ORIGINAL ARTICLE

Morphology of Mandibular Condyle in The Population of Sarawak: A Retrospective Cross-sectional Study Using Digital Panoramic Radiograph

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ABSTRACT

Introduction: The morphology of the condyles changes naturally with age, gender, face type, occlusal force, functional load, malocclusion type, and the right and left sides. Although condylar shape and size differ throughout populations, there have been few investigations on condylar morphology, particularly in the Malaysian population. **Methods:** This retrospective, observational, cross-sectional survey was conducted at the Oral and Maxillofacial Surgery Clinic of Sarawak General Hospital from September 2021 to March 2022, involving radiographic assessment of condylar morphology from 893 panoramic radiographs. Age, gender, ethnicity and dentition status using Eichner index were extracted from the data. Descriptive statistics were used. Pearson's chi-square test was used to determine the association between the independent variables (age, gender, ethnicity and dentition status) and the shape of the mandibular condyle. A p-value of < 0.05 was considered statistically significant. **Results:** Only 450 panoramic radiographs were included in this study. The condyles were outlined and grouped into four categories, namely pointed (40.2%), round (32.8), angled (18.8), and flat (8.2%). Condylar morphology was found to be significantly associated with gender (p<0.005) and insignificant with other independent variables. **Conclusion:** The findings suggest that the most prevalent condylar morphology among the Sarawak population is the pointed shape, in contrast with other previous studies that reported the round shape condylar morphology as the majority shape.
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INTRODUCTION

In dentistry, panoramic radiography (PR) is the most frequently used imaging technology because it comprehensively covers the facial features in a single picture, including the maxilla, the mandible, and both condyles. Due to its low radiation dosage and easy accessibility, PR is also a suitable alternative for the initial evaluation of the bone components of the jaws (1).

While cone beam computed tomography (CBCT) and computed tomography (CT) are more accurate than PR for assessing different temporomandibular joint (TMJ) bone components and disorders, including joint remodelling, erosion, osteophyte development, and subcortical sclerosis, these modern imaging techniques have drawbacks. CBCT and CT emit more radiation than standard imaging techniques, and they are also more expensive and less available. Additionally, some individuals may be unable to undergo an MRI due to claustrophobia (2). Due to the cost and risk of computed tomography, the American Academy of Oral and Maxillofacial Radiology recommends a routine panoramic view for examining the structural components of the TMJ (3).

Natural variations in condylar morphology (CM) occur with age, gender, facial type, occlusal force, functional load, malocclusion, and between the right and left sides (4). Although condylar shape and size differ throughout populations, there have been few investigations on CM, particularly in the Malaysian population. The shape of the mandibular condyles on panoramic radiographs varied substantially across the population studied (5).

Variation in CM in different populations has been reported in previous studies (1, 6, 7). Oliveira et al. (6) classified CM into four types: round, flat, angled and pointed. Round, followed by angled, is the most common shape, especially among younger individuals in the Brazilian population. According to Singh et al (5), the most prevalent condyle morphology in the Indian population is a round-shaped condyle, followed by pointed and angled-shaped condyles, with flat-shaped condyles being the least common.

On the other hand, Sonal et al. (1) categorised CM in the Indian population as oval, bird-beak, diamond, and crooked-finger shaped. Nonetheless, differences in CM in PR, particularly the angle or bird-beak form, may suggest TMJ disease. A.H. Shaikh et al. (8) evaluated condyle morphology in Pakistani population and classified it as oval, bird beak, crooked finger, diamond and mixed shape.

