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A 3D cone beam computed tomography (CBCT) investigation of mandibular condyle morphometry: Gender determination, disparities, asymmetry assessment and relationship with mandibular size

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KEYWORDS

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Abstract *Objective:* CBCT (cone beam computed tomography) analysis of condyle morphometry, to investigate the gender differences, symmetry and relationship with mandibular size.

Materials and methods: This is a retrospective study. 800 CBCT scan obtained for the measurement of condyle in anterior-posterior and medio-lateral aspect using OnDemand 3D software. Participants were Saudi nationals of age above 18 years. 395 Males and 405 Females with the mean age of 38.2 ± 10.5 years. Right and left anterior-posterior width and medio-lateral width of the condyle were measured. Condyles were not isolated on the CBCT for volume measurement.

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Results: Mean right and anterior-posterior condyle width was 9.02 mm and 8.74 mm in males whereas in females it was 9.01 mm 8.69 mm respectively. For males mean medio-lateral width of the condyle in right and left side was 17.40 mm and 16.95 mm. For females, mean medio-lateral width of the condyle in right and left side was 17.14 mm and 16.93 mm. The prediction rate of gender was 57.2% for males and 53.3% for females. Statistically significant differences ($p < 0.05$) were found in the anterior–posterior and medio-lateral width of right and left condyles among males and females. Left anterior-posterior and medio-lateral width of average vs small mandible shows statistically significant difference ($p < 0.05$).

Conclusion: Condyle morphometry is a weak predictor for gender. Irrespective of gender, right and left condyle are asymmetrical in relation to condyle morphometry of anterior-posterior and medio-lateral aspect. Left mandibular condyle morphometry is different in relation to the mandible size.

1. Introduction

The mandibular condyle shows variations in its appearance which may be as a result of subtle variations that are bound to exist during normal development or adaptive condylar remodelling to meet developmental changes, trauma, malocclusion, developmental anomalies, etc. (Shakya et al., 2013). The mandibular condyle may vary to a great extent in its appearance from one individual to another and between different age groups. Hence, to differentiate a normal variant from that of an abnormal condyle, a thorough knowledge of the structure, anatomy and morphology becomes very important. Many studies have evaluated if there is any correlation between the anatomy of TMJ and TMD and have established that there is definite association between TMD and dental occlusion, occlusal curvatures and the inclination of the articular eminence (Kanavakis and Mehta, 2013). The human condylar size ranges between 15 and 20 mm and 8–10 mm mediolaterally and anterio-posteriorly (Standring et al., 2005). Condyle is the area of interest for anthropologists, and it has been proposed that size of the condyle in males is greater than females (Hinton, 1983). The morphology, dimensions and relationship between the component tissues of TMJ may vary to a considerable extent. Such variation may act as a vital factor in the diagnosis of the TMD (Sahithi et al., 2016).

Tadej et al proposed that the condylar size exhibited sexual dimorphism with males having larger condyles than the females and that with growth, major changes in its size occurs

