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Three-dimensional evaluation of the mandibular condyle in adults with various skeletal patterns

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Objective: Morphometric and morphological evaluation of the mandibular condyle in adults and to identify its correlation with skeletal malocclusion patterns. **Methods:** Cone-beam computed tomography scans of 135 adult patients were used in this study and classified into groups according to four criteria: (1) sex (male and female); (2) sagittal skeletal discrepancy (Class I, Class II, and Class III); (3) vertical skeletal discrepancy (hyperdivergent, normodivergent, and hypodivergent); and age (group 1 ≤ 20 years, 21 ≤ group 2 < 30, and group 3 ≥ 30 years). The morphometrical variables were mandibular condyle height and width, and the morphological variable was the mandibular condyle shape in coronal and sagittal sections. Three-dimensional standard tessellation language files were created using itk-snap (open-source software), and measurements were performed using Meshmixer (open-source software). **Results:** The mandibular condyle height was significantly greater ($p < 0.05$) in patients with class III malocclusion than in those with class I or II malocclusion; the mandibular condyle width was not significantly different among different sexes, age groups, and sagittal and vertical malocclusions. There were no statistical associations between various mandibular condyle shapes and the sexes, age groups, and skeletal malocclusions. **Conclusions:** The condylar height was greatest in patients with class III malocclusion. The condylar height and width were greater among males than in females. The mandibular condyle shapes observed in sagittal and coronal sections did not affect the skeletal malocclusion patterns.

Key words: Growth and development, Temporomandibular joint, Class III malocclusion, Three-dimensional cephalometrics

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INTRODUCTION

The concept of occlusion in dentistry pertains to the relationship between all components of the masticatory system in normal and abnormal functions.[1-3] The bone and muscle components may dynamically affect each other's function, resulting in morphological changes of the bone.[4,5] Owing to greater masticatory forces, males show greater mandibular growth and remodeling than do females.[6] Morphological changes in the temporomandibular joint (TMJ) of young adults may result in malocclusion.[7] Morphological alterations occur based on simple developmental variability, such as remodeling of the condyle to adapt to developmental variations, malocclusion, trauma, and other developmental abnormalities and diseases.

The mandibular condylar morphology varies significantly between individuals[8,9] and is associated with age, sex, facial type, occlusal force, functional load, malocclusion type, and right and left sides.[10] In young adults, the mandibular condyle plays an essential role in the stability of long-term orthodontic and orthognathic treatments.[11,12] Many orthodontic studies have been conducted on TMJ spaces, morphological shapes, and volumetric size.[11,13-17] Anthropological studies have analyzed the mandibular condyle shape in different populations.[18-23] However, conventional two-dimensional imaging methods, such as panoramic radiography, are inadequate to accurately examine the three-dimensional (3D) mandibular condyle morphology.[10,24] Therefore, this study aimed to morphologically and morphometrically investigate the mandibular condyle based on sex and different sagittal and vertical skeletal malocclusions using cone-beam computed tomography (CBCT). Each orthodontist must understand the normal variations of the mandibular condyle to avoid misdiagnosis and provide more efficient orthodontic treatment.[7,11,12]

MATERIALS AND METHODS

Sample-size calculation

A power analysis using G*Power software (Power version 3.1.9.7; University of Dusseldorf, Dusseldorf, Germany) was used to estimate the required sample size to detect differences between group means using analysis of variance (ANOVA), with an effect size f = 0.40; 102 participants were required to achieve a power exceeding 0.90, $p = 0.05$.

Participants

This study was approved by the Nanjing Medical University Research Ethical Committee, Jiangsu province-affiliated hospital (PJ2018-059-001). All procedures followed in this experiment were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and the Helsinki Declaration of 1964 and its later versions. Informed consent was obtained from all patients for inclusion in the study.