To the best of our knowledge, there is a paucity of research in the literature on the variation of the morphology of mandibular condyle, particularly among the Malaysian population. The findings of this research can be used as a guide for future studies or in clinical application to differentiate between normal morphology of mandibular condyle in healthy individuals and those diagnosed with temporomandibular disorders that involve advanced bony alteration in mandibular condyle in the population. Moreover, the knowledge of variations in CM identified through PR can be employed as a screening method for personal identification in forensic dentistry where the cadaver is burnt and unrecognizable (9). By understanding the variations of CM, this research also provides insight to the improvement of the manufacturing of custom-made or stock prostheses for mandibular condyle replacement in cases of bilateral total TMJ reconstruction that is appropriate for clinical application on the local population. The limited ability of a few standard implant sizes to accommodate the wide range of clinically observed jaw morphologies and bone pathologies, particularly in significant bone loss following major tumour removal, may result in severe abnormalities and poor mandibular function due to stock prosthetic components not being appropriately used (10). Therefore, the present study aims to document the variations of the morphology of mandibular condyle in the population in Sarawak, one of the states of Malaysia located in East Malaysia.

MATERIALS AND METHODS

This retrospective, observational, cross-sectional study using pre-existing digital panoramic radiographs was conducted at Oral and Maxillofacial Surgery (OMFS) Clinic, Sarawak General Hospital (SGH), Kuching, Sarawak, from September 2021 to March 2022. Ethical approval was obtained from The Medical Research and Ethics Committee (MREC), the Ministry of Health Malaysia (NMRR-21-1676-60715). Informed consent was not obtained from the patients because this is a retrospective study.

The patients who came for digital panoramic radiograph investigation in the OMFS clinic, SGH between the period of December 2020 and June 2021 were selected in this study based on inclusion and exclusion criteria. This study aimed to determine the shape (%) and symmetry (%) of the mandibular condyle in the population. The sample size is determined based on a formula to determine the prevalence in a targeted population. By estimating the prevalence can be low, moderate or high, this study estimated the prevalence as 50.0% (since the prevalence of 50.0% with a fixed margin of error will yield a larger sample size) with a margin of error of 5.0%. Hence, based on a 95% confidence interval, the minimum sample size required is 384 subjects. The sample size is calculated using the Epi Info™ software version 7.2 (Epi Info™, Division of Health Informatics & Surveillance (DHIS), Center for Surveillance, Epidemiology & Laboratory Services (CSELS)).

The inclusion criteria for this study were patients aged 18 years old and above with no known medical condition that would affect the morphology of the mandible or pre-existing TMJ problem, the adult who came for digital panoramic radiograph due to surgical removal of impacted wisdom tooth, periodontal problem and routine dental check-up at the Oral and Maxillofacial Surgery (OMFS) Clinic, Sarawak General Hospital.

On the other hand, patients with underlying temporomandibular joint diseases (TMD), facial trauma, condylar fractures, severe malocclusion, and skeletal deformity, those who had completed orthodontic treatment and poorly showed condylar anatomy on radiographs were excluded from the study.

All panoramic images were taken with Planmeca ProMax 3D (Planmeca Oy, Helsinki, Finland; 66-68 kVp, 9-13 mA, 18.9-s exposure time, total filtration of 2.5 mm aluminium). A single observer, calibrated by an oral and maxillofacial surgeon, analyzed and evaluated the radiographs. To reduce the risk of observer bias, 10% of the data collected has been validated by the oral and maxillofacial surgeon. The similarity of results between the first and second observers was 90%, indicating high consistency and reliability. Any disagreement in the radiograph interpretation was resolved through discussion between the observers until a consensus was reached. The condyles, as identified by Oliveira-Santos et al, were outlined and grouped into four categories based on their shape: (a) angled, (b) flat, (c) pointed, and (d) round. It was also noted if the same form showed bilaterally or if each participant had various shapes. The subjects were classified into five age groups: 18-29, 30-39, 40-49, 50-59, 60 years old and above.

