Condylar Size and Position, Comparison among Different Sagittal Skeletal Relationships: A CBCT Study

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ABSTRACT

Objective: To compare the size and spatial position of mandibular condyles among different sagittal skeletal patterns using CBCT imaging.

Study Design: A cross-sectional study.

Place and Duration of the Study: Department of Orthodontics, Armed Forces Institute of Dentistry, Rawalpindi, Pakistan, from 20th March 2021 to 4th January 2022.

Methodology: CBCT scans of 66 subjects (33 males, 33 females) were divided into three equal groups on basis of sagittal skeletal relationships (Class I, Class II, and Class III). Condylar size and position were determined using the method described by Hilgers *et al.* and Ricketts *et al.* respectively. Independent samples t-test was applied to compare condylar size and position variables between the right and left condyles and between male and female subjects. All study groups were compared using ANOVA and Post Hoc Tukey's test.

Results: In males, the condylar size was larger and condyles were slightly more anteriorly positioned. Condylar width and height were smallest in skeletal Class II relation and largest in skeletal Class III relation. Regarding the condylar position, the anterior distance was investigated to be the smallest in Class II. The posterior distance was lesser in skeletal Class I subjects whereas the superior distance was lesser in Class III subjects. Angle of articular eminence was greater in class I, intermediate in class II, and lower in class III. Height of articular eminence was the lowest in Class III subjects.

Conclusion: Statistically significant differences existed for the size and position of mandibular condyles among different sagittal skeletal relationships.

Key Words: *Temporomandibular joint, Condylar position, Condylar size, Sagittal skeletal relationships, CBCT.*

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INTRODUCTION

The knowledge of morphology and position of mandibular condyle improves the understanding of normal craniofacial growth as well as temporomandibular joint pathology. A thorough evaluation of temporomandibular joints is essential from a clinical perspective and is necessary for the establishment of functional occlusion and a balanced stomatognathic system.[1] Therefore, in patients with a history of signs and symptoms of TMDs, caution is required when planning and executing orthodontics.

Morphology and position of TMJs are important features regarding the stability of orthodontic treatment[2] and can be affected by several factors including age, gender, growth pattern, functional loading, masticatory and muscular activity, and occlusal alterations.[3,4]

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Mechanical and functional alterations can lead to remodelling of TMJ bony surfaces and condyle behaves as a site of compensatory growth under functional loading. Type of malocclusion can also affect the morphology and position of temporomandibular joint.[5,6] Park *et al.* showed that condylar morphology and position alter in different vertical facial patterns and found statistically significant variation between hypodivergent and hyperdivergent groups.[7] Discrepancies in the sagittal skeletal pattern might affect the morphology and spatial position of adjacent hard tissue structures such as temporomandibular joints and can lead to its alteration.

Various methods have been used to analyse the morphology of temporomandibular joints such as the study of autopsy human skulls, histology and microscopy, radiographic techniques, computed tomography, and magnetic resonance imaging. Two-dimensional radiography has limitations as compared to three-dimensional imaging such as distortion, magnification, superimpositions of multiple osseous structures, and lack of ability to view three-dimensional changes in size and shape.[8] CBCT provides multiplanar high-resolution images with low radiation exposure and is an investigation of choice for the assessment of temporomandibular osseous structures. The development of three-dimensional imaging has contributed to the diagnosis, treatment planning, management, and prognosis of disease processes.[9]

The objective of this study was to compare the size and spatial position of condyles among different sagittal skeletal patterns using CBCT imaging.

METHODOLOGY

This cross-sectional study was undertaken at the Orthodontics Department, Armed Forces Institute of Dentistry (AFID), Rawalpindi after taking ethical approval from the Ethical Review Committee of the Institute (Ref. Letter No. 905/Trg-ABP1K2). A total sample size of 66 subjects was determined using the G Power software, keeping the value of effect size as 0.40, alpha error as 0.05 and power as 0.80.