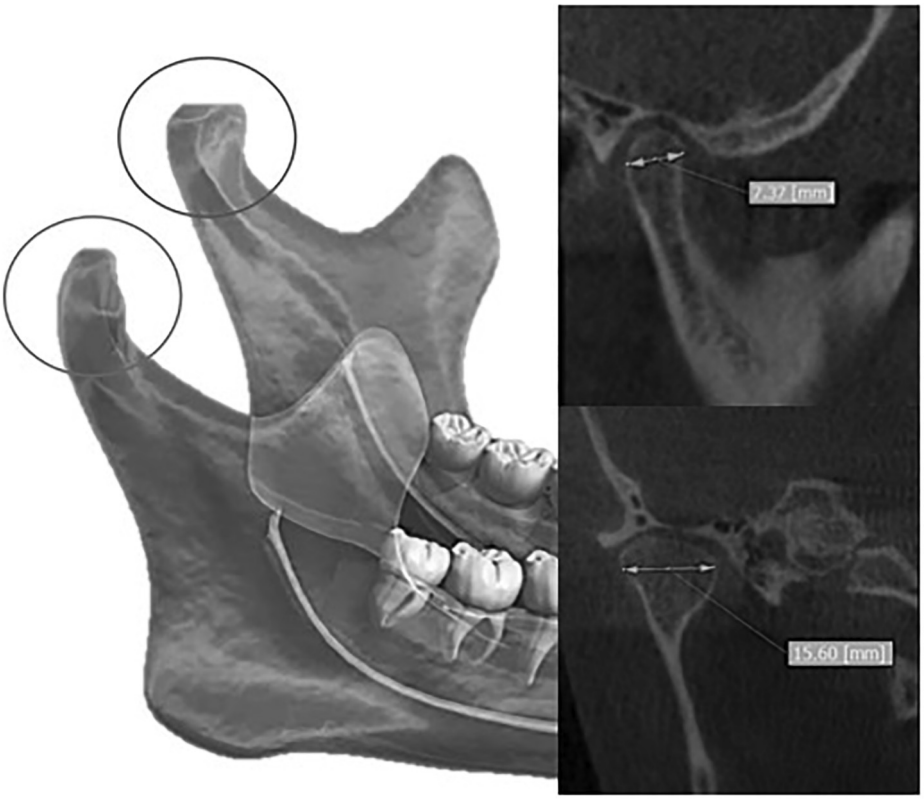

Fig. 1 Mandibular condyle morphometry.

in medio-lateral dimension than in its antero-posterior dimension (Tadej et al., 1989). Condylar dimensions may be more accurately measured and analyzed by CBCT. Neto et al reported that growth condyles were symmetric in the age group below 20 years with the changes occurring in frontal dimension during growth (Valladares Neto et al., 2010). Recent reports evaluated only the dimensional changes of condyle, without any comparison in relation to mandible size, however mandible size is an important predictor for gender prediction.

We hypothesize that differences in the condyle size exists between males and females, size of condyle would predict the gender and symmetry between right and left condyles. Hence, the objectives of this study were to -

(1) analyze gender differences
(2) explore gender determination probabilities
(3) assess asymmetry
(4) explore relationship with the mandible size

2. Materials & methods

Ethical clearance has been obtained from the local committee of bioethics (LCBE) with the approval number of 9-16-8/39. CBCT scans were collected from the archive (2015–2018) of the radiology department, College of Dentistry, Jouf University, based on the inclusion criteria;

- Age: Above 18 years
- High volumetric CBCT data

The syndromic patients, craniofacial deformity, previous history of craniofacial surgery, facial asymmetric, history of TMD and mandibular trauma cases were excluded from the study. It was ensured that all the CBCT scans were taken by the same radiographer (2015–2018) under the standard settings with the teeth in centric occlusion.

CBCT images acquired were analyzed using the On-Demand 3D software (Seoul, Korea) for effective exposure time 2.4–6 s with FOV as 7.5x10. The present retrospective study was done on total of 800 CBCT scans which were taken for the purpose of implant, maxillofacial surgical and orthodontic therapy.

2.1. Measurement of condyle

The CBCT images of frontal and lateral views of the condyles were taken for measuring the condylar dimensions between the anatomical landmarks, considering the greatest dimensions between them (Fig. 1) as proposed by Schleuter et al. as shown in Table 1.

2.2. Sample size calculations

Sample size was determined as per the recommendations of Hair et al (Hair et al., 1998) in which at least 200 samples are needed for each independent variable in the multiple discriminant analysis. In this study, four independent variables were considered in discriminate analysis ($4 \times 200 = 800$), so final sample size was determined as 800.

Table 1 Demographic data, Selection Criteria and Armamentarium.

Selection Guideline	Good quality CBCT with high volumetric data and patients without craniofacial deformity and history of any surgical procedure
Study design	Retrospective study
Sample selection	943 CBCT were assessed for eligibility. Finally, 800 CBCT were selected based on selection guideline
Age	38.2 ± 10.5 years old (Mean ± SD)
Gender	Male = 395 Female = 405
Measurements of Variables	
m (medial condylar surface)	most medial point of the mandibular condyle on the frontal view.
l (lateral condylar surface)	most lateral point of the mandibular condyle on the frontal view.
a (anterior condylar surface)	most anterior point of the mandibular condyle on lateral view.
p (posterior condylar surface)	most posterior point of the mandibular condyle on lateral view.
Rap	Anterior posterior width of condyle measured on right side
Lap	Anterior posterior width of condyle measured on left side
Rml	Medio-lateral width of condyle measured on right side
Lml	Medio-lateral width of condyle measured on left side
Armamentarium	1. CBCT 2. OnDemand 3D software (Seoul, Korea). 3. Statistical Package for the Social Sciences (version 22, SPSS Inc, Chicago, USA).
Ethical consideration	The study was approved by the ethics committee of the College of Dentistry, Aljouf University, Sakaka, KSA.