According to Yoshino K et. al., the Eichner index can be estimated by analyzing the number of present teeth in the oral cavity. Any opposing pair of maxillary and mandibular teeth with the same tooth number was counted as one occlusal support (11). In this study, the dentition status was estimated and categorized using Eichner Index by analyzing patients' records, based on the number of present teeth and the distribution of occlusal support teeth, as shown in Figure 1. The Eichner Index is based on the occlusal contacts in each molar and premolar region, which are called supporting zones. Group A had occlusal contact in four support zones; group B had one to three zones of contact or just touch in the anterior region; and group C had no occlusal contact at all, although a few teeth may have remained, if any (12). In this study, fully and partially erupted permanent teeth were defined as "present teeth", while supernumerary teeth, third molars, pontics of fixed prostheses and implant-supported superstructures were not counted as present teeth.

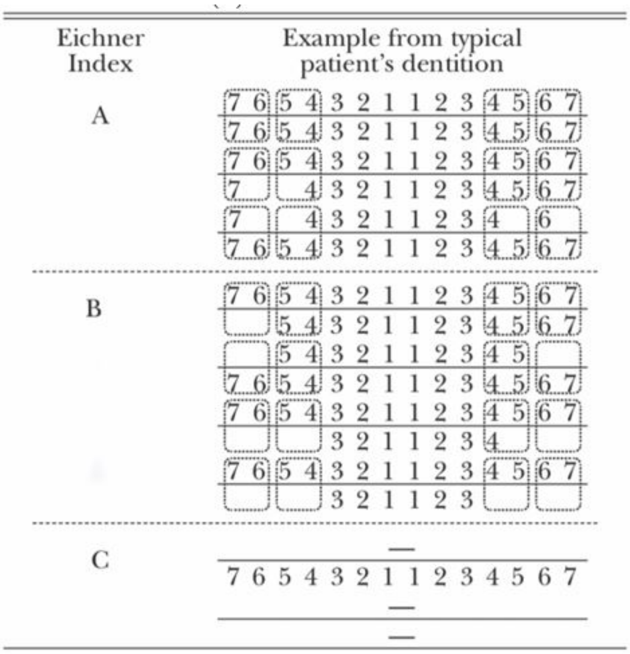

Figure 1: Classification of Eichner Index (11)

Descriptive statistics were used to describe the subjects' characteristics and the prevalence of mandibular condyle shape and symmetry. Pearson's chi-square test was used to determine the association between the independent variables (age, gender, ethnicity and dentition status) and the shape of the mandibular condyle, with a p-value of < 0.05 considered statistically significant. All analyses were performed using SPSS version 21.0 (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.)

RESULTS

Table I shows the demographic data of the eligible subjects, consisting of profile and clinical data. Out of 893 PRs that were assessed, 450 PRs (900 mandibular condyles) of the eligible subjects were included in this study. The ages ranged from 18 to 83, with a mean age of 40.83±15.796 years. Among 450 subjects, 56.9% (N=256) were male, and 43.1% (N=194) were female. Three ethnicities in the population of Sarawak were identified in this study, namely Malay (40.7%), Chinese (25.3%) and the Indigenous of Sarawak (34%).

Table I: Demographic Data (Profile and Clinical Data) of Eligible Subjects(N=450)

Profile	N (%)
Age Group (Years)	
18-29	134(29.8)
30-39	113(25.1)
40-49	68(15.1)
50-59	67(14.9)
≥60	68(15.1)
mean: 40.83±15.796, range: 18-83	
Gender	
Male	256(56.9)
Female	194(43.1)
Ethnicity	
Chinese	114(25.3)
The Indigenous	153(34.0)
Malay	183(40.7)
Clinical Data	
Eichner Index	
A	324(72)
B	88(19.6)
C	38(8.4)
Morphology of Mandibular Condyle (Both)	
Angled	169(18.8)
Flat	74(8.2)
Pointed	362(40.2)
Round	295(32.8)
Morphology of Mandibular Condyle (Right)	
Angled	93(20.7)
Flat	36(8.0)
Pointed	167(37.1)
Round	154(34.2)
Morphology of Mandibular Condyle (Left)	
Angled	76(16.9)
Flat	38(8.4)
Pointed	195(43.3)
Round	141(31.3)
Bilateral Similar Morphology	
Yes	264(58.7)
No	186(41.3)