Based on the sagittal skeletal relationship determined by Steiner's ANB angle, the sample was divided into three equal groups with 22 subjects each having skeletal class I (ANB: 0° to 4°), skeletal class II (ANB: 5° to 10°), and skeletal class III (ANB: −1° to −6°).

The sample was selected using the non-probability consecutive sampling method and included adult patients with ages ranging from 18 to 35 years, subjects having a full set of permanent dentitions with teeth in maximum intercuspation, subjects with no history of temporomandibular joint dysfunction and mandibular deformity and subjects without any history of previous orthodontic or orthopaedic treatment.

Exclusion criteria consisted of subjects with a history of systemic diseases, congenital syndromes, craniofacial deformities, cleft lip and palate, subjects with condylar abnormalities such as hyperplasia, elongation, resorption, erosions or osteophytes and subjects with facial asymmetry.

CBCT images used for the study were taken from available diagnostic records of patients currently under treatment at the Orthodontic Department. CBCT images were taken using the Carestream imaging system (CS 9000 3D imaging system, New York, USA) with a tube voltage of 85kV, tube current of 12mA, and exposure time was 10.8 seconds and voxel size was 76 x 76 x 76 µm.

The CBCT image of the skull was oriented parallel to the Frankfurt plane (Orbitale- Porion). ANB angle was measured in the sagittal view at the midsagittal plane cut. Using a custom TMJ slicing option on axial view scan at the same level, 3D image slices of right and left condyles were obtained in anteroposterior and coronal views keeping zoom at 1.5 mm and slice thickness of 300 µm (Figure 1). Linear distances and angles for condylar size and position were measured on anteroposterior and coronal 3D cropped condylar images.

Superior mandibular condyle point (SC) was the most superior point on the convexity of condylar head in the sagittal view. Anterior mandibular condyle point (AC) was the most anterior extent of condylar head located 4 mm inferior to superior condyle point in the sagittal view. Posterior mandibular condyle point (PC) was the most posterior extent of condylar head located 4mm inferior to superior condyle point in sagittal view. Lateral mandibular condyle point (LC) was the most lateral extent condylar head viewed coronally. Medial mandibular condyle point (MC) was the most medial extent of condylar head viewed coronally. Inferior sigmoid notch (InfSig) was the most inferior apex on concavity between coronoid and condylar process of mandible in sagittal view. Superior glenoid fossa point (SG) was the point of greatest concavity of the glenoid fossa. Anterior glenoid fossa point (AG) was the point on the anterior wall of glenoid fossa closest to the anterior mandibular condyle point. Posterior glenoid fossa point (PG) was the point on the posterior wall of glenoid fossa closest to the posterior mandibular condyle point. Tangent to posterior slope of eminence (PE´) was the line tangential to the posterior wall of the articular eminence. Tangent to inferior edge of eminence (IE´) was the line parallel to the Frankfurt plane passing through the lower edge of the articular eminence.

The condylar size was evaluated using landmarks described above. Linear distances used to determine the condylar size are described in Figure 2 as proposed by Hilgers *et al.*[10] The condylar position was evaluated using the landmarks described above. Linear distances and angular measurements were used to establish the spatial position of the condyle as proposed by Ricketts (Figure 2).[11]

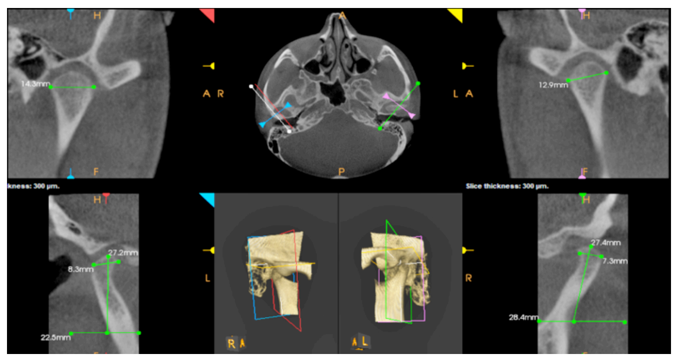

Figure 1: TMJ custom slicing using CBCT to obtain anteroposterior and coronal three-dimensional views of mandibular condyles.