2.3. Statistical analysis

Statistical software for Social Sciences was used to analyze the data collected (SPSS, Chicago, IL, USA). Descriptive statistics were done initially, independent samples 't' test was used to compare mean values between males and females. Discriminant function analysis was used for the gender prediction. Paired 't' test was used to compare between right and left side and ANOVA with multiple comparison test was used to find the relationship with the mandible size. p value ≤ 0.05 was considered as statistically significant for all comparisons. 20% of the CBCT scan were randomly selected, re-measurements were done after 2 weeks of interval. Intra-class correlation coefficient (ICC) was used to test the error.

Table 2 Discriminate analysis of measured variables of condyles and gender disparities.

Variables	Gender	Mean	SD	95% CI		p value
				Lower	Upper	
Rap	Male	9.028	0.969	−0.231	0.261	0.906
	Female	9.013	0.926	−0.229		
Lap	Male	8.745	0.862	−0.161	0.268	0.623
	Female	8.692	0.778	−0.156		
Rml	Male	17.400	1.600	−0.137	0.654	0.199
	Female	17.142	1.407	−0.124		
Lml	Male	16.955	1.231	−0.295	0.341	0.885
	Female	16.931	1.235	−0.295		

SD: Standard deviation; CI: Confidence Interval.

Table 3 Box's M statistics for Gender identification& prediction accuracy.

Box's M 15.527	F			
	Approximate	df1	df2	p
	1.523	10	9.8	0.124
Prediction accuracy	Male	Female	Overall	
	57.2%	53.3%	55.2%	

Table 4 Canonical discriminant function.

Parameters	Unstandardized coefficients	Sectioning point	
		Male	Female
Rap (Anterior posterior width of condyle measured on right side)	−0.800	0.128	−0.222
Lap (Anterior posterior width of condyle measured on left side)	0.542		
Rml (Medio-lateral width of condyle measured on right side)	1.402		
Lml (Medio-lateral width of condyle measured on left side)	−1.266		

3. Results

Average ICC value of all 4 variables was 0.934, which depicts excellent reliability of the measurements. Table 2 show the descriptive measurements of discriminant analysis and the gender disparities. Mean value comparison shows statistically insignificant. The Box's M statistics was applied to verify the condyle morphometry in gender prediction. Values indicate that gender can be predicted using these four variables which is statistically significant (p = < 0.001) [Table 3]. Unstandardized coefficient values obtained from Canonical Discriminant Function Coefficients [Table 4] were used in gender prediction. The estimated gender was calculated using the following equation N = −17.3 + (0.31x Gn-M0) + (0.149x RtGn-M) + (0.86x Lt Gn-M) + (−0.07x RtGn- Lt Gn). The sectioning (Eigen) value for gender prediction was 0.128, if the calculated value is 0.12 or above, then that condyle belongs to Male and for Females it is below 0.12 [Table 4]. Considering the four independent variables, 57.2% of males were correctly classified and 53.33% were correctly classified as females and overall prediction accuracy of this model is 55.2% (Table 3). The difference between the right and left condyle morphometry in antero-posterior and medio-lateral aspect were found to be statistically significant (p < 0.05). [Table 5]. In relation to 3 different mandible size, Lap and Lml showed significant differences among average vs small mandible (Table 6).

4. Discussion

The present study is largest ever 3D CBCT done on such a huge sample size. The mandibular condyle may vary to a great extent from one person to another and with age in its appearance. In addition, the variation in the morphology of the con-

Table 5 Asymmetry assessment.

Paired Variable	Mean	SD	95% CI		P value
			Lower	Upper	
Rap - Lap	0.29553	0.48744	0.23506	0.35601	< 0.001
Rml - Lml	0.36142	0.72292	0.27174	0.45111	< 0.001

SD: Standard deviation; CI: Confidence Interval.

Table 6 Mandibular condyle morphometry in relation to different mandibular size.

