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ORIGINAL RESEARCH

Improved Visualization and Assessment of Condylar Position in the Glenoid Fossa for Different Occlusions: A CBCT Study

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ABSTRACT

Introduction: The position of the condyle in the glenoid fossa plays an important role in the stability of occlusion after orthodontic treatment. Cone beam computed tomography (CBCT) provides an optimal imaging of the osseous components of the temporomandibular joint (TMJ) and give a full size truly three-dimensional (3D) description in real anatomical size. The present study aimed to visualize and compare the position of condyle in the glenoid fossa for different occlusions by using CBCT.

Materials and methods: Cone beam computed tomographic images of 45 subjects, aged 18 to 42 years, were evaluated. Subjects were equally divided into three groups according to the A point, nasion, B point (ANB) angle.

Results: In the sagittal plane, condyle is positioned nonconcentrically; positioned anteriosuperiorly in class I and III occlusions and lies posteriosuperiorly in class II occlusion. In the frontal plane, condyle is positioned centrally (mediolaterally) in all the three types of occlusions. In the axial plane, the parameters showed significant difference between the different occlusions. No statistical significant distinction could be made in the position of the condyle when comparing the right and left joints.

Conclusion: The position of condyle in glenoid fossa influences sagittal, transverse, and vertical relationships of the jaws which eventually contribute to development of various malocclusions. Nonconcentricity is the feature of the condyle in the sagittal plane in different malocclusions.

Clinical significance: An important consideration in orthodontic treatment is the recognition of the importance that the dentition should be in harmony with the related musculoskeletal structures. Therefore, the condylar position is an important concern in maintaining or restoring temporomandibular harmony with the dentition and the position of the condyle in the glenoid fossa plays an important role in the stability of occlusion after orthodontic treatment.

Keywords: Condyle, Cone beam computed tomography, Glenoid fossa.

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INTRODUCTION

In general, malocclusion is the result of various combinations of underlying dental and skeletal relationships in the craniofacial region.[1] An important consideration in orthodontic treatment is the recognition of the importance that the dentition should be in harmony with the related musculoskeletal structures. Therefore, the condylar position is an important concern for maintaining or restoring temporomandibular harmony with the dentition, and the position of the condyle in the glenoid fossa plays an important role in the stability of occlusion after orthodontic treatment.

As form and function are intimately related to each other, the functional loads applied to the temporomandibular joint (TMJ) might influence its morphology and *vice versa*. The load to which TMJ is subjected varies according to the subject's dentofacial morphologies and different types of malocclusions, which may result in

different shapes of condyle and glenoid fossa.[2] For the establishment of an occlusal harmony, evaluation of the direction of the growth of condyle and its movement in the glenoid fossa play a key role in the establishment of different craniofacial patterns.[3]

The TMJ is a difficult area to investigate radiographically. Conventional radiographic methods show only the two-dimensional images and have limitations for accurately showing the anatomic characteristics of TMJ. This is because TMJ is a small joint with complex morphology surrounded by osseous tissues which produce superimposition of images, particularly the petrous region of the temporal bone, the mastoid process, and the articular eminence.[4,5]

Cone beam computed tomography (CBCT) imaging of the TMJ provides better imaging compared to traditional radiography and helical CT. It shows greater sensitivity and accuracy in the identification of mandibular condyle anatomy and provides high diagnostic quality imaging with lower patient radiation exposure and excellent high-contrast resolution.[6]

Therefore, the present study was designed with the aim to visualize and compare the position of condyle in the glenoid fossa for different occlusions using CBCT.

MATERIALS AND METHODS

Prior to the commencement of the study, all the subjects were informed and consent was obtained. Sample size involved 45 subjects (18–42 years); which were divided into three groups, that is, 15 subjects in each class according to the A point, nasion, B point (ANB) angle: Group I (Skeletal class I), group II (Skeletal class II), and group III (Skeletal class III).

