW

A comprehensive literature search was conducted to identify studies evaluating morphological variations of the mandibular condyle using panoramic radiography. The search strategy was developed based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework.

The literature was retrieved from three major databases—PubMed, ScienceDirect, and Google Scholar—focusing on articles published from 2015 to 2023. The search was performed using a combination of the following keywords: "*mandibular condyle*", "*morphological variation*", "*panoramic radiograph*", "*orthopantomogram*", "*temporomandibular joint*", and "*condylar shape classification*". Boolean operators such as **AND** and **OR** were used to combine terms appropriately.

Inclusion Criteria in this research: 1. Original research articles published in English; 2. Human subject studies; 3. Use of panoramic radiography for condyle morphology analysis; 4. Full-text availability; 5. Retrospective or cross-sectional study design.

Exclusion Criteria in this research: 1. Case reports, reviews, and meta-analyses; 2. CBCT- or MRI-only based studies; 3. Animal studies.

CASE STUDY LITERATURE

Morphological Variations of the Mandibular Condyle

The anatomical morphology of the mandible varies based on functional load and jaw activity; the condylar bone undergoes continuous changes from early life, even during embryonic development.[18,19] Age and dental status are associated with morphological differences in adults. Condylar morphology is influenced by pressure on the joint surface.[20]

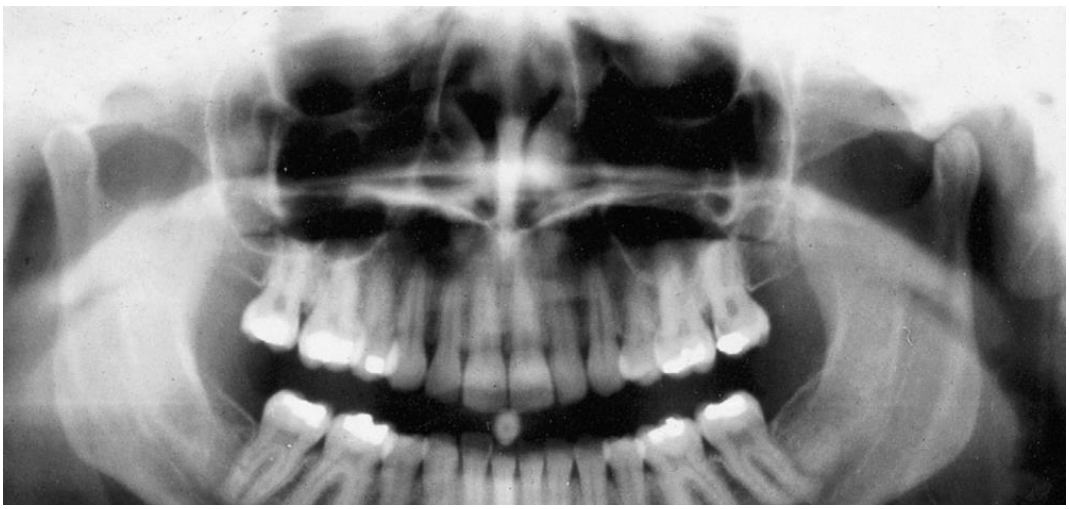

Figure 1. Normal Condition of the Mandibular Condyle

According to Nagaraj et al., the shape of the mandibular condyle is classified into four types: round, angled, convex, and flat.[21]