The study sample comprised 135 patients, including 54 males (23.7 ± 4.39 years) and 81 females (21 ± 3.89 years) who visited our institution seeking various dental treatments. They were classified according to the sagittal skeletal relationship (A point-nasion-B point [ANB] angle): skeletal Class I (1° ≤ ANB ≤ 4°), skeletal Class II (ANB > 4°), and skeletal Class III (ANB < 1°). They were also classified according to the vertical skeletal relationship based on the sella-nasion and mandibular plane (SN-MP angle) as follows: hypodivergent (SN-MP < 27°), normodivergent (27° ≤ SN-MP ≤ 37°), and hyperdivergent (SN-MP > 37°). According to age, the sample was classified into three groups (group 1 ≤ 20 years; 21 years ≤ group

Table 1. Sample distribution

Groups	Variables	Sex		ANB angle			SN-MP angle		
		Male	Female	1 ≤ ANB ≤ 4 Class I	ANB > 4 Class II	ANB < 1 Class III	SN-MP < 27° Hypodivergent	27° ≤ SN-MP ≤ 37° Normodivergent	SN-MP > 37° Hyperdivergent
SN-MP angle	Hypodivergent	11	24	20	3	12	35		
	Normodivergent	27	39	15	26	25		66	
	Hyperdivergent	16	18	10	16	8			34
ANB angle	Class I	17	28	45			20	15	10
	Class II	14	31		45		3	26	16
	Class III	23	22			45	12	25	8
Sex	Male	54		17	14	23	11	27	16
	Female		81	28	31	22	24	39	18

ANB, A point-nasion-B point; SN, sella-nasion plane; MP, mandibular plane.

2 < 30 years; and group 3 ≥ 30 years) (Table 1). CBCT images were obtained using NewTom VGi Evo (Cefla S.C., Imola, Italy) with the following exposure parameter settings: 17 seconds scan time, 18 × 16-cm field of view, and 0.5-mm voxel size. The patients were instructed to sit upright, bite in centric occlusion (CO), and look forward to maintain the Frankfort horizontal plane parallel to the floor. The CBCT data were saved in Digital Imaging and Communications in Medicine (DICOM) files. Patients were excluded if they had a history of previous orthodontic treatment, CO-centric relationship discrepancy, trauma to the dentofacial region, TMJ disorders, and diseases affecting bone metabolism.

Study design

Morphological and morphometric variables were blindly investigated in each patient group. Dolphin© (version 11.9.20; Dolphin Imaging & Management Solutions, Chatsworth, CA, USA) was used for cephalometric analysis. The ITK-SNAP software (version 3.8; Penn Image Computing and Science Laboratory at the University of Pennsylvania, the Scientific Computing and Imaging Institute at the University of Utah) was used for mandible segmentation by outlining the boundaries using semiautomated discrimination procedures to create a 3D standard tessellation language (STL) model of the area of interest. The Meshmixer software (version 3.5 Autodesk open-source) was used to determine the variable locations, shapes, and measurements, and all variables on both sides were evaluated separately. The Frankfort and orbital planes were parallel to the floor (Figure 1).

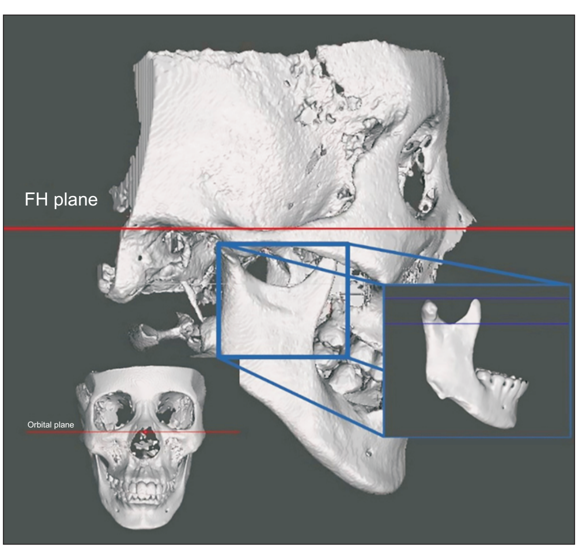

Figure 1. Three-dimensional model orientation: the Frankfort horizontal (FH) and orbital planes parallel to the floor and the sigmoid plane in the box parallel to the Frankfort plane.