All subjects met the following requirements: All permanent teeth erupted, except third molars; and no functional mandibular deviations, crossbites, open bites, evident facial asymmetry, or temporomandibular disorders.

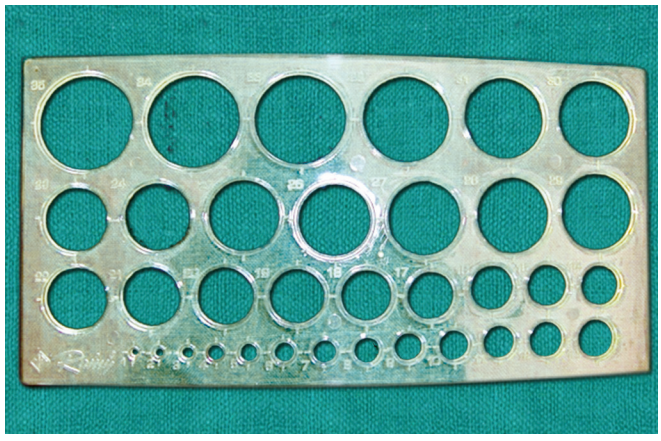


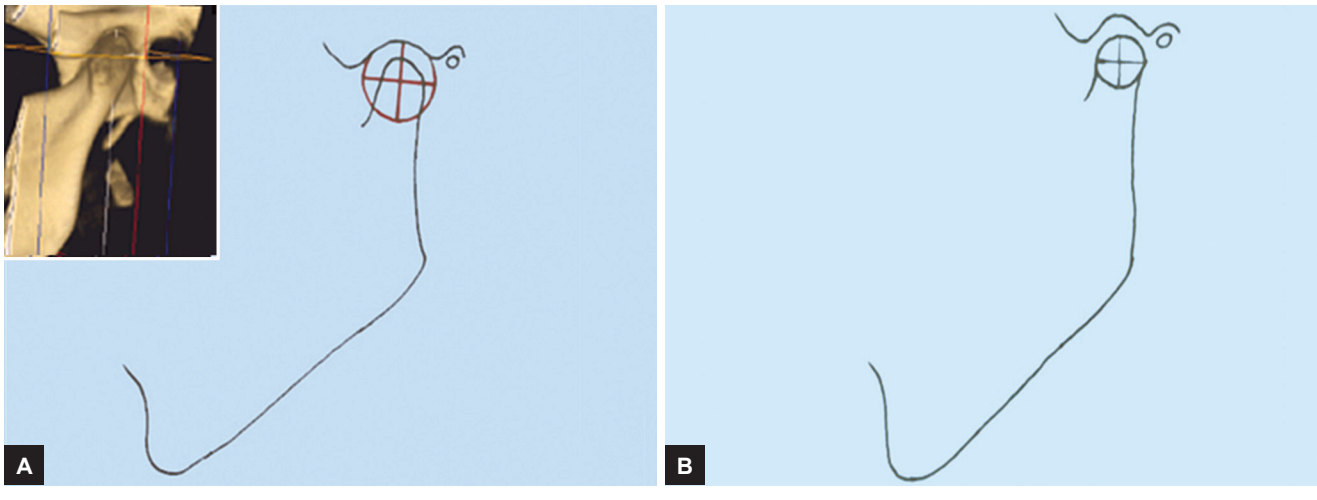
Fig. 1: A template (grid) used for locating the position of condyle in glenoid fossa

Cone beam computed tomography scans were acquired with Kodak CS 9300 CBCT machine (CS9300) manufactured by Carestrem Health, Inc. The CBCT images were obtained with patients in centric occlusion (maximum dental intercuspation), and their heads were positioned so that the midsagittal plane was perpendicular to the floor. The scanning conditions were 85 kVp, 10 mA, and 10 seconds with FOV of 17 × 13.5. Software used in Kodak CS 9300 CBCT machine was Trophy DICOM.