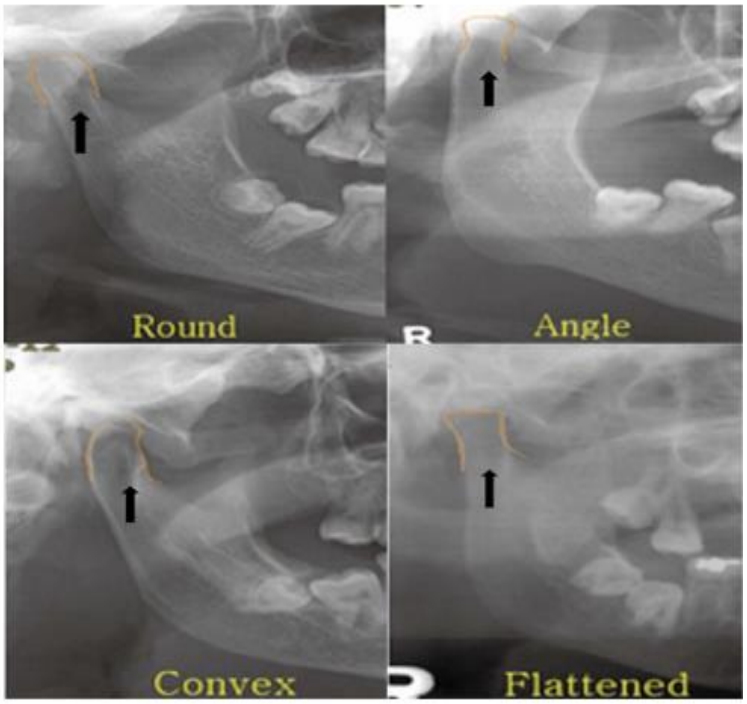

Figure 2. Shapes of the Mandibular Condyle: Round, Angled, Convex, and Flat

The rough, oval-shaped mandibular condyle typically measures 15-20 mm medially and 8-10 mm posteriorly.[22] Several hypotheses exist regarding condylar shapes, with the most common morphology reported as a convex curve along its length. Both sides should be symmetrical, meaning any deviation from this convex shape is often considered pathological. However, normal variations do occur.[13,23,24] A particular form of bone variation known as multiheaded condyles includes the bifid mandibular condyle, first described by Hrdlicka in 1941.[25]

Panoramic Radiography in Observing Morphological Variations of the Mandibular Condyle

Dentists frequently use panoramic radiography to gain essential information on teeth, the mandible, and other related jaw structures. This imaging method is invaluable for identifying anatomical variations in the maxilla and mandible, as well as observing bone expansion or changes over time. Panoramic radiography is widely employed, in line with recommendations from the American Academy of Oral and Maxillofacial Radiology, to assess the structural components of the temporomandibular joint (TMJ).[26] In dental diagnosis and arch examination, orthopantomograms (OPG) are a vital component of radiographic evaluation.[18] Panoramic radiography is indeed the easiest and most reliable method to identify morphological changes in the mandible for living individuals.[3,27]

However, conventional radiographic methods, such as panoramic radiography, have limitations when confirming various pathologies, as they cannot capture the condyle's morphology in three dimensions.[28]

Relationship Between Mandibular Condyle Morphology and Other Clinical Factors

The anatomy of the condyle is influenced by age, gender, facial type, functional load, occlusal force, and malocclusion.[29,30,31] Each condyle's shape and size vary; there are numerous age- and gender-related variations in condylar profiles. Condyle shape and angulation are highly individualized and often differ from left to right. Facial shape, occlusal style, and functional load are additional factors influencing condyle shape under normal conditions.[32,33]

Research by Ramadhan et al. showed that tooth loss could alter dental morphology. Findings indicated that the most common condylar morphological variation was flattening, followed by osteophyte formation in both edentulous free-end and full dentition cases. In degenerative conditions, the condyle typically flattens. Gharge et al. used panoramic imaging to assess TMJ changes in edentulous and dentulous patients, finding that bone changes were most prevalent in dentulous and partially dentulous patients.[16] The size and position of the mandibular condyle are determined by craniofacial morphology and temporomandibular disorders.[34]