Based on previous studies,[18,22,23] the landmarks used for analysis are illustrated in Figures 2 and 3. Condylion (Con) is the most superior point of the head of the mandibular condyle in the sagittal section; condylion lateral (ConL) is the most lateral point of the condyle process in the coronal section; condylion medial (ConM) is the most medial point of the condylion process in the

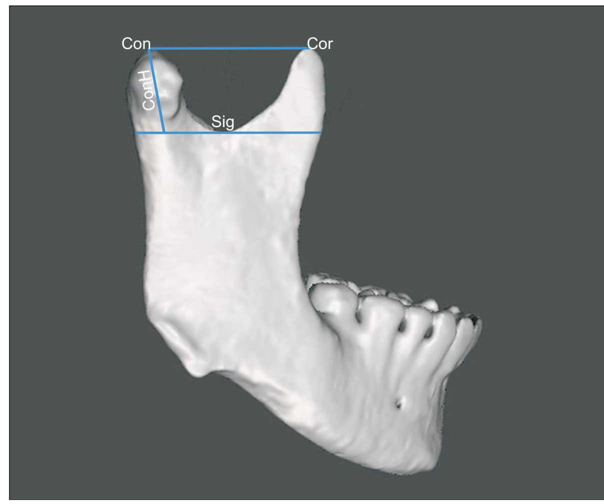

Figure 2. Sagittal view showing the landmarks used for measurements of the mandibular condyle.
Con, the most superior point of the mandibular condyle; Cor, the most superior point of the coronoid process; ConH, a line extending from Con to the sigmoid plane, intersecting the long axis of the mandibular condyle; Sig, sigmoid notch.

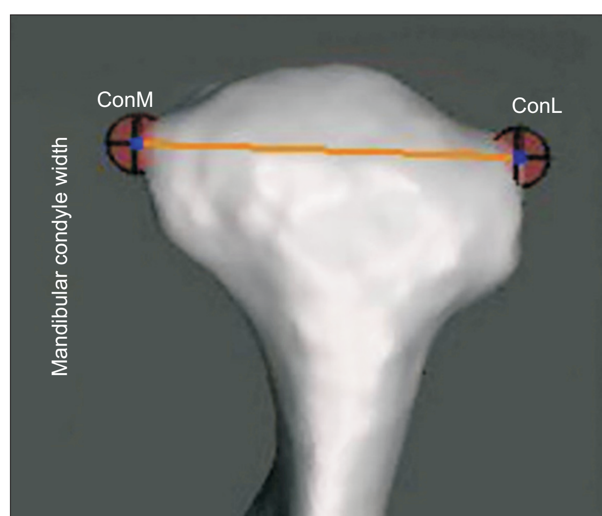

Figure 3. Coronal section of the left mandibular condyle width, which extends from the medial aspect of the condylion (ConM) to its lateral aspect (ConL).

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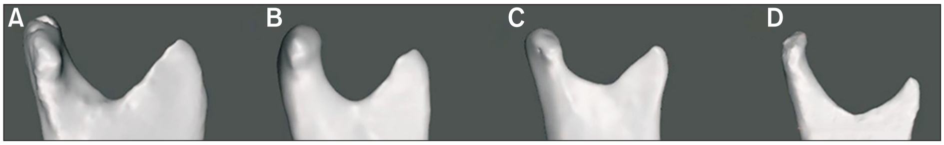

Figure 4. Mandibular condyle shapes. **A**, Bird beak. **B**, Diamond. **C**, Oval. **D**, Crooked finger.