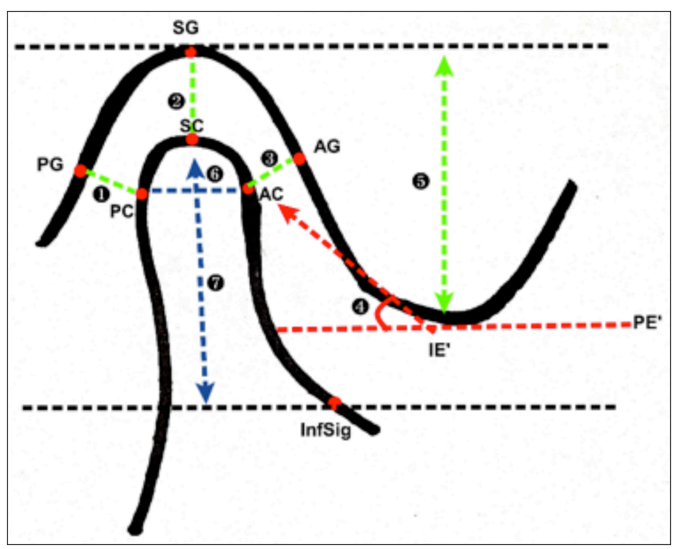

Figure 2: Schematic diagram to depict measurements used to determine condylar size and position on sagittal view (1) Posterior Distance PC-PG, (2) Superior Distance SC-SG, (3) Anterior Distance AC-AG, (4) Angle of Eminence PE'-IE', (5) Height of Eminence SG-IE', (6) Condylar length PC-AC, (7) Condylar height SC-InfSig).

Table I: The difference in condylar size and position variables between male and female subjects.

Variables	Gender	N	Mean	Std. Deviation	t	p-value
Condylar Width	Male	33	15.48	1.8	4.020	<0.001*
	Female	33	13.70	1.6		
Condylar Length	Male	33	8.02	0.4	6.693	<0.001*
	Female	33	7.34	0.4		
Condylar Height	Male	33	21.03	2.6	2.837	0.006*
	Female	33	19.01	3.1		
Anterior Distance	Male	33	2.71	0.5	-2.926	0.005*
	Female	33	3.05	0.4		
Posterior Distance	Male	33	11.09	1.1	0.427	0.671
	Female	33	10.97	1.1		
Superior Distance	Male	33	6.14	0.9	0.225	0.822
	Female	33	6.06	1.7		
Angle of Eminence	Male	33	35.33	3.9	0.934	0.354
	Female	33	34.18	5.8		
Height of Eminence	Male	33	6.77	0.8	-0.338	0.736
	Female	33	6.85	1.1		

*Independent samples t-test. *p-value ≤0.05.*

Table II: ANOVA analysis for comparison of mandibular condylar size and position among various sagittal skeletal patterns.

Condylar Size and Position	Class I n= 22	Class II n= 22	Class III n= 22	Minimum	Maximum	F	p-value
Condylar Width	14.79 ± 1.1	12.83 ± 1.5	16.16 ± 1.7	10.4	19.4	28.828	<0.001*
Condylar Length	7.75 ± 0.6	7.77 ± 0.6	7.54 ± 0.2	6.8	8.7	1.307	0.278
Condylar Height	19.65 ± 2.4	17.93 ± 2.0	22.47 ± 2.8	15.4	26.9	19.675	<0.001*
Anterior Distance	3.09 ± 0.4	2.61 ± 0.6	2.96 ± 0.3	1.7	3.7	6.048	0.004*
Posterior Distance	10.5 ± 1.4	11.29 ± 0.6	11.31± 0.8	7.4	12.9	4.500	0.015*
Superior Distance	6.69 ± 1.2	6.19 ± 1.0	5.43 ± 1.7	1.8	8.5	5.001	0.010*
Angle of Eminence	38.45 ± 4.4	34.55 ± 4.1	31.27 ± 3.7	26	45	16.916	<0.001*
Height of Eminence	7.06 ± 0.7	7.31± 0.6	6.08 ± 1.2	4.0	8.0	12.150	<0.001*

*ANOVA test. *p-value ≤0.05.*

Condylar length (PC-AC): The linear distance between the posterior mandibular condyle point and the anterior mandible condyle point in the sagittal plane.

