TURKISH JOURNAL of ORTHODONTICS

DOI: 10.5152/TurkJOrthod.2022.21136

Original Article

The Correlation Between Morphologic Characteristics of Condyle and Glenoid Fossa with Different Sagittal Patterns of Jaw Assessed by Cone-Beam Computed Tomography

Navid Kariminasab[1], Zahra Dalili Kajan[2], Arefeh Hajian-Tilaki[3,4]

[1]Department of Orthodontics, Faculty of Dentistry, Guilan University of Medical Sciences, Rasht, Iran
[2]Dental Sciences Research Center, Department of Maxillofacial Radiology, Faculty of Dentistry, Guilan University of Medical Sciences, Rasht, Iran
[3]Oral Health Research Center, Health Research Institute, Babol University of Medical Science, Babol, Iran
[4]Department of Orthodontics, Faculty of Dentistry, Babol University of Medical Sciences, Babol, Iran

Cite this article as: Kariminasab N, Dalili Kajan Z, Hajian-Tilaki A. The correlation between morphologic characteristics of condyle and glenoid fossa with different sagittal patterns of jaw assessed by cone-beam computed tomography. *Turk J Orthod.* 2022;35(4):268-275.

Main Points

- Glenoid fossa depth and glenoid fossa width were significantly different between different sagittal skeletal groups.
- There was a significant difference between articular eminence inclination of different sagittal skeletal patterns of jaw.
- No significant difference was found between the three groups in terms of the condylar position related to the glenoid fossa.

ABSTRACT

Objective: This study aimed to determine the relationship between the morphologic characteristics of condyle and glenoid fossa in different sagittal skeletal patterns using cone-beam computed tomography.

Methods: In this cross-sectional study, the lateral cephalometric and cone-beam computed tomography images of 90 patients were evaluated. The patients were categorized into three equal groups of sagittal skeletal patterns, according to the ANB angle. The greatest anteroposterior and mediolateral diameters of the mandibular condyles, as well as the angle between the long axis of the mandibular condyles and the midsagittal plane, were measured on the axial view of cone-beam computed tomography images. The anterior joint space, superior joint space, posterior joint space, articular eminence inclination, depth of the glenoid fossa, and width of the glenoid fossa were also measured on the central sagittal slices. One-way analysis of variance (ANOVA), Tukey's post hoc test and chi-square test were performed.

Results: Patients with the skeletal Class III had a significantly higher articular eminence inclination, while Class II patients had a lower articular eminence inclination ($P = .001$). In Class III patients, the depth of the glenoid fossa was greater, and the width of the glenoid fossa was smaller than in the other groups ($P < .01$). The anterior and posterior joint space did not show any significant differences between the 3 groups.

Conclusion: There were significant differences in some morphological characteristics of the condyle and glenoid fossa in patients with different sagittal skeletal patterns; therefore, this relationship should be considered in the treatment of these patients.

Keywords: Mandibular condyle, glenoid cavity, temporomandibular joint, cone-beam computed tomography, sagittal skeletal pattern

INTRODUCTION

The temporomandibular joints (TMJ) connect the mandible to the skull through the condyle in the glenoid fossa against the articular eminence of the temporal bone.[1] The mandibular condyles, similar to other TMJ structures, are essential in creating a balanced occlusion and stomatognathic system.[2] Different factors, including age, gender, the pattern of facial growth, pathological and functional changes, and dental occlusion changes, can

Corresponding author: Arefeh Hajian-Tilaki, e-mail: dr.arefehajian@yahoo.com

Received: August 19, 2021
Accepted: February 25, 2022
Publication Date:
December 30, 2022

affect the TMJ morphology and position.[2-4] As a result of these changes, the re-modeling of the TMJ surface occurs as an adaptive reaction.[5]

Articular eminence is a region of the temporal bone that forms the anterior limit of glenoid fossa and the condylar process slides on it during different movements of mandible.[6,7] The articular eminence inclination is an essential factor in the biomechanics of TMJ and varies among different people. It represents the path of condylar movements and the amount of disk rotation on the condyle.[7-9] Different imaging modalities, such as panoramic imaging, lateral TMJ radiography, computed tomography (CT), cone-beam computed tomography (CBCT), and magnetic resonance imaging (MRI), can be used for evaluating the TMJ morphology.[2,10-12]