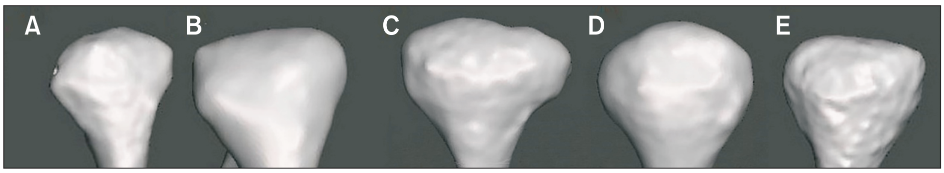

Figure 5. Condylar shapes from the coronal view. **A**, Angled. **B**, Convex. **C**, Concave. **D**, Round. **E**, Flattened.

Table 2. Intraexaminer repeatability test

Variable	Intraclass correlation coefficients	95% confidence interval	
		Lower limit	Upper limit
LCCS	0.95	0.93	0.98
LSCS	0.84	0.75	0.94
LCCW	0.93	0.90	0.96
LSCH	0.94	0.90	0.98
RCCW	0.87	0.82	0.92
RSCH	0.97	0.96	0.99
RCCS	0.80	0.66	0.94
RSCS	0.96	0.93	0.99

LCCS, left coronal condyle shape; LSCS, left sagittal condyle shape; LCCW, left coronal condyle width; LSCH, left sagittal condyle height; RCCW, right coronal condyle width; RSCH, right sagittal condyle height; RCCS, right coronal condyle shape; RSCS, right sagittal condyle shape.

Table 3. Independent *t*-test among male and female

Variable	Sex	Mean	SD	T-value	*p*-value
LCW	M	19.40	2.42	1.73	0.08
	F	18.64	2.55		
LCH	M	19.08	3.38	0.67	0.50
	F	18.69	3.23		
RCW	M	19.14	2.44	0.79	0.42
	F	18.80	2.39		
RCH	M	18.97	3.01	0.27	0.78
	F	18.82	3.14		

SD, standard deviation; M, male; F, female; LCW, left condylar width; LCH, left condylar height; RCW, right condylar width; RCH, right condylar height.

coronal section; sigmoid point (Sig) is the deepest point of the sigmoid notch of the mandible, which represents the sigmoid plane; the line passing from the condylion to the mandibular notch plane along the long axis of the condylar process is the ConH line; and the condylar width (ConL-ConM) line connects the most lateral and medial points of the condyle. Figures 4 and 5 show the morphological shapes of the mandibular condyle in sagittal and coronal sections.

Statistical analysis

The sample distributions are listed in Table 1. One investigator collected all measurements from the 135 participants. To evaluate intraexaminer reliability, the same examiner re-analyzed 20 randomly selected participants within a 3-week interval. The measures were evaluated using intraclass correlation coefficients. The results show good intraexaminer repeatability (Table 2). SPSS software (version 24.0 for Windows; IBM Corp., Armonk, NY, USA) was used for statistical analysis. The Shapiro–Wilk normality test was performed on continuous variables with a normal distribution pattern. We used an independent sample *t*-test to compare the participants' mean condylar height and width by sex (Table 3), while an ANOVA test was used to compare the mean values of the mandibular condyle height and width in various skeletal patterns and age groups (SN-MP, ANB) (Tables 4–6); Scheff's post hoc test was used when the ANOVA test was significant (Tables 4–6). The chi-square test was used to evaluate the prevalence of condyle shape in coronal and sagittal sections and determine whether there is a statistical association among different sexes, skeletal patterns, and age groups (Tables 7–10). Statistical significance was set at $p < 0.05$.