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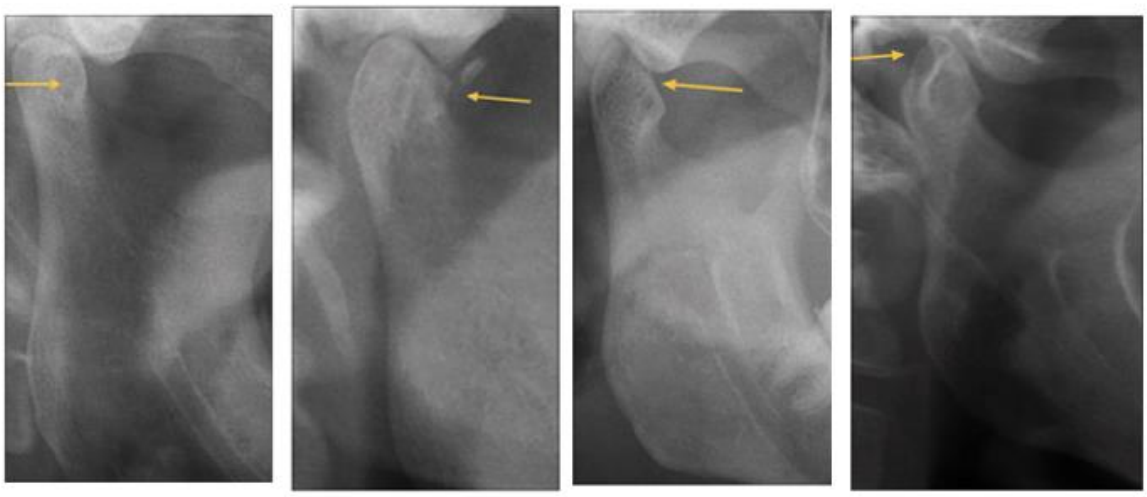

Figure 3. Subcondylar Cyst, Osteophyte, Erosion, Knife-Edge Margin[11]

Panoramic radiography has proven to be the first, easy, and useful method for assessing condylar abnormalities and morphology, such as resorption, erosion, sclerosis, and osteophyte formation.[35]

Table 1. Summary of research findings on mandibular condyle morphological variations

Author (year)	Title	Conclusion	Design of Study
Shaikh et.al (2021)	Assessment of radiographic morphology of mandibular condyles: a radiographic study	The four types of mandibular condyle morphology have been observed, with the oval shape being the most common across genders and all age groups. In future studies, including additional parameters and a larger sample size could provide unique insights.	Retrospective cros sectional
Onem et. al (2023)	Evaluation of Mandibular Condyle Shape Distribution Using Digital Panoramic Images	The results indicate that, regardless of the individual's gender or age, the oval shape is the most common morphology of the mandibular condyle. The least common cone shape observed in this study group was the bifid form.	Retrospective cross-sectional study
Lydia et.al (2021)	Morphological Appearance of Condylar Head in Mixed Denti tion Period (Evaluated from Panoramic Radiograph)	During the first mixed dentition transition period, the morphological appearance of the condylar head in normal individuals is primarily round (46.16%). It remains round during the interim transition period and becomes convex during the second mixed dentition transition period (58.50%).	This is a descriptive-analytical study with a retrospective design and a qualitative approach
Zaheri et. al (2021)	Evaluation of Morphological Variations of Iranian Mandible Condyles	Compared to other morphologies, the round morphology is more common across all populations and in both genders. However, no relationship between the two has been observed.	This is a retrospective study, and SPSS 16 software was used for data analysis. The chi-square test was applied for statistical analysis of the data
Jose et.al (2023)	Association Between Gender, Age, and Skeletal Class With Mandibular Condyle Morphology: A Retrospective Study	The study found a relationship between age and gender with the shape of the mandibular condyle. The results suggest that predicting condylar morphology by considering these demographic variables can lead to more clinically accurate assessments.	Retrospektif analysis