The use of conventional radiography has some inherent limitations, such as superimpositions of the surrounding structures, which can cause difficulties in the precise visualization of the condyles.[2,13,14] Among different imaging techniques, CBCT has some advantages over traditional two-dimensional radiography. It has been shown that CBCT produces three-dimensional images with high resolution, without magnification or distortion, and provides an estimate of the quantity and quality of bones.[11,12] The shorter scan time, lower absorbed dose of patients, and lower costs in contrast to CT imaging are among the other advantages of CBCT.[10-14]

Based on previous studies, the glenoid fossa and condyle shape may differ in people with various types of malocclusions. The data from some investigations report a significant association between different skeletal pattern and morphologic characteristics of TMJ.[2,13,15-18] In contrast, some studies have shown that the craniofacial morphology does not influence the morphology and position of the condylar area.[14,19,20] Since a long facial pattern can influence the condylar rotation, a vertical facial pattern may be an effective factor in the condyle-glenoid fossa relationship.[10] To eliminate this effect, the investigation of patients with a normal vertical skeletal pattern should be considered.

It seems that the sagittal jaw discrepancies and the morphology of the condyle and glenoid fossa may be related; however, there is controversial information in this area. Therefore, the aim of the present study was to determine the relationship between the morphological characteristics of the condyle and glenoid fossa in the different sagittal skeletal patterns (Class I, Class II, and Class III) using CBCT.

METHODS

This cross-sectional study was performed on the lateral cephalometric and CBCT images of 90 orthodontic patients, which were extracted from their orthodontic records. The radiographic records were obtained before the beginning of the orthodontic treatment and were not specifically taken for our study. At a confidence level of 95% and power of 80%, the sample size was estimated at 30 patients per skeletal group for detection of a standardized effect size of 0.7 regarding the morphological characteristics of the condyle between the groups. Finally, 90 patients who underwent CBCT scan for their orthodontic reasons were recruited in this study. All CBCT scans which presented bilateral condyles were included in this study. The selected patients did not have a history of TMJ disorders, trauma, TMJ surgery, cleft lip or palate, or craniofacial syndromes. Written consent was obtained from patients regarding that their orthodontic records were going to be used for study purposes. This study was approved in the ethics committee of Guilan University of Medical Sciences (Approval ID: IR:GUMS.REC.1396.475).

The patients' information, including age, sex, and cephalometric and condylar measurements, was recorded in a designed form for data collection. All CBCT scans were acquired using a NewTom VG CBCT system (QR SRL Company, Verona, Italy), with a field of view of 15×15 cm and an exposure factor of 110 kVp at 10-20 mA and exposure time of 3-5 s. The CBCT images were viewed by an observer in a semi-dark room on 1600 × 1200 pixel resolution with 24 inch monitor (Dell Inc, Round Rock, Tex, USA) on a computer running the Windows 7 (Microsoft, Redmond, Wash, USA) system.

According to the maxillofacial radiologist's report, a standard protocol was used for image acquisition. The CBCT images were acquired while the patient was in the maximum dental intercuspation. The patient's head was held down until the Frankfort plane was parallel to the floor, and the midsagittal plane was perpendicular to the floor.

The lateral cephalograms were acquired in a Planmeca ProMax device (Helsinki, Finland). Since the CBCT images of the patients were not full size we needed the lateral cephalograms to classify the subjects according to their sagittal skeletal pattern. Based on the lateral cephalometric examinations and manual technique tracing, the selected patients were categorized into three sagittal skeletal groups (30 patients per group), according to the ANB angulation: Class I (ANB, 2-4°), Class II (ANB > 4°), and Class III (ANB<2°). Class II patients were also divided into two subgroups (Class II division 1 and Class II division 2), based on the inclination of maxillary incisors. The inclination and distance of the upper incisor from the NA line (U1-Na) were recorded in degree and millimeter. Also, the Bjork's sum (N-S-Ar, S-Ar-Go, and Ar-Go-Me), lower anterior face height, Jarabak index (ratio of the posterior facial height [S-Go] to the anterior facial height [N-Me]), and Y-axis angle were calculated to determine the vertical facial pattern after tracing the lateral cephalogram. To eliminate the effect of different vertical facial patterns on the sagittal skeletal classification and the condyle-glenoid fossa relationship, all patients with a normal vertical skeletal pattern were considered."