Variables	Mandible Size	Mean	SD	Multiple Comparisons Bonferroni			95% CI Lower	95% CI Upper	p value
Rap	Av.Mn	9.170	0.987	Av.Mn	Vs	L.Mn	−0.205	0.365	1.000
	L.Mn	9.091	0.890	Av.Mn	Vs	S.Mn	−0.042	0.544	0.121
	S.Mn	8.920	0.952	L.Mn	Vs	S.Mn	−0.086	0.428	0.331
Lap	Av.Mn	8.875	0.917	Av.Mn	Vs	L.Mn	−0.171	0.329	1.000
	L.Mn	8.796	0.762	Av.Mn	Vs	S.Mn	0.015	0.530	0.034*
	S.Mn	8.602	0.817	L.Mn	Vs	S.Mn	−0.031	0.419	0.117
Rml	Av.Mn	17.588	1.554	Av.Mn	Vs	L.Mn	−0.304	0.613	1.000
	L.Mn	17.434	1.486	Av.Mn	Vs	S.Mn	−0.072	0.872	0.127
	S.Mn	17.188	1.496	L.Mn	Vs	S.Mn	−0.168	0.659	0.462
Lml	Av.Mn	17.278	1.234	Av.Mn	Vs	L.Mn	−0.129	0.610	0.354
	L.Mn	17.037	1.222	Av.Mn	Vs	S.Mn	0.139	0.900	0.003**
	S.Mn	16.758	1.189	L.Mn	Vs	S.Mn	−0.055	0.611	0.135

SD: Standard deviation; CI: Confidence Interval, Av.MN: Average mandible size, L.Mn; Large mandible size, S.Mn: Small mandible size, vs: Versus.

dyle may depend on a variety of factors such as the gender of the individual, age, functional and occlusal load, facial and malocclusion type, and between the two sides (Kilic et al., 2008, Laster et al., 2005, Yale et al., 1966). A study by Matsumoto et al had shown that the mean values of both antero-posterior and medio-lateral dimension of the condyle was slightly more in the males as compared to that in the females. However, they were not statistically significant between the sexes (Matsumoto and Bolognese, 1995). In the present study, results showed that gender prediction accuracy using condyle morphometry is 57.2% for males and 53.3% (Table 5). These findings are in accordance with the results of present study as the gender prediction rate is nearly the same for the males and females. According to a study by Christiansen and Thompson, it was shown that in all normal adult joints, the transverse condylar dimension was substantially higher in men (19.6 mm) as compared that in women (17.7 mm) (Cristiansen and Thompson, 1990). The findings of our study are similar to their study as the condyle width in medio-lateral is more in males when compared to females (Table 2). In a study by Ishwar Kumar et al, it was noted that the antero-posterior condylar length was 9.23 mm and 9.57 mm in males and 8.73 mm and 8.66 mm in females on the right and left sides' respectively (Ishwarkumar et al., 2016). Our study noted that the anteroposterior condylar length to be 9.02 ± 0.96 mm and 8.74 ± 0.86 mm in males and 9.01 ± 1.92 mm and 8.69 ± 1.77 mm in females on the right and left sides respectively which was similar to their study. Condylar height between the males and females and has shown that there was significant difference ($p < 0.05$) in the height of the mandibular condyle on both right and left sides (Chaurasia and Giri, 2017). Our study showed a significant difference between the sides in both anteroposterior and mediolateral dimensions of the mandibular condyle which was in accordance with their study. Tadej reported that midline discrepancy with malocclusion significantly caused an alteration in condylar size during growth period (Tadej et al., 1989). Large mandibles are associated with Class III malocclusion and small mandibles with class II malocclusion. Moreover, skeletal malocclusion depends on size of maxilla, mandible and both in relation to cranial base. It is inevitable to do assessment solely based on mandibular morphology. Direct comparisons in relation to mandible size and condyle dimensions cannot be compared with any other study as this study is first of its kind. We therefore encourage such similar studies to confirm the present findings and to correlate them to gender, facial patterns and condyle types.

5. Conclusion

Gender prediction is a sub-discipline of the forensic sciences and it is of utmost importance for differentiating the gender in criminal law cases, social benefits, employment. Condyle morphometry is a weak predictor for gender. Irrespective of gender, right and left condyle are asymmetrical in relation to condyle morphometry of anterior-posterior and medio-lateral aspect.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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