Author (year)	Title	Conclusion	Design of Study
Aswinirani et. al (2017)	Morphological variations of condylar process and sigmoid notch using Orthopantomograms in Western part of Maharashtra population	The round condyle shape is the most common, followed by oval, angled, and convex shapes, with the flat shape being the rarest, consistent with the findings of Nagaraj T et al. Among genders, the round condylar process is more common in women than in men in our study, as shown by Sahithi et al.	Statistical analysis, Chi-square test
Abhisek et. al (2022)	Assessment of Condylar Shape through Digital Panoramic Radiograph among Nepalese Population: A Proposal for Classification	It was found that the round or oval condyle shape is the most common in Lalitpur, followed by flat condyles, with hook-shaped and bifid condyles being the rarest.	Studi cross-sectional
Anshu et. al (2021)	Variations in Shapes of Mandibular Condyles on Digital Orthopantomograph Among Patients Visiting A Dental College	It can be concluded that the round/oval condyle shape is most commonly seen in the Indian and Jharkhand populations, followed by the diamond/angled shape, with hook-shaped and bifid condyles being the rarest	Studi retrospektif cross-sectional

DISCUSSION

The mandibular condyle exhibits different shapes in each individual, whether normal or pathological. According to Yale, the classification of mandibular condyle morphology used in Jay et al.'s study includes four main categories: convex, round, flat, and angled. Most adults have a convex condylar head, according to previous theories and research. A round, condensed head is also considered normal.[36,26]

The temporomandibular joint (TMJ) is one of the joints responsible for the opening and closing of the mouth during processes such as chewing, swallowing, and speaking. When the jaw joint experiences excessive pressure or trauma, damage to the joint structures, known as temporomandibular disorder (TMD), can occur in the disc, condyle, glenoid fossa, and articular eminence.[12,32,37]

In addition to functioning as a joint, the mandibular condyle, which is in the form of a roll, also serves as a growth area within the cartilage. The condylar head should be convex and symmetrical on the opposite side in a normal state. The human condyle can move over 200 times a day, making it one of the most active parts of the body. During the opening and closing of the mandible, the condyle undergoes complex movements.[32]

The shape of the mandibular condyle varies with age and between individuals.[38] Changes in condylar morphology on panoramic TMJ imaging are considered an early indicator of degenerative joint disease. To detect early changes on radiographs, it is essential to understand the normal morphology of the TMJ. Bone damage in the mandibular condyle may occur if these changes are not identified and addressed early.[11] In Dalili et al.'s research, it was found that men have larger linear measurements of the joint space compared to women,[39] particularly in the posterior and superior regions. Men tend to have a larger joint space, possibly due to thicker soft tissue in the TMJ compartments. Hinton.[40] The mandibular condyle is one of the primary facial growth locations, expressed in an upward and backward direction.[41]

The shapes of the condyle observed in panoramic images include round, angled, finger-like, and bird-beak shapes, according to Zaheri et al.'s study. The results indicated that the round shape is more common compared to other forms. On the other hand, the condylar shape is also evaluated by gender. The study found that men have more bird-beak-like, round shapes compared to women, while women have more diamond and finger-like shapes than men, although these differences were not statistically significant. At Mahidol University in Thailand, Arayapisit et al. examined changes in mandibular cone shape on panoramic images. Smooth, dot, angled, round, and irregular shapes were found in patients in Zaheri et al.'s study. Data showed that men have more round shapes compared to women.[23] Malocclusion and facial asymmetry, as morphological and functional expressions of such changes, may also be influenced by functional changes in the mandibular condyle.[42]

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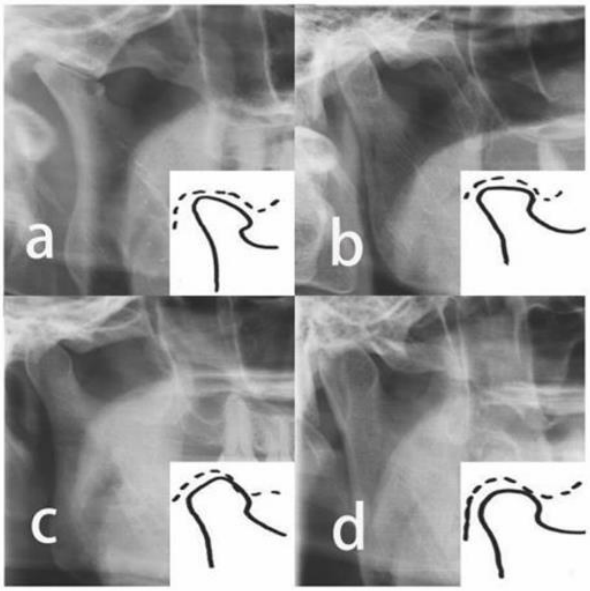