For each sample, the right and left condyles were assessed separately. In the axial view, images that had the widest mediolateral

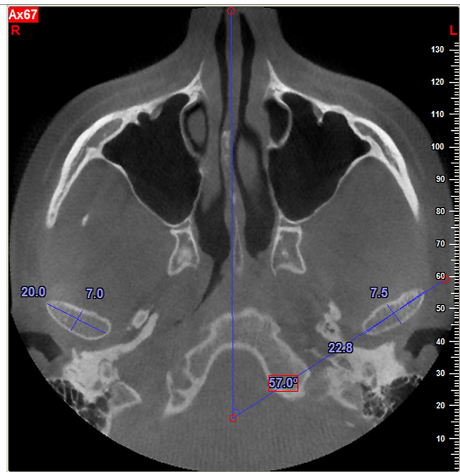

Figure 1. Linear measurement of the greatest anteroposterior and mediolateral diameter of the mandibular condyles and the angle between the long axis of the mandibular condyles and the midsagittal plane in axial view

diameter of the right and left condylar heads were selected (Figure 1). The following measurements were performed in the axial section: (1) the greatest anteroposterior diameter of the mandibular condyles; (2) the greatest mediolateral diameter of the mandibular condyles; and (3) the angle between the long axis of the mandibular condyles and the midsagittal plane. In the axial view, a line parallel to the long axis of the condyle was drawn (Figure 2A), so sagittal images were reconstructed with 2-mm thickness and interval (Figure 2B). Moreover, on the central sagittal images, the following measurements were obtained:

- Anterior joint space is defined as the shortest distance between the anterior wall of the glenoid fossa and the most anterior point of the condyle (Figure 3A).
- Superior joint space is defined as the shortest distance between the most superior point of the mandibular fossa and the most superior point of the condyle (Figure 3A).
- Posterior joint space is defined as the shortest distance between the posterior wall of the glenoid fossa and the most posterior point of the condyle (Figure 3A).
- Articular eminence inclination is defined as the angle between the true horizontal plane and the plane passing through the most inferior point at the crest of the articular eminence and the most superior point in the roof of the fossa (Figure 3B).
- Depth of the glenoid fossa is defined as the perpendicular distance between the highest point of the fossa and the line passing through the posterior glenoid process and the most inferior point of the articular eminence.
- Width of the glenoid fossa is defined as the distance between the posterior glenoid process and the most inferior point of the articular eminence.

The centric position of the condyles was evaluated by comparing the measurements of the anterior and posterior joint spaces in the right and left condyles. According to the formula proposed by Pullinger et al.[21] the condylar position was classified as anterior, concentric, and posterior:

Linear ratio= $(P-A)/(P+A)\times 100$.

The letters A and P indicate anterior and posterior joint spaces, respectively. If this ratio is less than -12%, the condylar position is considered posterior, if it is between -12% and +12% it is considered as concentric position, and if its more than +12% it is classified as anterior condylar position. The condylar position was evaluated by an examiner, who was blind to the patients' skeletal classification. All measurements were done by the same examiner after a two-week interval. The intra-observer reliability was above 0.85 for all measurements. The mean values of duplicate measurements were used for statistical analyses. Also, for the right and left sides, the mean values were measured separately.

Statistical Analysis

The statistical analysis was performed by using Statistical Package for the Social Science software version 23.0 (IBM SPSS Corp., Armonk, NY, USA). Descriptive statistics are presented as mean ± standard deviation (SD), according to the anterior-posterior skeletal relationships. The normal distribution of condylar measurements was examined by the Kolmogorov-Smirnov test,

Figure 2. A, B. Reconstruction of CBCT sections in a sample case. (a) Axial views in which the condylar process had its widest mediolateral diameter, (b) Central sagittal section of the condyle