This study recorded the angled, flat, pointed and round shapes of CM, as shown in Figure 2. Our study concluded that the pointed shape (40.2%) is the most common CM. Table II shows the distribution of the total number of CM according to patient factors. The

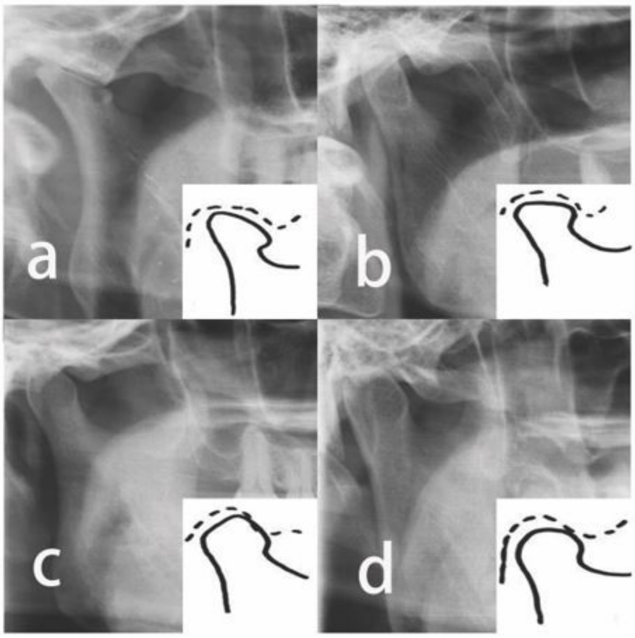

Figure 1: Examples of condyle outlines are divided into the following categories: (a) angled; (b) flat; (c) pointed; and (d) round (6).

pointed shape (67.1%) is the most common CM among females, whereas the round shape (54.2%) is the most common CM among males and is statistically significant (p<0.001). The pointed shape is the most common in Group A and B of dentition status, whereas the pointed shape is equally as common as the round shape of CM in subjects with Group C of dentition status (p=0.902).

The most common type of CM for the right side is the pointed shape (37.1%). Table II shows the distribution of CM on the right side according to patient factors. The majority of the subjects in each age group have pointed-shape CM over the right side, but it is not statistically significant (p=0.598). In terms of gender, pointed shape (65.3%) and round shape (52.6%) are the most frequent right CM in females and males, respectively, and are statistically significant (p=0.012). Most of the subjects in each ethnicity group have pointed-shape right mandibular condyle (p=0.226). Most of the subjects with Group A, B and C of dentition status have pointed-shape right mandibular condyle (p=0.983).

In the current study, the most common type of CM for the left side is the pointed shape (43.3%). Table II depicts the distribution of CM on the left side according to patient factors. The pointed-shape CM is the most common over the left side regarding age group (p=0.877). Pointed shape (68.7%) and round shape (56.0%) are the most common left CM in females and males, respectively, and are statistically significant (p<0.001). The majority of the subjects in each ethnicity group have a pointed shape on the left mandibular condyle (p=0.983).

Table II: Distribution of morphology of mandibular condyle (both, right and left) according to age, gender, ethnicity and Eichner index