Figure 4. Example of condylar lines divided into several categories
(a) Angled; (b) Flat; (c) Pointed; (d) Round[43]

According to Bae et al., the mandibular body growth in males is significantly greater than in females between the ages of 13 and 15 years.[44] The condyle has various shapes, including flat, angled, round, convex, and concave. Shape changes can be caused by structural changes, diseases, trauma, hormonal disorders, and radiotherapy. The shape and size of the condyle are also influenced by age and genetics.[45]

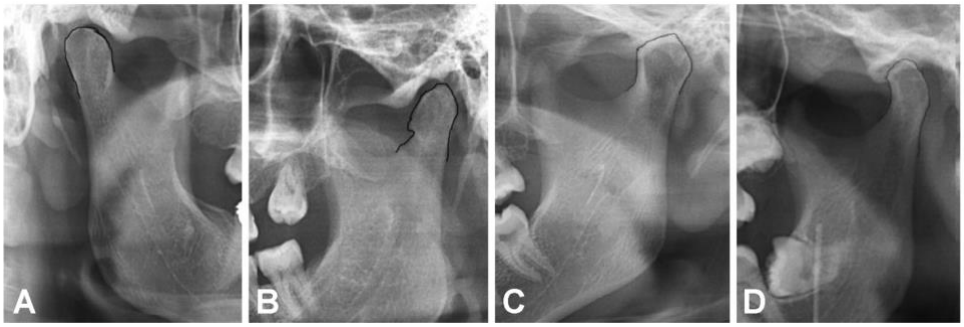

Figure 5. Types of Mandibular Condyle Shapes
A. Oval, B. Bird-Beak, C. Diamond, D. Hook-Shaped [10,27]

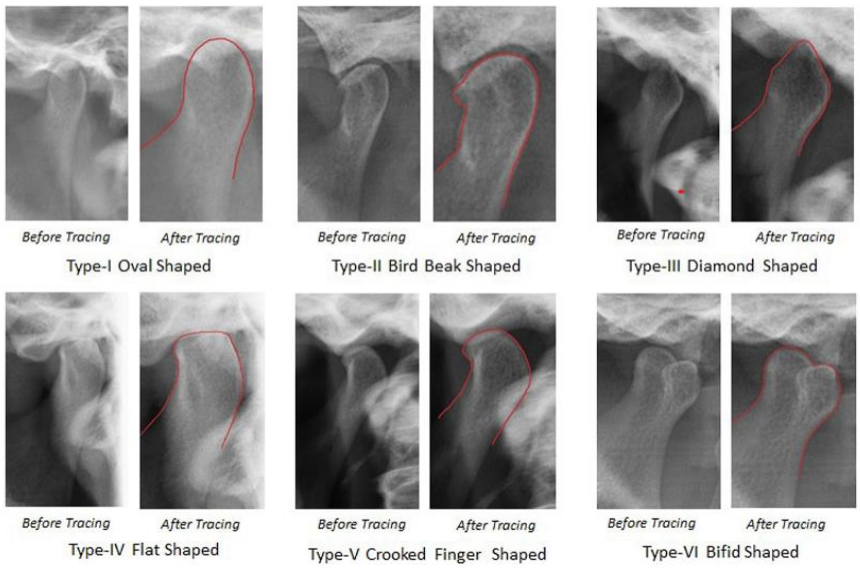

Figure 6. Six Types of Condylar Shapes [14]