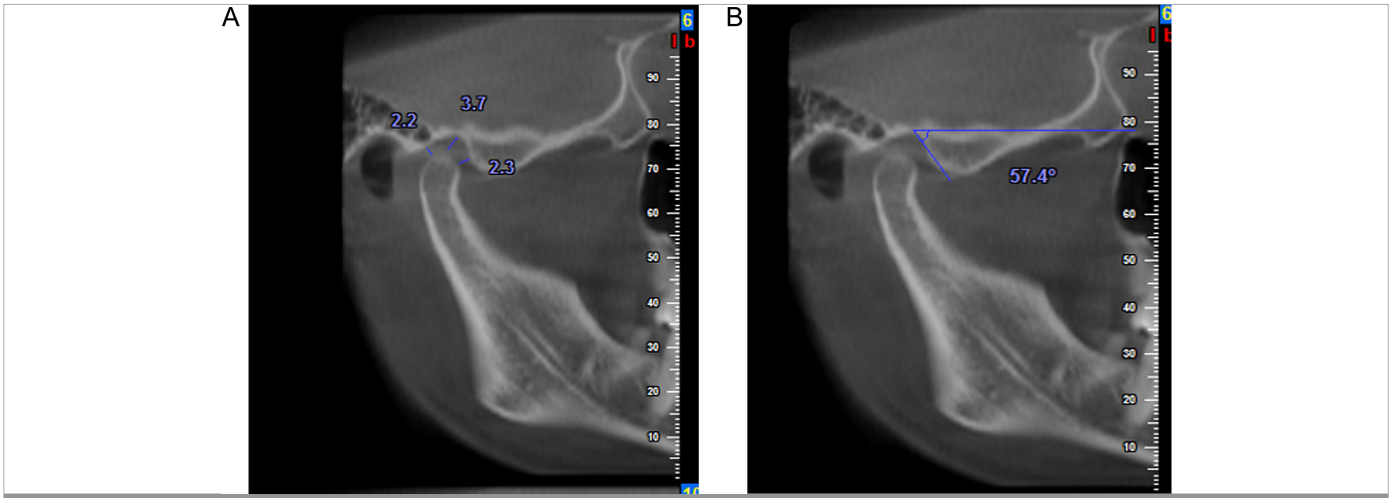

Figure 3. A, B. Linear measurement of anterior, superior, and posterior joint spaces (A) and articular eminence inclination (B) on a central sagittal view

and all variables satisfied the normality assumption. One-way ANOVA was performed to compare the mean condylar measurements in different skeletal relationships. Pairwise comparison between the groups was also performed using Tukey's post hoc test. A chi-square test was used to assess the association between the condylar position and craniofacial morphology. In addition, Pearson's correlation coefficient was measured to determine the correlations between the condylar measurements of the right and left sides. A P-value of less than 0.05 was considered significant in all tests.

RESULTS

The mean age (±SD) of the patients was 20.78 ± 4.72 years (range: 18-35 years). The study population comprised 41 (45.6%) males and 49 (54.4%) females. The descriptive characteristics, including sex and age, and other cephalometric features of Class I, Class II, and Class III malocclusions, are shown in Table 1. The mean Jarabak index and Bjork's sum were 64.02 ± 3.44 and 395.67 ± 3.80, respectively.

The mean values of the right and left condylar and glenoid fossa measurements are presented in Table 2. The mean articular eminence inclination on the right side was 49.59 ± 4.75°, 32.94 ± 7.60°, and 55.80 ± 2.97° in Class I, Class II, and Class III patients, respectively. On the other hand, the mean articular eminence inclination on the left side was 49.24 ± 4.80°, 33.32 ± 8.10°, and 55.69 ± 3.05° in Class I, Class II, and Class III patients, respectively. There was no significant difference in the articular eminence inclination between the right and left sides. The articular