		Morphology of Mandibular Condyle				*p* value
		Angled N(%)	Flat N(%)	Pointed N(%)	Round N(%)	
Age Group(Years)						
18-29						
	Both	50(29.6)	23(31.1)	100(27.6)	95(32.2)	
	Right	26(28.0)	14(38.9)	47(28.1)	47(30.5)	
	Left	24(31.6)	9(23.7)	53(27.2)	48(34.0)	
30-39						
	Both	39(23.1)	20(27.0)	90(24.9)	77(26.1)	
	Right	21(22.6)	6(16.7)	40(24.0)	46(29.9)	
	Left	18(23.7)	14(36.8)	50(25.6)	31(22.0)	
40-49						
	Both	25(14.8)	11(14.9)	62(17.1)	38(12.9)	
	Right	13(14.0)	7(19.4)	32(19.2)	16(10.4)	
	Left	12(15.8)	4(10.5)	30(15.4)	22(15.6)	
50-59						
	Both	27(16..0)	11(14.9)	56(15.5)	40(13.6)	
	Right	16(17.2)	4(11.1)	25(15.0)	22(14.3)	
	Left	11(14.5)	7(18.4)	31(15.9)	18(12.8)	
≥60						
	Both	28(16.6)	9(12.2)	54(14.9)	45(15.3)	0.961[a]
	Right	17(18.3)	5(13.9)	23(13.8)	23(14.9)	0.598[b]
	Left	11(14.5)	4(10.5)	31(15.9)	22(15.6)	0.877[c]
Gender						
Male						
	Both	73(43.2)	36(48.6)	119(32.9)	160(54.2)	
	Right	38(40.9)	17(47.2)	58(34.7)	81(52.6)	
	Left	35(46.1)	19(50.0)	61(31.3)	79(56.0)	
Female						
	Both	96(56.8)	38(51.4)	243(67.1)	135(45.8)	<0.001*[a]
	Right	55(59.1)	19(52.8)	109(65.3)	73(47.4)	0.012*[b]
	Left	41(53.9)	19(50.0)	134(68.7)	62(44.0)	<0.001*[c]
Ethnicity						
Chinese						
	Both	48(28.4)	21(28.4)	90(24.9)	69(23.4)	
	Right	28(30.1)	11(30.6)	40(24.0)	35(22.7)	
	Left	20(26.3)	10(26.3)	50(25.6)	34(24.1)	
Indigenous Sarawak						
	Both	50(29.6)	19(25.7)	127(35.1)	110(37.3)	
	Right	27(29.0)	6(16.7)	62(37.1)	58(37.7)	
	Left	23(30.3)	13(34.2)	65(33.3)	52(36.9)	
Malay						
	Both	71(42.0)	34(45.9)	145(40.1)	116(39.3)	0.463[a]
	Right	38(40.9)	19(52.8)	65(38.9)	61(39.6)	0.226[b]
	Left	33(43.4)	15(39.5)	80(41.0)	55(39.0)	0.983[c]
Eichner Index						
A						
	Both	122(72.2)	56(75.7)	257(71.0)	213(72.2)	
	Right	65(69.9)	28(77.8)	119(71.3)	112(72.7)	
	Left	57(75.0)	28(73.7)	138(70.8)	101(71.6)	
B						
	Both	33(19.5)	11(14.9)	77(21.3)	55(18.6)	
	Right	19(20.4)	6(16.7)	34(20.4)	29(18.8)	
	Left	14(18.4)	5(13.2)	43(22.1)	26(18.4)	
C						
	Both	14(8.3)	7(9.5)	28(7.7)	27(9.2)	0.902[a]
	Right	9(9.7)	2(5.6)	14(8.4)	13(8.4)	0.983[b]
	Left	5(6.6)	5(13.2)	14(7.2)	14(9.9)	0.709[c]

p-value were evaluated by Pearson's chi-square test.
[a] significance level between morphology of mandibular condyles (both) and independent variables (age, gender, ethnicity, Eichner index).
[b] significance level between morphology of mandibular condyles (right) and independent variables (age, gender, ethnicity, Eichner index).
[c] significance level between morphology of mandibular condyles (left) and independent variables (age, gender, ethnicity, Eichner index).
**p*-value<0.05.

It was also recorded that the same shape of the CM was seen in 58.7% of the eligible subjects. Table III depicts the distribution of the similarity of CM according to patient factors. Overall, 41.7% of males and 58.3% of females presented with the same bilateral shape of the CM (p=0.461). Of all the independent variables, only gender is statistically significant to the distribution of both the right and the left side of CM observed in this study.