MEASUREMENTS

Measurements made in Sagittal Plane

A template (grid) (Fig. 1) consisting of several circles whose radii are increased in 0.5 mm increments was constructed. By superimposing the largest template circle tangent to the anterior, posterior, and superior borders of the glenoid fossa, the corresponding circle center is identified. This center is taken as the planar geometric center of glenoid fossa (Fig. 2A). Similarly, geometric center of condyle is identified (Fig. 2B).



Figs 2A and B: (A) Locating geometric centers of glenoid fossa in the sagittal plane; and (B) locating geometric centers of mandibular condyle in the sagittal plane

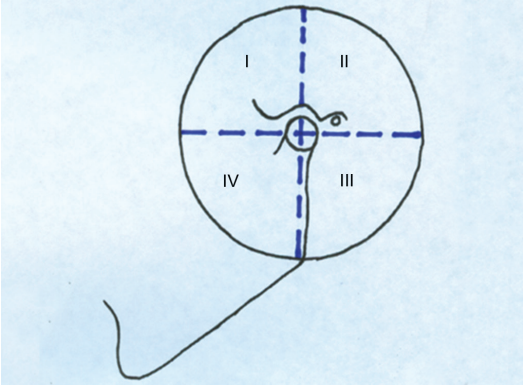
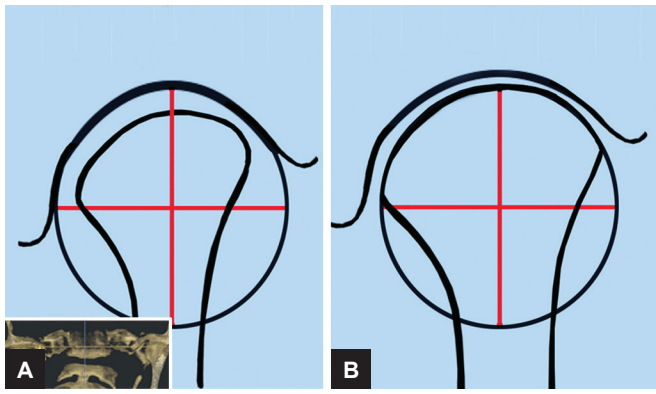


Fig. 3: Coordinate and quadrant relationship of fossa and condyle



Figs 4A and B: (A) Locating geometric centers of glenoid fossa in the frontal plane; and (B) locating geometric centre of mandibular condyle in the frontal plane

Two planar geometric centers are thus identified, and their relationship to each other is described with a rectangular coordinate system. Orthogonal axes were drawn through the glenoid fossa geometric center. The *x* and *y* coordinates of the condyle geometric center are now identified relative to the fossa center. The condyle center is further described as located in quadrant I, II, III, or IV (Fig. 3). Thus, if the condyle is displaced downward and forward, it is described as being in a quadrant IV location. When the geometric centers are not displaced with respect to each other, they are concentric (c).

Measurements made in Frontal Plane

By using the same template and superimposing the largest template circle tangent to the medial, lateral, and superior borders of the glenoid fossa, the corresponding circle center is identified. This center is taken as the planar geometric center of the glenoid fossa (Fig. 4A). Similarly, geometric centre of condyle is identified (Fig. 4B).

As done in sagittal plane, the condyle center is described as located in quadrant I, II, III, or IV (Fig. 5).