Table 1. Descriptive statistic of study samples by skeletal pattern

Skeletal Pattern Variables		Class I (n = 30)	Class II (n = 30)		Class III (n = 30)
			Div I (n = 19)	Div II (n = 11)	
Sex (%)	Male	11 (36.7)	8 (42.1)	4 (36.4)	18 (60.0)
	Female	19 (63.3)	11 (57.9)	7 (63.6)	12 (40.0)
Age (years) Mean ± SD		19.1 ± 3.7	21.4 ± 6.5	20.2 ± 4.2	22.3 ± 4.0
SNA (°) Mean ± SD		79.9 ± 2.2	82.8 ± 3.6	82.5 ± 3.2	79.4 ± 3.7
SNB (°) Mean ± SD		76.9 ± 2.5	77.1 ± 3.4	77.0 ± 3.6	79.5 ± 3.7
ANB (°) Mean ± SD		3.1 ± 0.7	5.7 ± 1.7	6.4 ± 1.4	0.1 ± 1.2
U1–NA (°) Mean ± SD		19.7 ± 5.5	27.9 ± 8.3	8.4 ± 3.8	24.7 ± 5.2
U1-NA (mm) Mean ± SD		4.4 ± 1.3	6.7 ± 2.3	0.9 ± 1.8	5.7 ± 0.9
NSAr (°) Mean ± SD		125.5 ± 5.8	126.2 ± 4.5	124.4 ± 5.6	124.9 ± 4.4
SarGo (°) Mean ± SD		141.2 ± 6.9	141.2 ± 5.1	143.7 ± 6.5	142.9 ± 4.8
ArGoMe (°) Mean ± SD		128.9 ± 4.0	127.8 ± 4.6	126.0 ± 5.6	128.6 ± 5.6
Sum (°) Mean ± SD		395.7 ± 3.7	395.2 ± 4.1	394.1 ± 3.6	396.5 ± 3.8
Yaxis (°) Mean ± SD		59.4 ± 2.9	61.1 ± 4.6	59.8 ± 4.7	59.9 ± 3.0
LAFH (mm) Mean ± SD		60.7 ± 4.5	65.7 ± 6.4	61.3 ± 5.0	65.5 ± 5.6
Jarabak index (S-Go/N-Me) (%) Mean ± SD		62.7 ± 3.2	65.9 ± 4.3	65.1 ± 3.1	63.7 ± 2.5

SD, standard deviation; LAFH, lower anterior face height.

Table 2. Mean values of condylar and glenoid fossa measurements between 3 sagittal skeletal patterns in the tight and the left sides

		Skeletal Pattern				
			Class II			
Morphologic Characteristics		Class I (Mean ± SD)	Div1 (Mean ± SD)	Div2 (Mean ± SD)	Class III (Mean ± SD)	*P*
Articular eminence inclination (°)	R	49.59 ± 4.75	32.36 ± 8.17	33.94 ± 6.74	55.80 ± 2.97	.001
	L	49.24 ± 4.80	32.97 ± 8.74	33.93 ± 7.21	55.69 ± 3.05	.001
Glenoid fossa depth (mm)	R	6.36 ± 0.99	7.09 ± 1.40	6.55 ± 1.73	8.64 ± 4.58	.007
	L	6.46 ± 0.93	7.06 ± 1.14	6.63 ± 1.94	8.47 ± 4.30	.01
Glenoid fossa width (mm)	R)	17.05 ± 1.79	17.44 ± 2.61	17.64 ± 4.39	15.28 ± 3.56	.01
	L	16.96 ± 1.57	17.52 ± 2.46	17.25 ± 4.24	15.37 ± 3.47	.01
Anterior joint space (mm)	R	1.60 ± 0.72	1.67 ± 0.51	1.18 ± 0.68	1.65 ± 0.29	.09
	L	1.56 ± 0.73	1.51 ± 0.53	1.13 ± 0.60	1.49 ± 0.33	.2
Superior joint space (mm)	R	2.48 ± 0.51	3.23 ± 1.30	2.87 ± 0.84	2.68 ± 0.65	.02
	L	2.64 ± 0.52	2.79 ± 0.95	2.97 ± 0.91	2.56 ± 0.66	.37
Posterior joint space (mm)	R	1.73 ± 0.57	1.91 ± 0.78	1.97 ± 0.53	1.61 ± 0.49	.2
	L	1.71 ± 0.58	1.81 ± 0.71	1.89 ± 0.40	1.76 ± 0.53	.8
Anteroposterior diameter of condylar process (mm)	R	7.75 ± 0.95	8.54 ± 1.59	8.35 ± 1.74	7.47 ± 1.29	.01
	L	8.19 ± 1.41	8.49 ± 1.50	8.48 ± 1.30	7.69 ± 1.01	.06
Mediolateral diameter of condylar process (mm)	R	17.35 ± 3.12	18.83 ± 2.68	17.16 ± 2.87	18.51 ± 1.69	.2
	L	17.57 ± 2.73	18.69 ± 3.12	17.12 ± 3.02	17.96 ± 1.62	.7
Angle between condylar process/midsagittal plan (°)	R	69.32 ± 7.80	67.00 ± 6.63	65.71 ± 8.06	70.31 ± 4.17	.07
	L	68.95 ± 7.29	66.22 ± 7.34	64.65 ± 6.60	71.78 ± 4.1	.001

SD, standard deviation; R, right; L, left; *P*-values were calculated using the *F*-test in the analysis of variance.

eminence inclination was found to be the highest in Class III patients, followed by Class I and Class II, respectively.