The condylar head exhibits different shapes in every individual, both in normal and pathological conditions. Yale provides a classification for condensed head shapes. The four primary types are convex, round, flat, and angled. Theoretically, based on previous research, most adults with a convex condyle have a normal condylar morphology with a round head.[26,46] In the study by Aswinirani et al., the most common condyle shape was round, followed by oval, angled, and convex, with flat being the rarest, consistent with Nagaraj T et al.'s study. Among genders, the round condylar process is more common in women than in men in our study, as indicated by Sahithi et al.[47]

For the first time, Hrdliwka reported a rare anatomical condition known as a bifid condyle.[48,49] This condition is characterized by a depression or cleft in the centre of the condylar head with an anteroposterior or mediolateral orientation. The cause remains unknown and is varied, as it can result from congenital abnormalities, trauma, or even tumor lesions.[50]

Figure 7. Panoramic Radiograph Showing Bifid Mandibular Condyle [20]

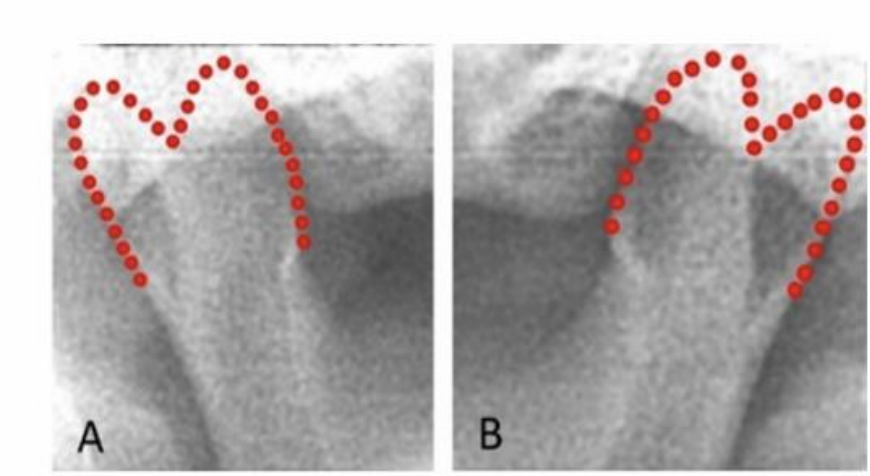

Figure 8. Bifid Condyle Shape Type [25]

Compared to other TMJ anomalies, a bifid condyle is a relatively rare condition. As it often shows no symptoms, it is usually diagnosed incidentally during routine radiographic exams. Panoramic radiography is a popular, inexpensive, and easily accessible method for patients. "Bifid" comes from Latin, meaning "split into two parts".[41]

The exact cause of a bifid condyle is unknown. Possible causes include congenital abnormalities, trauma, infections, nutritional disorders, radiation exposure, developmental anomalies, teratogenic embryopathies, tumors, or condylectomies. A bifid condyle can also be a differential diagnosis for pathologies such as condylar hyperplasia and osteochondroma.[50]

Factors such as sexual dimorphism can affect the size and shape of the condyle, with males generally having a larger joint space than females. Studies also show variation in condyle shapes between genders, with round shapes being more common in men and diamond or hook shapes more common in women. Changes in the mandibular condyle can also contribute to malocclusion and facial asymmetry. This underscores the importance of a thorough understanding of the morphology and function of the mandibular cone in the diagnosis and management of temporomandibular disorders.

CONCLUSION

Panoramic radiography remains an accessible and effective imaging modality for observing morphological variations of the mandibular condyle. The condyle exhibits various shapes, such as round, flat, convex, angled, and, in rare cases,

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bifid. These variations are closely linked to factors such as age, gender, dentition status, occlusal force, and skeletal pattern. Understanding these differences is crucial for accurate diagnosis, early detection of temporomandibular disorders, and appropriate clinical management. Further studies are encouraged to standardize the classification of condylar morphology and to explore the relationship between condylar variation and clinical manifestations using larger and more diverse populations.

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FOOTNOTES

The authors declare no conflict of interest in the authorship or publication of this article.

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