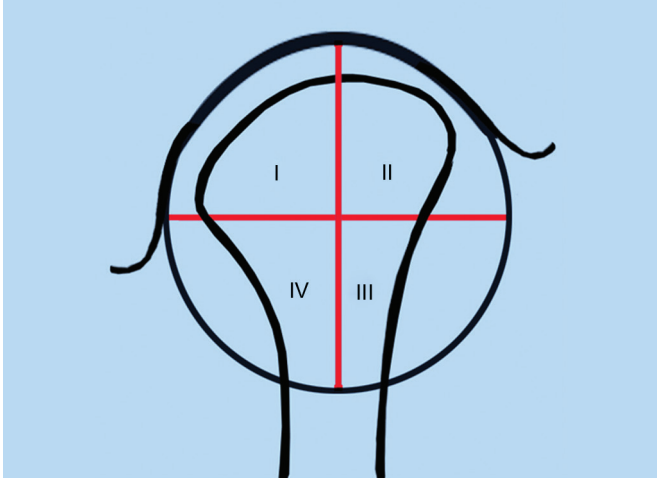


Fig. 5: Coordinate and quadrant relationship of fossa and condyle

Thus, if the condyle is displaced medially and upward, it is described as being in a quadrant I location.

Measurements made in Axial Plane

The following measurements were assessed:

- The greatest mediolateral diameter of the mandibular condylar processes (Fig. 6A).
- The angle between the long axis of the mandibular condylar process and the midsagittal plane (Fig. 6B).

Statistical Analysis

All statistical tests were carried out with statistical software (SPSS for Windows, version 16.0). Descriptive statistics were calculated for each parameter in all the three groups. The comparison between the classes I, II, and III occlusions was performed by a nonparametric test (Chi-square test at $p = 0.05$). Chi-square tests measure of association were computed for significant variables and tested for associations between the three occlusions. The left and right joints were evaluated independently and were compared with each other. *Post hoc* multiple comparisons Bonferroni test was used to test the significance of the difference between the group means in the axial plane.

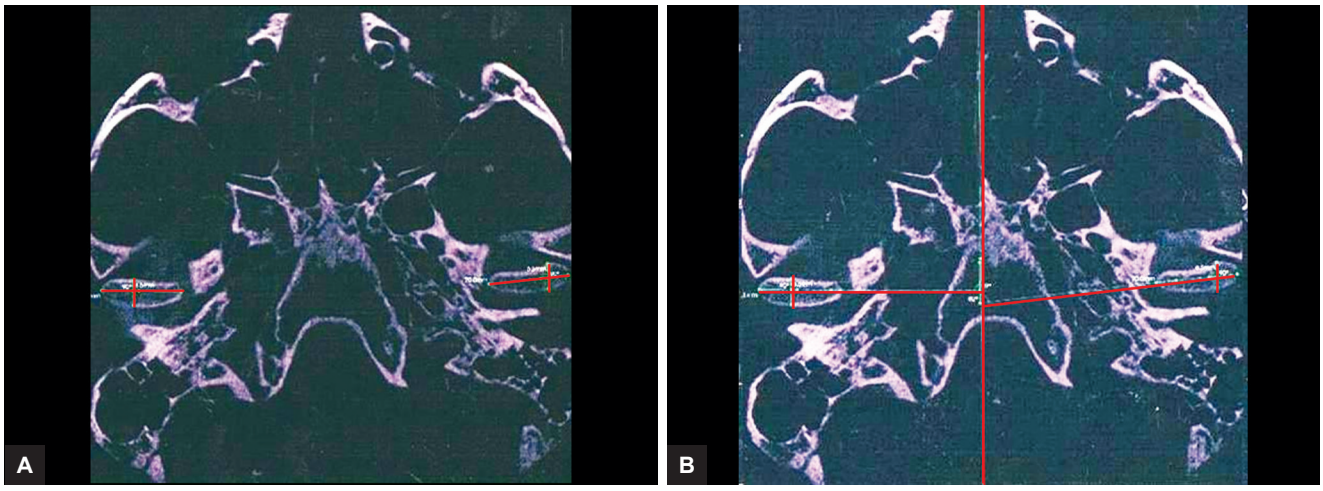
To reduce the method error in defining the different measuring points and reference structures, all CBCT images were analyzed twice by the same examiner within 2-week interval between the recordings. The mean value of the two recordings was taken as the final value.