RESULTS

The mean values of the mandibular condyle height and width among males were more prominent than those among females; there was a significant difference in condylar height ($p < 0.05$) in different (ANB) groups (Table 4), and the mean condylar height values in Class III malocclusion were more prominent than those in

Table 4. ANOVA of the mandibular condylar height and width in different sagittal skeletal patterns

Variables	ANB groups	Mean	SD	*p*-value†	Mean difference			*p*-value‡
LCW	Class I	18.85	2.36	0.454	Class I	Class II	0.18	0.942
	Class II	18.66	2.71			Class III	−0.46	0.683
	Class III	19.32	2.48		Class II	Class I	−0.18	0.942
						Class III	−0.65	0.476
LCH	Class I	18.49	3.17	0.000***	Class I	Class II	0.84	0.438
	Class II	17.65	3.07			Class III	−1.92	0.015
	Class III	20.41	3.05		Class II	Class I	−0.84	0.438
						Class III	−2.76	0.000***
RCW	Class I	18.84	2.20	0.510	Class I	Class II	0.14	0.963
	Class II	18.70	2.64			Class III	−0.42	0.703
	Class III	19.27	2.38		Class II	Class I	−0.14	0.963
						Class III	−0.56	0.538
RCH	ClassI	18.74	2.72	0.000***	Class I	Class II	1.15	0.168
	Class II	17.58	3.11			Class III	−1.58	0.037
	Class III	20.32	2.81		Class II	Class I	−1.15	0.168
						Class III	−2.74	0.000***

ANOVA, analysis of variance; ANB, A point-nasion-B point; SD, standard deviation; LCW, left condylar width; LCH, left condylar height; RCW, right condylar width; RCH, right condylar height.
***$p < 0.001$.
†ANOVA test was performed.
‡Scheff's post hoc test was performed.

Table 5. ANOVA of the mandibular condylar height and width in different vertical skeletal patterns

Variables	SN-MP groups	Mean	SD	*p*-value†	Mean difference			*p*-value‡
LCW	Hypodivergent	19.25	2.03	0.553	Hypodivergent	Normodivergent	0.28	0.861
	Normodivergent	18.96	2.51			Hyperdivergent	0.66	0.555
	Hyperdivergent	18.59	2.98		Normodivergent	Hypodivergent	−0.28	0.861
						Hyperdivergent	0.37	0.784
LCH	Hypodivergent	18.87	3.23	0.986	Hypodivergent	Normodivergent	0.06	0.995
	Normodivergent	18.80	3.29			Hyperdivergent	−0.04	0.998
	Hyperdivergent	18.92	3.44		Normodivergent	Hypodivergent	−0.06	0.995
						Hyperdivergent	−0.11	0.987
RCW	Hypodivergent	19.31	2.01	0.276	Hypodivergent	Normodivergent	0.30	0.837
	Normodivergent	19.01	2.45			Hyperdivergent	0.91	0.295
	Hyperdivergent	18.40	2.67		Normodivergent	Hypodivergent	−0.30	0.837
						Hyperdivergent	0.60	0.489
RCH	Hypodivergent	18.87	2.88	0.999	Hypodivergent	Normodivergent	−0.01	1.000
	Normodivergent	18.89	2.90			Hyperdivergent	−0.01	1.000
	Hyperdivergent	18.88	3.65		Normodivergent	Hypodivergent	0.01	1.000
						Hyperdivergent	0.00	1.000

ANOVA, analysis of variance; SN, sella-nasion plane; MP, mandibular plane; SD, standard deviation; LCW, left condylar width; LCH, left condylar height; RCW, right condylar width; RCH, right condylar height.
†ANOVA test was performed.
‡Scheff's post hoc test was performed.

Table 6. ANOVA of the mandibular condyle height and width in different age groups