Condylar width (MC-LC): The linear distance between the medial mandibular condyle point and the lateral mandible condyle point in the coronal plane.

Condylar height (SC-InfSig): Perpendicular linear distance from superior mandible condyle point (SC) to tangent constructed from the most inferior point of coronoid sigmoid notch (InfSig) parallel to the true horizontal line.

Superior distance (SC-SG): Upper distance from the highest part of the condyle to the deepest part of the glenoid fossa.

Posterior distance (PC-PG): Posterior distance from the most convex part of the posterior wall of the condyle to line PG on posterior wall of glenoid fossa.

Anterior distance (AC-AG): Anterior distance joining the most convex point on the anterior wall of the condyle with point AG on anterior wall of glenoid fossa.

Angle of Eminence (PE’-IE’): The angle between the tangent passing through the posterior wall of the articular eminence and the IE’ plane parallel to the Frankfurt plane

Height of Eminence (SG-IE’): Height of the eminence from the deepest part of the glenoid fossa SG to the IE′ plane parallel to the Frankfurt plane.

Statistical analysis was carried out using SPSS statistics (version 25.0). To assess the interobserver variation, fifteen CBCT images were randomly selected and condylar size, and position variables were re-measured at two weeks intervals by the same observer. Normality of the data was assessed using the Shapiro-Wilk test (p-value >0.05), indicating that the data was normally distributed. Descriptive statistics were used to analyse qualitative and quantitative variables. Quantitative variables like age, ANB, and condylar size and position variables were measured as mean and standard deviation. Qualitative variables like gender were measured as frequency. Independent samples t-test was applied to evaluate the difference in size and position of mandibular condyles between the right and left sides. Male and female subjects were compared for differences between the condylar size and position variables using independent samples t-test. Comparison of condylar size and position variables among sagittal skeletal patterns was done using ANOVA and Post Hoc Tukey's test. Statistical significance was defined at p-value ≤0.05.

RESULTS

Mean age of the sample was 25.8 ± 5 years. A total sample of 66 subjects was equally divided into three study groups consisting of 22 subjects each. An equal number of male and female subjects (11 males and 11 females) were included in each study group.

Table III: Tukey Post HOC for multiple comparisons.

Dependent Variable	(I) Sagittal Skeletal Relationship	(J) Sagittal Skeletal Relationship	Mean Difference (I-J)	Std. Error	Sig.
Condylar Width	Class I	Class II	1.9545*	.4410	<0.001*
		Class III	-1.3773*	.4410	.008*
	Class II	Class III	-3.3318*	.4410	<0.001*
Condylar Length	Class I	Class II	-.0273	.1599	.984
		Class III	.2091	.1599	.396
	Class II	Class III	.2364	.1599	.308
Condylar Height	Class I	Class II	1.7182	.7310	.056*
		Class III	-2.8227*	.7310	.001*
	Class II	Class III	-4.5409*	.7310	<0.001*
Anterior Distance	Class I	Class II	.4773*	.1421	.004*
		Class III	.1273	.1421	.645
	Class II	Class III	-.3500*	.1421	.043*
Posterior Distance	Class I	Class II	-.7818*	.3036	.033*
		Class III	-.7955*	.3036	.029*
	Class II	Class III	-.0136	.3036	.999
Superior Distance	Class I	Class II	.5000	.4009	.430
		Class III	1.2591*	.4009	.007*
	Class II	Class III	.7591	.4009	.149
Angle of Eminence	Class I	Class II	3.909*	1.236	.007*
		Class III	7.182*	1.236	<0.001*
	Class II	Class III	3.273*	1.236	.027*
Height of Eminence	Class I	Class II	-.2500	.2631	.611
		Class III	.9773*	.2631	.001*
	Class II	Class III	1.2273*	.2631	<0.001*

*Tukey Post Hoc test . *The mean difference is significant at the 0.05 level.*

No statistically significant differences were found in condylar size and position variables between the right and left sides.