RESULTS

Results Obtained in the Sagittal Plane

Class I Malocclusion

On right side, 80% of the subjects exhibited superioanterior position of the condyle (quadrant I) which



Figs 6A and B: (A) Axial CBCT image of the TMJ showing greatest mediolateral diameter of the mandibular condylar process; and (B) axial CBCT image of the TMJ showing lateromedial plane angle of the condylar process/midsagittal plane

was statistically significant ($p \leq 0.001$). 6.7% exhibited condyle/fossa concentricity. Rest 13.4% was divided equally exhibiting inferioposterior (quadrant III) position and inferioanterior (quadrant IV) position. Whereas on left side, 73.3% of the subjects exhibited a superioanterior position of the condyle (quadrant I) which was statistically significant ($p = 0.001$). 6.7% exhibited condyle/fossa concentricity. Rest 20.1% was divided equally in quadrant II, III and IV (Table 1).

Class II Malocclusion

On right side, 60% exhibited superioposterior condyle position (quadrant II) which was statistically significant ($p \leq 0.016$); 6.7% exhibited a superioanterior position of the condyle (quadrant I); 13.3% exhibited condyle/fossa concentricity; and 20% exhibited inferioposterior (quadrant III) position of condyle. Whereas on left side 66.7% of the subjects exhibited superioposterior condyle position (quadrant II) which was statistically significant ($p = 0.002$); 6.7% exhibited a superioanterior position of the condyle (quadrant I); 6.7% exhibited condyle/fossa concentricity; and 20% exhibited inferio – posterior (quadrant III) position of condyle (Table 1).

Class III Malocclusion

On right side, 66.7% of the subjects exhibited a superioanterior position of the condyle (quadrant I) which was statistically significant ($p = 0.003$); 13.3% exhibited condyle/fossa concentricity; 6.7% of the subjects exhibited inferioposterior (quadrant III) position; and the remaining 13.3% exhibited inferioanterior (quadrant IV) position. Whereas on left side 66.7% of the subjects exhibited an superioanterior position of the condyle (quadrant I) which was statistically significant ($p = 0.003$); 13.3% exhibited condyle/fossa concentricity; 6.7% of the subjects' exhibited inferioposterior (quadrant III); and 13.3% exhibited inferioanterior (quadrant IV) position of the condyle (Table 1).

Comparing the concentric position of the condyles on the right and left sides, no statistical significant difference was found in all three occlusions (Table 2).

Results Obtained in the Frontal Plane

Class I Malocclusion

On right side, 73.3% of the subjects exhibited condyle/fossa concentricity and the results were statistically significant ($p = 0.001$); 13.3% of the subjects showed medially

Table 1: Position of condyle in the glenoid fossa on right and left sides in sagittal plane[#]

	Quadrant (Count (%))						
Class	*C*	*I*	*II*	*III*	*IV*	*Chi-square value*	*p-value*
Right side							
I	1 (6.7)	12 (80)	0	1 (6.7)	1 (6.7)	24.2	<0.001*
II	2 (13.3)	1 (6.7)	9 (60)	3 (20)	0	10.33	<0.016*
III	2 (13.3)	10 (66.7)	0	1 (6.7)	2 (13.3)	14.06	0.003*
Left side							
I	1 (6.7)	11 (73.3)	1 (6.7)	1 (6.7)	1 (6.7)	26.667	0.001*
II	1 (6.7)	1 (6.7)	10 (66.7)	3 (20)	0	14.6	0.002*
III	2 (13.3)	10 (66.7)	0	1 (6.7)	2 (13.3)	14.067	0.003*

[#]Data Count (Percentage); *p < 0.05– Significant

Table 2: Comparison between right and left side in positioning of condyle in the glenoid fossa in sagittal plane[#]