Variables	SN-MP groups	Mean	SD	*p*-value†	Mean difference			*p*-value‡
LCW	Group 1 ≤ 20 yr	18.31	2.28	0.233	Group 1 ≤ 20 yr	21 yr ≤ Group 2 < 30 yr	–0.88	0.238
	21 yr ≤ Group 2 < 30 yr	19.2	2.38			Group 3 ≥ 30 yr	–0.72	0.550
	Group 3 ≥ 30 yr	19.04	3.13		21 yr ≤ Group 2 < 30 yr	Group 1 ≤ 20 yr	0.88	0.238
						Group 3 ≥ 30 yr	0.15	0.963
LCH	Group 1 ≤ 20 yr	18.57	3	0.844	Group 1 ≤ 20 yr	21 yr ≤ Group 2 < 30 yr	–0.39	0.844
	21 yr ≤ Group 2 < 30 yr	18.97	3.21			Group 3 ≥ 30 yr	–0.3	0.942
	Group 3 ≥ 30 yr	18.87	3.95		21 yr ≤ Group 2 < 30 yr	Group 1 ≤ 20 yr	0.39	0.844
						Group 3 ≥ 30 yr	0.09	0.991
RCW	Group 1 ≤ 20 yr	18.14	2.07	0.084	Group 1 ≤ 20 yr	21 yr ≤ Group 2 < 30 yr	–1.06	0.099
	21 yr ≤ Group 2 < 30 yr	19.21	2.32			Group 3 ≥ 30 yr	–1.04	0.257
	Group 3 ≥ 30 yr	19.18	2.9		21 yr ≤ Group 2 < 30 yr	Group 1 ≤ 20 yr	1.06	0.099
						Group 3 ≥ 30 yr	0.02	0.990
RCH	Group 1 ≤ 20 yr	18.44	3.04	0.501	Group 1 ≤ 20 yr	21 yr ≤ Group 2 < 30 yr	–0.46	0.767
	21 yr ≤ Group 2 < 30 yr	18.91	2.96			Group 3 ≥ 30 yr	–0.95	0.504
	Group 3 ≥ 30 yr	19.4	3.48		21 yr ≤ Group 2 < 30 yr	Group 1 ≤ 20 yr	0.46	0.767
						Group 3 ≥ 30 yr	–0.49	0.789

ANOVA, analysis of variance; SN, sella-nasion plane; MP, mandibular plane; SD, standard deviation; LCW, left condylar width; LCH, left condylar height; RCW, right condylar width; RCH, right condylar height.
†ANOVA test was performed.
‡Scheff's post hoc test was performed.

Table 7. Chi-square test; prevalence of mandibular condyle shapes by sex

Variables	Shape	Sex				Total (%)	*p*-value	
		Male		Female			Left	Right
		Left (%)	Right (%)	Left (%)	Right (%)			
Coronal condyle shape	Angled	22.2	22.2	24.7	25.9	24.0	0.336	0.283
	Concave	5.6	5.6	7.4	7.4	6.6		
	Convex	44.4	44.4	29.6	28.4	35.1		
	Flattened	7.4	7.4	4.9	4.9	5.9		
	Round	20.4	20.4	33.3	33.3	28.1		
Sagittal condyle shape	Bird beak	20.4	20.4	13.6	22.2	18.9	0.701	0.987
	Crooked finger	7.4	7.4	9.9	7.4	8.1		
	Diamond	20.4	18.5	18.5	19.8	19.3		
	Oval	51.9	53.7	58.0	50.6	53.7		

Class I and II malocclusions (Table 4). There were no differences between the mean condylar height and width values in the SN-MP groups (Table 5). Table 6 presents the mean condylar height and width values among different age groups, with no significant differences among the age groups. The chi-square test results based on sex (Table 7), skeletal pattern (Tables 8 and 9), and age (Table 10) showed that the most prevalent shape of the condyle in the coronal view was convex (35.1%); the convex shape was also the most prevalent among males (44.4%) and in the Class I (33.3%), Class II (35.6%), Class III (36.7%), hypodivergent (31.4%), normodivergent (35.6%), and hyperdivergent (38.2%) groups. The most prevalent condylar shape among females was round (33.3%). In the sagittal view, the prevalence of the oval condyle shape was 53.7% overall, 52.7% among males, 54.3% among females, 50% in the Class I, 45.5% in the Class II, 65% in the Class III, 58.5% in the hypo-

Table 8. Chi-square test; prevalence of mandibular condyle shapes by the sagittal skeletal pattern