The mean glenoid fossa depth on the right side was 6.36 ± 4.75°, 6.89 ± 1.58°, and 8.64 ± 4.58° in Class I, Class II, and Class III patients, respectively. The mean glenoid fossa depth on the left side was 6.46 ± 0.93°, 6.90 ± 1.54°, and 8.47 ± 4.30° in Class I, Class II, and Class III patients, respectively. The mean value of glenoid fossa width on the right side was 17.05 ± 1.79°, 17.51 ± 3.49°, and 15.28 ± 3.56° in Class I, Class II, and Class III patients, respectively. The mean glenoid fossa depth on the left side was 16.96 ± 1.57°, 17.42 ± 3.34°, and 15.37 ± 3.47° in Class I, Class II, and Class III patients, respectively. There was a significant difference in the glenoid fossa depth and glenoid fossa width between different sagittal skeletal groups ($P<0.05$). The depth of the glenoid fossa was significantly larger ($P=0.07$ in right side and $P=0.01$ in left side), and the width of the glenoid fossa was significantly smaller ($P=0.01$ in right and left side) on both sides in Class III patients, compared to the other groups. Also, the glenoid fossa depth was significantly higher in Class III patients, followed by Class II div. 1, Class II div. 2, and Class I. Nevertheless, the mean anteroposterior and mediolateral diameters of the condyles were not significantly different between the right and left sides ($P>.05$). The frequency of anterior, concentric, and posterior condylar positions on the right and left condylar sides in Class I, Class II, and Class III patients is presented in Table 3. No significant difference was found between the three groups in terms of the condylar position ($P=.40$ for right and $P=.08$ for left side). The *P*-values of Tukey's pairwise comparison between the groups were shown in Table 4.

DISCUSSION

In the current study, the morphological characteristics of the glenoid fossa and condylar eminence were assessed in 90 patients according to the sagittal skeletal relationships, using CBCT.

Table 3. Distribution of condylar position in each group

	Condylar Position							
	Anterior, n (%)		Concentric, n (%)		Posterior, n (%)		*P*	
Skeletal Pattern	R	L	R	L	R	L	R	L
Class I	14 (46.7)	12 (40)	10 (33.3)	12 (40)	6 (20)	6 (20)		
Class II	16 (53.3)	15 (50)	10 (33.3)	12 (40)	4 (13.3)	3 (10)	.40	.08
Class III	7 (23.3)	7 (23.3)	17 (56.7)	22 (73.3)	6 (20)	1 (3.3)		

R, right; L, left; *P*-values were calculated by Chi-square test.

Table 4. Pairwise comparison of morphologic characteristics in different skeletal pattern

Morphologic characteristics	Skeletal pattern	Class I vs II	Class I vs III	Class II vs III
Articular eminence inclination (degree)	R	0.001	0.001	0.001
	L	0.001	0.001	0.001
Glenoid fossa depth (mm)	R	0.74	0.007	0.05
	L	0.79	0.01	0.06
Glenoid fossa width (mm)	R	0.81	0.06	0.01
	L	0.81	0.08	0.01
Anterior joint space (mm)	R	0.7	0.9	0.5
	L	0.4	0.8	0.7
Superior joint space (mm)	R	0.01	0.61	0.12
	L	0.48	0.90	0.25
Posterior joint space (mm)	R	0.41	1.00	0.43
	L	0.64	0.09	0.46
Anteroposterior diameter of condylar process(mm)	R	0.09	0.68	0.01
	L	0.63	0.31	0.05
Mediolateral diameter of condylar process (mm)	R	0.40	0.21	0.90
	L	0.69	0.82	0.97
Angle condylar process/ midsagittal Plan (degree)	R	0.22	0.83	0.07
	L	0.11	0.19	0.001

According to the findings, Class III patients had a significantly higher articular eminence inclination, while Class II patients had a lower articular eminence inclination. Also, Class III patients had a significantly higher glenoid fossa depth and a smaller glenoid fossa width.