Table III: Distribution of similar morphology of mandibular condyle according to age, gender, ethnicity and Eichner index.

	Similarity of Morphology of Mandibular Condyle		*p* value
	Unilateral N(%)	Bilateral N(%)	
Age Group (Years)			
18-29	55(29.6)	79(29.9)	
30-39	51(27.4)	62(23.5)	
40-49	18(9.7)	50(18.9)	
50-59	30(16.1)	37(14.0)	
≥60	32(17.2)	36(13.6)	0.087
Gender			
Male	84(45.2)	110(41.7)	
Female	102(54.8)	154(58.3)	0.461
Ethnicity			
Chinese	54(29.0)	60(22.7)	
Indigenous Sarawak	55(29.6)	98(37.1)	
Malay	77(41.4)	106(40.2)	0.167
Eichner Index			
A	134(72.0)	190(72.0)	
B	36(19.4)	52(19.7)	
C	16(8.6)	22(8.3)	0.992

p-value were evaluated by Pearson's chi-square test.

DISCUSSION

This retrospective research evaluated the CM of non-TMD patients in the PR. We found that most of the patients who came to the OMFS clinic of SGH were younger than 40 years old. Although statistically insignificant, we concluded that the pointed shape was more prevalent in subjects of all age groups. In contrast, previous studies from different populations reported round shape CM as the most prevalent type of CM (1, 6, 13). However, no significant association was observed between CM and age groups in the present study, consistent with previous findings (5, 14, 15).

The majority of the subjects with round shape of CM were younger than 40 years old, and the number of round shapes of CM decreased with increasing age. This is likely due to normal physiological changes, including chewing habits that caused the morphological changes of the CM. In the previous study, Singh et al. (5) reported that the majority of those with bilaterally round-shaped condyles reported no specific chewing habits. The likelihood of being round shape was higher in those with undefined chewing patterns and in people who chewed bilaterally.

In the present study, we discovered that almost two-thirds of the individuals had the same condyle form on both sides. This frequency was discovered to be comparable to the findings of Oliveira et al. (6). However, the youngest age group had the highest incidence of bilateral occurrence of the same form, whereas the oldest age group had the lowest incidence. Interestingly, the number of subjects with the bilateral occurrence of the same shape of condyles decreased as the age increased. Similar findings were noticed in previous studies (5, 6, 16). The decline in the bilateral occurrence of CM might be due to some underlying parafunctional habits as age increases. Previous studies had reported a positive correlation between the similarity of CM and the presence of parafunctional habits, as most of the subjects with parafunctional habits had dissimilar condyles (5, 17).

Generally, we reported that the pointed shape is the most common CM for females, while the round shape is the most common for males, and this finding is statistically significant for both the right and left sides of the CM. However, in a previous study, no statistically significant difference was observed when both genders were compared (8). In the previous studies done in the Turkish population, the round shape was uncommon in both sexes, but the flat type was more prevalent in men than women (18).

Regarding ethnicity, the pointed shape is the most common shape for Malays, Chinese and the Indigenous group of Sarawak. This shows that the shape of CM does not affect by the ethnic group. This is congruent with a study that examined differences in CM within the same ethnic group as well as between ethnic groups and found no significant difference between Malay and Chinese due to their shared East Asian origin (19).

Tooth loss is another factor that influences CM. Changes in the structure of the mandibular condyle may be related to tooth loss and posterior crossbite (20). According to Singh et al. (5), there was a statistically significant link between age groups and dentition status, with dentition status drifting toward Eichner Class C as age progressed, as well as a significant relationship between dentition status and CM. With increasing age, a better distribution of condylar forms may be seen, with the prevalence of round, pointed, and angled condyles being substantially comparable. However, the present study reported that the most common CM for patients with Eichner index Class A, B and C is the pointed shape of CM, with no discernible trend between dentition status and CM. This shows that dentition status does not affect the remodelling/reshaping of CM over time in the current study population, which is in line with previous studies (21-23).