Statistically significant gender differences (p <0.05) were found in condylar size variables and anterior distance of condyle from wall of glenoid fossa (Table I). The condylar size was larger in males in all three dimensions i.e., width, length, and height. Condyles in males were positioned slightly anteriorly as compared to females (Table I).

Table II shows ANOVA analysis for the comparison of mandibular condylar size and position among study groups. The difference in condylar width and height was statistically significant in sagittal skeletal patterns (p<0.001). Condylar width and height were smallest in Class II relation and largest in Class III relation. No statistically significant differences in condylar length were shown (p >0.05).

Anterior distance from condyle to articular eminence was significantly different among study groups (p <0.05). The anterior distance was investigated to be the smallest in Class II subjects. Tukey's post hoc test (Table III) suggested statistically significant differences when comparing class I with class II (p = 0.004) and class III with class II (p = 0.043). No statistically significant differences were found when comparing class I with class III (p = 0.645).

The posterior distance was significantly different (p = 0.015) among the three skeletal classes. On comparing, class I with class II and class III statistically significant differences were found in the posterior distance (p = 0.033 and 0.029, respectively). However, no significant differences were found between skeletal class II and III subjects (p = 0.99). The posterior distance was lesser in skeletal class I subjects as compared to skeletal class II and class III.

The superior distance is significantly different among the three skeletal classes (p = 0.010). The superior distance was smallest in class III subjects and largest in class I subjects. A statistically significant difference of superior distance was observed between I and III cases (p = 0.007).

Statistically significant differences (p <0.001) among the study groups were seen in the articular eminence angle as it was higher in sagittal skeletal class I, intermediate in class II and lower in skeletal class III.

Statistically significant differences (p <0.001) were seen in height of articular eminence. It was the smallest in class III subjects. Significant differences were found in the comparison of class III with class I and II (p = 0.001 and <0.001, respectively). However, there were no statistical differences reported between skeletal class I and II cases (p = 0.61).

DISCUSSION

The morphology and spatial position of the mandibular condyle are essential features of TMJ-oriented diagnosis and treatment planning. A sound understanding of TMJ physiology and function is required to diagnose and treat the dysfunction of the masticatory system.

The volume, shape, and size of the mandibular condyle can be affected by resorption, hyperplasia, osteophytes, erosions or sclerosis.[12] The condylar size was reported to vary according to the functional loading of the condyle and was larger in hypodivergent subjects as compared to hyperdivergent subjects[13]

The contribution of condylar position in the functioning of the masticatory system is a topic of vast research and may be related to malocclusion or temporomandibular dysfunction. Pullinger *et al.* concluded the presence of both concentric and eccentric condyles in asymptomatic subjects;[14] however, Insecu *et al.* related posteriorly placed condyles with internal joint derangements.[15]

The present study investigated the differences in both condylar size and position variables of right and left mandibular condyles among various sagittal skeletal dimensions using CBCT images. Knowledge of normal condylar morphology and position is helpful in the identification of joint disease and its relationship with skeletal patterns is of utmost importance for accurate diagnosis in various malocclusions.

The present study suggests gender differences in mandibular condylar size. Condylar size in all three dimensions *i.e*., height, width, and length were larger in male subjects. Similar results of larger condylar sizes in males were reported by Hasebe *et al.* using CBCT imaging and Coogan *et al.* using cadaveric mandibular condyles.[13,16] This difference in condylar size is explained by sexual dimorphism in skeletal size as growth continues for a longer duration in males and they achieve larger bone sizes. Moreover, on comparing the condylar position between genders, anteriorly positioned condyles in males were seen. Various studies show the same trend of anterior positioning of condyles in males as compared to females.[14,17] A possible reason for the anterior positioning of condyles is a tendency towards a straight facial profile and anteriorly placed mandible in males, and a more convex profile with posteriorly placed mandible in females.