Variable	Shapes	Class I		Class II		Class III		Total (%)	*p*-value	
		Left (%)	Right (%)	Left (%)	Right (%)	Left (%)	Right (%)		Left	Right
Coronal condyle shape	Angled	15.6	15.6	26.7	26.7	28.9	31.1	24.0	0.487	0.450
	Concave	11.1	11.1	6.7	6.7	2.2	2.2	6.6		
	Convex	33.3	33.3	35.6	35.6	37.8	35.6	35.1		
	Flattened	8.9	8.9	6.7	6.7	2.2	2.2	5.9		
	Round	31.1	31.1	24.4	24.4	28.9	28.9	28.1		
Sagittal condyle shape	Bird beak	15.6	20.0	22.2	33.3	11.1	11.1	18.9	0.726	0.118
	Crooked finger	8.9	6.7	8.9	6.7	8.9	8.9	8.1		
	Diamond	24.4	24.4	17.8	20.0	13.3	15.6	19.3		
	Oval	51.1	48.9	51.1	40.0	66.7	64.4	53.7		

Table 9. Chi-square test; prevalence of mandibular condyle shapes by the vertical skeletal pattern

Variable	Shapes	Hypodivergent		Normodivergent		Hyperdivergent		Total (%)	*p*-value	
		Left (%)	Right (%)	Left (%)	Right (%)	Left (%)	Right (%)		Left	Right
Coronal condyle shape	Angled	28.6	28.6	27.3	28.8	11.8	11.8	24.0	0.196	0.181
	Concave	8.6	8.6	7.6	7.6	2.9	2.9	6.6		
	Convex	31.4	31.4	36.4	34.8	38.2	38.2	35.1		
	Flattened	5.7	5.7	1.5	1.5	14.7	14.7	5.9		
	Round	25.7	25.7	27.3	27.3	32.4	32.4	28.1		
Sagittal condyle shape	Bird beak	11.4	17.1	13.6	21.2	26.5	26.5	18.9	0.516	0.862
	Crooked finger	11.4	8.6	10.6	9.1	2.9	2.9	8.1		
	Diamond	17.1	17.1	19.7	19.7	20.6	20.6	19.3		
	Oval	60.0	57.1	56.1	50.0	50.0	50.0	53.7		

Table 10. Chi-square test; prevalence of the mandibular condyle shapes by age

Variable	Shapes	Age ≤ 20 yr		21 yr ≤ Age < 30 yr		Age ≥ 30 yr		Total (%)	*p*-value	
		Left (%)	Right (%)	Left (%)	Right (%)	Left (%)	Right (%)		Left	Right
Coronal condyle shape	Angled	26.5	26.5	23.7	25	20	20	24.0	0.253	0.255
	Concave	0.0	0.0	7.9	7.9	12	12	6.6		
	Convex	35.3	35.3	36.8	35.5	32	32	35.1		
	Flattened	8.8	8.8	6.6	6.6	0.0	0.0	5.9		
	Round	29.4	29.4	25	25	36	36	28.1		
Sagittal condyle shape	Bird beak	17.6	23.5	11.8	15.8	28	36	18.9	0.394	0.363
	Crooked finger	2.9	2.9	11.8	9.2	8	8	8.1		
	Diamond	17.6	17.6	19.7	19.7	20	20	19.3		
	Oval	61.8	55.9	56.6	55.3	44	36	53.7		

divergent, 53% in the normodivergent, and 50% in the hyperdivergent groups. Chi-square test results showed no statistically significant associations of the mandibular condyle shapes in different sections with sex or skeletal pattern ($p > 0.05$).