In our findings, the most probable CM shape for subjects aged 30 years and below is the pointed shape followed by the round shape. We have also raised the issue that a consensus should be made for classifying CM worldwide based on the evaluation of CM using radiographic modalities. This would facilitate ease of comparison clinically and communication of cases among dental professionals. Currently, several types of classification have been used to categorized CM assessed using OPG and 3D scans such as CBCT and CT. However, professional bodies have issued no agreement on the classification system. Therefore, a consensus on the classification of CM is strongly warranted and should be looked into in future studies. The authors used the classification system proposed by Oliveira-Santos et al in this study due to its ease of understanding, commonly used in other studies, and its acceptable reliability in reflecting the actual CM.

The limitations of this study are that the study sample from a single centre is taken, which might not represent the whole population. Furthermore, the PR was used to assess the CM despite the availability of CBCT machine, which provides a 3D image and is more accurate than conventional imaging. Future prospective research can be done to compare the CM changes between healthy individuals and those with diagnosed TMJ pathology/diseases to observe the morphological changes of condyle over time and to determine how the findings aid in the diagnosis and treatment of TMJ pathology, particularly those involving the mandibular condyle.

CONCLUSION

The findings suggest that the most prevalent shape of CM among the Sarawak population in Malaysia is the pointed shape, in contrast to previous studies that reported the round shape CM as the majority shape. The shape of CM in the study population is significantly associated with the gender and insignificant with age changes, ethnicity and dentition status. Identifying variations in condyle morphology helps in diagnosing TMJ disease, post-mortem identification of the population and predicting future trends in prosthetic replacement of condyle reconstruction, which would greatly benefit the public.

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REFERENCES

1. Sonal V, Sandeep P, Kapil G, Christine R. Evaluation of condylar morphology using panoramic radiography. Journal of Advanced Clinical and Research Insights. 2016;3:5-8. doi: 10.15713/ins.jcri.94.
2. Talmaceanu D, Lenghel LM, Bolog N, Hedesiu M, Buduru S, Rotar H, et al. Imaging modalities for temporomandibular joint disorders: an update. Clujul Med. 2018;91(3):280-7. doi: 10.15386/cjmed-970.
3. Epstein JB, Caldwell J, Black G. The utility of panoramic imaging of the temporomandibular joint in patients with temporomandibular disorders. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2001;92(2):236-9. doi: 10.1067/moe.2001.114158.
4. Yale SH, Allison BD, Hauptfuehrer JD. An epidemiological assessment of mandibular condyle morphology. Oral Surg Oral Med Oral Pathol. 1966;21(2):169-77. doi: 10.1016/0030-4220(66)90238-6.
5. Singh B, Kumar N, Balan A, Nishan M, Haris P, Jinisha M, et al. Evaluation of Normal Morphology of Mandibular Condyle: A Radiographic Survey. J Clin Imaging Sci. 2020;10. doi: 10.25259/JCIS_84_2020.
6. Oliveira-Santos C, Bernardo RT, Capelozza A. Mandibular condyle morphology on panoramic radiographs of asymptomatic temporomandibular joints. International Journal of Dentistry. 2009;8.
7. Honda E, Yoshino N, Sasaki T. Condylar appearance in panoramic radiograms of asymptomatic subjects and patients with temporomandibular disorders. Oral Radiology. 1994;10(2):43-53. doi: 10.1007/BF02390715.
8. Shaikh AH, Ahmed S, Ahmed AR, Das G, Taqi M, Nisar S, et al. Assessment of radiographic morphology of mandibular condyles: a radiographic study. Folia Morphol (Warsz). 2021. doi: 10.5603/FM.a2021.0049.
9. Krishan K, Kanchan T, Garg AK. Dental Evidence in Forensic Identification - An Overview, Methodology and Present Status. Open Dent J. 2015;9:250-6. doi: 10.2174/1874210601509010250.
10. Ackland DC, Robinson D, Redhead M, Lee PVS, Moskaljuk A, Dimitroulis G. A personalized 3D-printed prosthetic joint replacement for the human temporomandibular joint: From implant design to implantation. J Mech Behav Biomed Mater. 2017;69:404-11. doi: https://doi.org/10.1016/j.jmbbm.2017.01.048.
11. Yoshino K, Kikukawa I, Yoda Y, Watanabe H, Fukai K, Sugihara N, et al. Relationship between Eichner Index and number of present teeth. Bull Tokyo Dent Coll. 2012;53(1):37-40. doi: 10.2209/tdcpublication.53.37.