			Side				
Class	*Quadrant*	*Count (%)*	*Right*	*Left*	*Total*	*Chi-square value*	*p-value*
I	C	Count	1 (6.7)	1 (6.7)	2 (6.7)	0.00	1
	I	Count	12 (80)	11 (73.3)	23 (76.7)	0.043	0.835
	II	Count	0	1 (6.7)	1 (3.3)	0.00	1
	III	Count	1 (6.7)	1 (6.7)	2 (6.7)	0.00	1
	IV	Count	1 (6.7)	1 (6.7)	2 (6.7)	0.00	1
II	C	Count	2 (13.3)	1 (6.7)	3 (10)	0.33	0.564
	I	Count	1 (6.7)	1 (6.7)	2 (6.7)	0.00	1
	II	Count	9 (60)	10 (66.7)	19 (63.3)	0.053	0.819
	III	Count	3 (20)	3 (20)	6 (20)	0.00	1
III	C	Count	2 (13.3)	2 (13.3)	4 (13.3)	0.00	1
	I	Count	10 (66.7)	10 (66.7)	20 (66.7)	0.00	1
	III	Count	1 (6.7)	1 (6.7)	2 (6.7)	0.00	1
	IV	Count	2 (13.3)	2 (13.3)	4 (13.3)	0.00	1

[#]Data Count (Percentage); *p < 0.05- Significant

Table 3: Position of condyle in the glenoid fossa on right and left sides in frontal plane [#]

	Quadrant (Count (%))						
Class	*C*	*I*	*II*	*III*	*IV*	*Chi-square value*	*p-value*
Right side							
I	11 (73.3)	2 (13.3)	2 (13.3)	0	0	26.67	0.001*
II	10 (66.7)	3 (20)	2 (13.3)	0	0	24.2	<0.01*
III	11 (73.3)	3 (20)	1 (6.7)	0	0	26.46	0.002*
Left side							
I	11 (73.3)	3 (20)	1 (6.7)	0	0	26.46	0.002*
II	11 (73.3)	2 (13.3)	2 (13.3)	0	0	26.67	0.001*
III	10 (66.7)	3 (20)	2 (13.3)	0	0	24.2	<0.01*

[#]Data Count (Percentage); *p<0.05– Significant

placed condyle (quadrant I), and 13.3% showed laterally positioned condyle (quadrant II). On left side, 73.3% of the subjects exhibited condyle/fossa concentricity and the results were statistically significant (p = 0.002); 20% of the subjects showed medially placed condyle (quadrant I); and 6.7% showed laterally positioned condyle (quadrant II) (Table 3).

Class II Malocclusion

On right side, 66.7% of the subjects exhibited condyle/fossa concentricity and the results were statistically significant (p ≤ 0.01); 20% of the subjects showed medially placed condyle (quadrant I), and 13.3% showed laterally positioned condyle (quadrant II). On Left side, 73.3% of the subjects exhibited condyle/fossa concentricity and the results were statistically significant (p = 0.001); 13.3% of the subjects showed medially placed condyle (quadrant I); and 13.3% showed laterally positioned condyle (quadrant II) (Table 3).

Class III Malocclusion

On right side, 73.3% of the subjects exhibited condyle/fossa concentricity and the results were statistically significant (p = 0.002); 20% of the subjects showed medially placed condyle (quadrant I); and 6.7% showed laterally positioned condyle (quadrant II). Whereas, on left side, 60% of the subjects exhibited condyle/fossa concentricity and the results were statistically significant (p ≤ 0.01); 20% of the subjects showed medially placed condyle (quadrant I); and 20% showed laterally positioned condyle (quadrant II) (Table 3).

Comparing the concentric position of the condyles on the right and left sides, no statistical significant difference was found in all three occlusions (Table 4).

Results obtained in the Axial Plane

Class I Malocclusion

For the mediolateral diameter of the condylar processes, mean value was 18.45 mm, and the measurement for the angle between the plane of the largest mediolateral diameter of the condylar processes and the midsagittal plane was 70.13° (Table 5).