DISCUSSION

Our study investigated the morphology and morphometrics of the mandibular condyle. Several previous anthropological studies[18,20,22,23,25] have investigated the morphological shapes of the mandibular condyle based on sex; however, no study has attempted to identify the morphological variations in the condyle between different sagittal and vertical skeletal malocclusions. Lopez et al.[25] and Ishwarkumar et al.[20] found that the mandibular condyle height and width were more prominent in males than in females. Previous studies[16,26] have reported a greater mandibular condyle volume among skeletal Class III malocclusion patients. Noh et al.[17] observed that the condylar height and width were greater in Class III malocclusion than in Class II malocclusion, and the condylar width of hypodivergent patients was greater than that of hyperdivergent patients. In line with previous studies, the current research indicates that the condylar height of patients with Class III malocclusion is greater than that of patients with Class I and II malocclusion. We found that the condylar width was more prominent in Class III malocclusion than in Class I and II malocclusions and greater in the hypodivergent group than in the normodivergent and hyperdivergent groups. These findings may indicate that there is excessive vertical development of the mandibular ramus in patients with Class III malocclusion. It is likely that condylar height plays an essential role during the development of Class III malocclusion but has no impact on vertical skeletal malocclusions. In the current study, patients ≤ 20 years had a lower condylar height than those > 20 years. Although this difference was not statistically significant, it might be related to late mandibular condyle growth. Wolff's law[27] states that bone morphology and internal architecture depend on the load applied to the bone. Previous studies have found that hypodivergent patients have higher maximum bite forces.[28,29] In contrast, hyperdivergent patients have weaker bite forces during clenching and chewing because of decreased muscle tonicity;[30] thus, it may affect the mandibular condyle shape viewed in sagittal or coronal sections because of different loads applied by the masticatory muscles. Our findings contradicted the hypothesis as no statistical association was found between the mandibular condyle shape and different groups of sex, age, and sagittal and vertical skeletal patterns. Tassoker et al.[18] and Yale et al.[31] observed the that the condylar shape was predominantly convex in the coronal view. Similarly, we found that the most prominent shape of the mandibular condyle is convex and has no clinical association with sex, age, or sagittal and vertical skeletal malocclusions. Previous anthropological studies[18,21,23,32-34] reported that the round/oval shape of the mandibular condyle is the most common in sex from the sagittal view. Vahanwala et al.[35] and Anisuzzaman et al.[36] reported that most common condylar shape was oval (> 60%) and the least common was the crooked-finger shape (2%). Our study found that the most common condylar shape from the sagittal view was oval shape (53.7%) and the least common was the crooked finger shape (8.1%). The morphological shape of the condyle showed no statistical association with sex, age, and sagittal and vertical skeletal malocclusions. However, it might be related to TMJ spaces where the crooked finger-shaped condyle had the smallest size in comparison with that of condyles with other shapes. The differences in the measurements might be attributed to racial diversity, sample size, and study design. Our findings suggest no association between mandibular condyle shape variations and sex, age, and sagittal and vertical skeletal malocclusion. At the same time, there was a statistically significant relationship between the mandibular condyle height and skeletal sagittal malocclusion, suggesting that the mandibular condyle growth potential in Class III malocclusion was higher than that in Class I and II malocclusion patients.

A potential limitation of our study is an insufficient age group distribution, which might have affected the accuracy of our results. Future studies on the morphological shapes of the mandibular condyle and their relation to the TMJ and dysfunctions are necessary.

CONCLUSIONS

This study morphologically and morphometrically evaluated the relationship between mandibular condyles and various skeletal malocclusion patterns in adults, using CBCT.

- There were no statistical associations between the morphological shapes of the mandibular condyle and sex and sagittal and vertical skeletal malocclusions.
- The mandibular condyle height was greater in Class III malocclusion than in Class I and II malocclusions.
- The mandibular condyle width of males was greater than that of females.

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AUTHOR CONTRIBUTIONS

Conceptualization: LW, WBZ, AMM, AAN, JY. Data curation: AMM, JY, CC, AAN. Formal analysis: LW, WBZ, AMM, AAN, JY. Funding acquisition: LW, WBZ. Methodology: LW, WBZ, AMM. Project administration: LW, WBZ. Visualization: LW, WBZ. Writing–original draft:

AMM. Writing–review & editing: LW, WBZ, JY, AAN, CC.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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