The condylar size was compared among various sagittal skeletal patterns using CBCT. Condylar width and height varied significantly among study groups, however, no difference was found in condylar length. Class II malocclusion cases had the smallest condylar sizes while class III malocclusion cases had the largest condylar size. Similar results were obtained in the South East Asian population in the study of condyle morphology using CBCT.[18]

Statistically significant differences in the anterior distance among different anteroposterior skeletal patterns were found. Mean anterior distances show that condyles were placed most anteriorly in skeletal class II cases and most posteriorly positioned in class I. Various studies reported similar results with anteriorly placed condyles in class II cases.[14,19] The greatest decentralisation of condyle was reported in class II malocclusion.[20]

On comparing posterior distances, condyles were positioned most posteriorly in class I whereas there were no significant differences in posterior distance observed between class III and class II subjects. Similar results were concluded by Ricketts when analysing condylar position using TMJ laminography.[11]

In this study, condyles in skeletal Class III cases were found to have smaller superior distances and positioned superiorly placed as compared to class I. No significant differences in superior distances were reported between class I and II study groups. Ricketts and Katsavrias also confirmed more superiorly placed condyles in class III subjects.[11,21] The clinical importance of superior distance is that it indicates morphological changes of condyle as an increase or decrease in distance may be caused by condylar resorption or hyperplasia, respectively.

With regard to articular eminence angle and height, it was suggested that variation in morphology of articular eminence may affect TMJ function.[22] The steepness of eminence was investigated to be a predisposing factor for internal derangements such as disc displacements.[23] The present study revealed that the class III pattern had shallow slopes of articular eminence whereas the class I pattern had the most inclined slopes.

Articular eminence height was smaller in class III malocclusion than other sagittal skeletal patterns whereas no difference in articular eminence height was found between class I and II cases. Similar results regarding the angle and height of eminence were described by Miranda *et al.*[24]

The clinical importance of the present study is that the optimal position of condyle in various sagittal skeletal relationships can be identified and mean values for condylar size and spatial position variables can be defined. Identification of normal size and position of condyle is essential to differentiate from pathological alterations such as degenerative diseases of TMJ. CBCT is an effective tool for assessing normal anatomy and establishing diagnosis of temporomandibular disorders.[25]

The limitations of this study are that the relationship of condylar size and position with vertical facial dimensions was not studied and condylar position in dynamic relation of condyle to glenoid fossa was not observed.

CONCLUSION

Condylar sizes were larger in males than in females. Slightly anterior position of condyles observed in males as compared to females. Condylar size was smallest in the class II pattern group, intermediate in class I, and largest in the skeletal Class III pattern.

In skeletal class II cases, condyles were most anteriorly positioned, whereas in skeletal class I cases condyles were most posteriorly positioned. Most superiorly positioned condyles were found in skeletal class III cases. The slope of articular eminence was shallow in class III cases and steep in class I cases. Lower height of articular eminence was found in class III sagittal skeletal pattern.

ETHICAL APPROVAL:

Ethical Approval was received from the ethical review committee of AFID, Rawalpindi (Ref Letter No: 905/Trg-ABP1K2) on 02-03-2020.

PATIENTS' CONSENT:

Patient's consent was obtained prior to acquiring and reproducing diagnostic records and that no identifying information will be disclosed while publishing data.

COMPETING INTEREST:

All authors certify that they have no affiliations with or involvement in any organisation or entity with any financial or non-financial interest in the subject matter or materials discussed in this manuscript. No funding was received for conducting this study.

AUTHORS' CONTRIBUTION:

QAT, AJ: Conceptualisation, data acquisition, analysis, interpretation, revision and editing.
QAT: Writing original draft of the manuscript.
AJ: Supervision.
All the authors have approved the final version of the manuscript to be published.

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