Evaluation of the morphology of TMJ according to the sagittal skeletal relationships remains a challenge for clinicians.[10-14] Understanding the normal relationship of the condyle and the glenoid fossa can help clinicians identify the early onset of degenerative joint diseases, evaluate the established problems, and improve diagnosis and treatment plans for patients.[10,22] Different radiographic modalities, such as conventional radiography, conventional tomography, CT, MRI, and CBCT, have been proposed for evaluating the articular eminence inclination[23-28]; in the current study, CBCT was used.

Measurement of the articular eminence inclination varies in different studies.[6,8,9] It can be defined as the angle between the horizontal reference line (e.g., occlusal plane, palatal plane, Frankfort horizontal plane, and true horizontal plane) and the line that connects the highest point of the fossa and the most inferior point of the articular eminence. It can also be defined as the angle between the horizontal reference line and the best fit line drawn along the posterior slope of the articular eminence[6,8,9]; the first approach was used in the present investigation.

The articular eminence inclination can be evaluated in the most medial, central and most lateral slices, where the glenoid fossa and condyle are viewed. However, in the current study, for simplifying the assessment of our data, the articular eminence inclination was only examined in the central plane of the condyle, although the midpoint is preferable because it is the steepest part of the eminence.[8,29-31] According to a investigation by Katsavrias et al.[6] the articular eminence angle normally ranges from 30° to 60°. Articular eminence inclinations less than 30° and more than 60° were defined as flat and steep, respectively. Based on the outcomes of the present study, all of the patients were in the normal range of inclination. Although other factors, such as age, sex, dental occlusion, incisors, and canine guidance might affect variations of inclination in different skeletal patterns,[2] most of these variables were not considered in the present study.

Our results indicated that the glenoid fossa depth on the right and left sides was significantly higher in Class III patients, which is in accordance with the findings of studies conducted by Arieta-Miranda et al.[2] and Katsavrias et al.[16] On the other hand, the findings of a study by Krisjane et al.[13] demonstrated no significant difference between Class II and Class III patients. In the current study, the glenoid fossa width was considerably smaller in Class III patients. In contrast, Song et al.[32] evaluated TMJ in permanent dentition according to Angle's classification using CBCT and found that the width of the joint fossa was significantly larger in Class III patients. They also showed that the depth of the fossa was significantly smaller in Class III patients. This is in contrast to our findings. It should be mentioned that in their study the distance between the most inferior point of the articular eminence and the most inferior point of the external auditory meatus was defined as width of the glenoid fossa and the perpendicular distance between this line and the highest point of the fossa was defined as glenoid fossa depth which is different from the definition of glenoid fossa width and glenoid fossa depth in our study. Therefore conflicting results could be due to the variety in the external auditory meatus location in different sagittal skeletal classes.

In the axial slices, we assessed the symmetry of the condyles in the anteroposterior and mediolateral aspects. No considerable difference was observed in the condylar size between the three groups in the anteroposterior and mediolateral views. In a study by Rodrigus et al.[14] evaluating the TMJ parameters in Class II div 1 and Class III patients using CT, the mean anteroposterior and mediolateral diameters of the condyle were larger than our results.

According to several studies,[2,16,17,20,22] the condyles are positioned more anteriorly in Class II patients, while other studies have reported more posterior condyles in Class II patients.[33-34] In contrast, although most Class II patients had a more anteriorly positioned condyle in our study, the difference was not significant. Conflicting results in different communities may be attributed to the assessment method of the condylar position, ethnic background, and age range of the subjects. However, other factors, such as the radiographic modality and the method of assessing condylar position, may influence the outcomes, as well. A non-concentric condyle-fossa relationship may be also associated with the abnormal function of TMJ.[13]

The present study was conducted on patients with a normal vertical skeletal pattern to eliminate the effect of a vertical relationship between the jaws. Based on some previous studies, the condylar position may be correlated with the vertical skeletal pattern.[3,35] In this regard, Paknahad and Shahidi[3] evaluated the association between condylar position and vertical skeletal craniofacial morphology. They suggested that patients with high-angle vertical patterns had more anteriorly positioned condyles, compared to those with low- and normal-angle vertical patterns; nonetheless, they did not find any significant difference between low- and normal-angle subjects. Lack of attention to this point in previous investigations might be the cause of conflicting results regarding relationship between the condylar position and morphological characteristics in different communities.[1,13,14] Also, the morphology of TMJ can alter significantly as patients grow older; this might be due to re-modelling and degenerative changes of the joint components.[18] Therefore, only young adult patients (age: 20.78 ± 4.72 years) were evaluated in this study.