12. Ikebe K, Matsuda K, Kagawa R, Enoki K, Okada T, Yoshida M, et al. Masticatory performance in older subjects with varying degrees of tooth loss. J Dent. 2012;40(1):71-6. doi: 10.1016/j.jdent.2011.10.007.
13. Arayapisit T, Ngamsom S, Duangthip P, Wongdit S, Wattanachaisiri S, Joonthongvirat Y, et al. Understanding the mandibular condyle morphology on panoramic images: A conebeam computed tomography comparison study. CRANIO®. 2020:1-8. doi: 10.1080/08869634.2020.1857627.
14. Ashwinirani, Patil S, Nair B, Rajmane Y, Ka K. Morphological variations of condylar process and sigmoid notch using Orthopantomograms in Western part of Maharashtra population. International Journal of Applied Dental Sciences. 2018;4:160-3.
15. Md Anisuzzaman M, Khan SR, Khan MTI, Abdullah MK, Afrin A. Evaluation of Mandibular Condylar Morphology By Orthopantomogram In Bangladeshi Population. Update Dental College Journal. 2019. doi: https://doi.org/10.3329/updcj.v9i1.41203.
16. Sahithi D, Reddy S, Divya Teja DV, Koneru J, Sai Praveen KN, Sruthi R. Reveal the concealed – Morphological variations of the coronoid process, condyle and sigmoid notch in personal identification. Egyptian Journal of Forensic Sciences. 2016;6(2):108-13. doi: https://doi.org/10.1016/j.ejfs.2015.11.003.
17. Tao J, Wu J, Zhang X. Mandibular condylar morphology for bruxers with different grinding patterns. Cranio. 2016;34(4):219-26. doi: 10.1179/2151090315y.0000000023.
18. Yalcin ED, Ararat E. Cone-Beam Computed Tomography Study of Mandibular Condylar Morphology. J Craniofac Surg. 2019;30(8):2621-4. doi: 10.1097/scs.0000000000005699.
19. Al-koshab M, Nambiar P, John J. Assessment of condyle and glenoid fossa morphology using CBCT in South-East Asians. PLoS One. 2015;10(3):e0121682. doi: 10.1371/journal.pone.0121682.
20. Rodrigues VP, Freitas BV, de Oliveira ICV, Dos Santos PCF, de Melo HVF, Bosio J. Tooth loss and craniofacial factors associated with changes in mandibular condylar morphology. Cranio. 2019;37(5):310-6. doi: 10.1080/08869634.2018.1431591.
21. Mathew AL, Sholapurkar AA, Pai KM. Condylar Changes and Its Association with Age, TMD, and Dentition Status: A Cross-Sectional Study. International Journal of Dentistry. 2011;2011:413639. doi: 10.1155/2011/413639.
22. Pereira Jr FJ, Lundh H, Westesson P-L. Morphologic changes in the temporomandibular joint in different age groups: an autopsy investigation. Oral Surg Oral Med Oral Pathol. 1994;78(3):279-87. doi: 10.1016/0030-4220(94)90055-8.
23. Crow H, Parks E, Campbell J, Stucki D, Daggy J. The utility of panoramic radiography in temporomandibular joint assessment. Dentomaxillofacial Radiology. 2005;34(2):91-5. doi: 10.1259/dmfr/24863557.