Comparison of the right side with the left side showed that (Table 6):

For the mediolateral diameter of the condylar processes, the mean values were 18.43 mm for the right side

Table 4: Comparison between right and left side in positioning of condyle in the glenoid fossa in frontal plane[#]

Class	Quadrant	Count (%)	Side		Chi-square value	p-value
			Right	Left		
I	C	Count	11 (73.3)	11 (73.3)	0.00	1
	I	Count	2 (13.3)	3 (20)	0.091	0.763
	II	Count	2 (20)	1 (6.7)	0.091	0.763
	III	Count	0	0	0.00	1
	IV	Count	0	0	0.00	1
II	C	Count	10 (66.7)	11 (73.3)	0.333	0.564
	I	Count	3 (20)	2 (13.3)	0.077	0.782
	II	Count	2 (13.3)	2 (13.3)	0.00	1
	III	Count	0	0	0.00	1
	IV	Count	0	0	0.00	1
III	C	Count	11 (73.3)	9 (60)	0.333	0.564
	I	Count	3 (13.3)	3 (13.3)	0.00	1
	II	Count	1 (6.7)	3 (13.3)	0.091	0.763
	III	Count	0	0	0.00	1
	IV	Count	0	0	0.00	1

[#]Data Count (Percentage); *p < 0.05- Significant

Table 5: Comparison between different skeletal classes in axial plane

	Class I				Class II				Class III				
	95% Confidence Interval of the Difference				95% Confidence Interval of the Difference				95% Confidence Interval of the Difference				
	Mean	SD	Lower	Upper	Mean	SD	Lower	Upper	Mean	SD	Lower	Upper	p-value
M-L diameter of condyle	18.45	2.306	17.59	19.31	16.25	1.894	15.54	16.96	18.85	1.312	18.36	19.34	<0.001*
Angle,midsagittal plane	70.13	5.538	68.07	72.20	72.73	7.076	70.09	75.38	76.03	7.107	73.38	768.69	0.004*

*p<0.05- Significant; **p<0.01- Highly Significant

Table 6: Comparison between right and left sides in different skeletal classes in axial plane

Class		Mean Right	Mean Left	SD Right	SD Left	95% Confidence Interval of the Difference		p-value
						Lower	Upper	
I	M-L diameter of condyle	18.43	18.47	2.329	2.364	–0.377	0.297	0.803
	Angle, midsagittal plane	72.33	70.13	5.108	6.128	–0.0563	4.456	0.055
II	M-L diameter of condyle	16.21	16.29	1.947	1.907	–0.194	0.048	0.215
	Angle, midsagittal plane	73.93	71.53	7.787	6.323	–0.414	5.214	0.089
III	M-L diameter of condyle	18.89	18.81	1.374	1.295	–0.068	0.228	0.267
	Angle, midsagittal plane	76.80	75.27	6.721	7.630	–0.325	3.392	0.099

*p<0.05- Significant

and 18.47 mm for the left side; which was not statistically significant (p = 0.803).

The mean values for the angle between the plane of the largest mediolateral diameter of the condylar processes and the midsagittal plane were 72.33° for the right side and 67.93° for the left side, which was not statistically significant (p = 0.336).

Class II Malocclusion

For the mediolateral diameter of the condylar processes, mean value was 16.25 mm and the measurement for the angle between the plane of the largest mediolateral diameter of the condylar processes and the midsagittal plane was 72.13° (Table 5).

Comparison of the right side with the left side showed that (Table 6):

For the mediolateral diameter of the condylar processes, the mean values were 16.21 mm for the right side and 16.29 mm for the left side, which was not statistically significant (p = 0.215).

The mean values for the angle between the plane of the largest mediolateral diameter of the condylar processes and the midsagittal plane were 73.93° for the right side and 71.53° for the left side, which was not statistically significant (p = 0.089).

Class III Malocclusion

For the mediolateral diameter of the condylar processes, mean value was 18.85 mm, and the measurement for the angle between the plane of the largest mediolateral diameter of the condylar processes and the midsagittal plane was 76.03° (Table 5).

Comparison of the right side with the left side showed that (Table 6):

For the mediolateral diameter of the condylar processes, the mean values were 18.89 mm for the right side and 118.81 mm for the left side, which was not statistically significant (p = 0.267).

The mean values for the angle between the plane of the largest mediolateral diameter of the condylar processes and the midsagittal plane were 76.80° for the right side and 75.27° for the left side, which was not statistically significant (p = 0.099).

DISCUSSION

The TMJ is a difficult area to investigate radiographically. Cone beam computed tomography is a new technique which produces reconstructed images of high diagnostic quality using lower radiation doses and allows simultaneous visualization of both right and left TMJs. The TMJ status may not be correctly represented when viewed only in one dimension, indicating the need to assess in multiple dimensions. Cone beam computed tomography allows visualization of the joint in different planes (sagittal, frontal, and axial), possible.

The sagittal plane is considered as the most appropriate plane for assessing the condyle–fossa relationship. It allows analysis of condylar concentricity in different occlusions. Assessment of condylar position in sagittal plane for different malocclusions showed that the condyle is positioned anteriosuperiorly in class I occlusion. These results are in agreement with the previous study.[4]

In class II occlusion, results of the present study showed that the condyle is posteriosuperiorly positioned in the glenoid fossa. These findings corroborated previous reports.[1,7-10] However, a previous study[11] reported nonconcentric condylar positioning with more anterior positioned condyle was a feature of patients with class II Division 1 occlusion than in those with class I, whereas another study[12] stated that there was no significant difference in condylar position between class I and II occlusions.

The conflicting results of these studies are due to the fact that different measuring methods were used for assessment of condylar position. Other possible reasons could be different age distributions, and different criteria for assessing skeletal or dental relationships. Almost all these previous studies relied on linear or area measurements of the joint spaces to assess condylar position.

In class III occlusion, the condyle is positioned more anteriosuperiorly in the glenoid fossa which supported the findings of previous studies.[2,7,12,13] Thus, a positive corelation between condylar position and the skeletal relationship of the jaws had been shown in the present study. This is in accordance with another study.[14]

Frontal plane allows assessment of condylar and glenoid fossa morphology in the medial–lateral orientation in the same image, thereby allowing the comparison between the right and left sides. Results of the present study showed that the condyle is concentrically positioned mediolaterally in the glenoid fossa irrespective of the type of malocclusion present. Similar results were reported by a study conducted previously.[15]

The axial plane is considered as the most appropriate plane to assess the symmetry between the condyles because it shows both condyles in the same image and allows the determination of reference planes, such as the median sagittal plane. This also permits measuring the real dimensions of the condyles and their angulations.

In the present study, mediolateral dimensions of the condyle and angulation of the condylar processes in relation to the median sagittal plane showed significant difference between class I, II, and III malocclusions. These results were similar to the findings of a previous study.[5]

Evaluation of the concentric position of the condyles on the right and left sides in their respective mandibular fossae showed no significant difference between the right and left sides in all the three planes irrespective of the type of malocclusion present which supports the findings of previous studies.[5,9,16,17] Similarly, in the axial plane, comparison of mediolateral dimensions and angulation of the condylar processes in relation to the median sagittal plane on the right and left sides showed no significant difference between the two sides.

However, a previous study[12] reported that there were large variations in the spatial relationships within TMJs, and none of the patients had two perfectly centered condyles. This observation was made in relation to the mandibular fossa from anterior and posterior joint spaces. Therefore, the author stated that this conclusion was questionable, for the alteration can be due to asymmetries in the positioning and dimensions of the mandibular fossa.

CONCLUSION

Nonconcentricity is the feature of the condyle in the sagittal plane in different malocclusions, and the position of condyle in glenoid fossa influences sagittal, transverse, and vertical relationships of the jaws which eventually contribute to development of various malocclusions.

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