This study had some limitations. First, measurement of the muscle activity, masticatory muscle load, and relation with dental occlusion was not possible; these factors could affect the morphology of the condyle-fossa relationship, especially the articular eminence inclination. Second, although we obtained the CBCT data from central sagittal slices for simplifying the process of data analysis, the condylar and glenoid fossa dimensions are different in different slices of the joint. Therefore, in the future studies it is recommended to also measure the most medial and the most lateral sections.

CONCLUSION

By using a CBCT-based method, we found that some morphological characteristics of the condyle and glenoid fossa were related to the sagittal skeletal relationships in an Iranian population. This correlation should be considered in the diagnosis of the temporomandibular joint pathologies, identifying the onset of a degenerative joint disease or diagnosis of an already established problem. Such information also allows the clinician to propose a better diagnosis and treatment plan, especially when the treatment involves orthognathic surgical approaches, as they can potentially lead to changes in the occlusal plan and condyle position. Therefore understanding the normal condylar position can help the clinicians in detecting the abnormal morphology and position of the temporomandibular joint.

Ethics Committee Approval: Ethical committee approval was received from the Ethics Committee of Guilan University of Medical Sciences (Approval ID: IR:GUMS.REC.1396.475).

Informed Consent: Written informed consent was obtained from the patients.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – A.H.T., N.K., Z.D.K.; Design – A.H.T., N.K., Z.D.K.; Supervision – N.K., Z.D.K.; Materials – A.H.T., N.K., Z.D.K.; Data Collection and/or Processing – A.H.T.; Analysis and/or Interpretation – A.H.T.; Literature Review – A.H.T., N.K., Z.D.K.; Writing – A.H.T., N.K., Z.D.K.; Critical Review – A.H.T., N.K., Z.D.K.

Acknowledgments: The authors acknowledge the Deputy of Research and Technology of Guilan University of Medical Sciences for their support. We also would like to thank the staff of the radiology center for their assistance in collecting the radiographic files.

Declaration of Interests: The authors have no conflict of interest to declare.

Funding: The authors declared that this study has received no financial support.

REFERENCES

1. dos Santos PFd. Correlation between sagittal dental classes and sagittal condylar inclination. *J Stomat Occ Med*. 2013;6(3):96-100. [CrossRef]
2. Arieta-Miranda JM, Silva-Valencia M, Flores-Mir C, Paredes-Sampen NA, Arriola-Guillen LE. Spatial analysis of condyle position according to sagittal skeletal relationship, assessed by cone beam computed tomography. *Prog Orthod*. 2013;14(1):36. [CrossRef]
3. Paknahad M, Shahidi S. Association between condylar position and vertical skeletal craniofacial morphology: a cone beam computed tomography study. *Int Orthod*. 2017;15(4):740-751. [CrossRef]
4. Stocum DL, Roberts WE. Curr Osteoporos rep-Part I: development and physiology of the temporomandibular joint. *Curr Osteoporos Rep*. 2018;16(4):360-368. [CrossRef]
5. Arnett GW, Milam SB, Gottesman L. Progressive mandibular retrusion—idiopathic condylar resorption. Part II. *Am J Orthod Dentofacial Orthop*. 1996;110(2):117-127. [CrossRef]
6. Katsavrias EG. Changes in articular eminence inclination during the craniofacial growth period. *Angle Orthod*. 2002;72(3):258-264. [CrossRef]
7. İlgüy D, İlgüy M, Fişekçioğlu E, Dölekoğlu S, Ersan N. Articular eminence inclination, height, and condyle morphology on cone beam computed tomography. *Sci World J*. 2014;2014:761714. [CrossRef]
8. Sümbüllü MA, Cağlayan F, Akgül HM, Yilmaz AB. Radiological examination of the articular eminence morphology using cone beam CT. *Dento Maxillo Fac Radiol*. 2012;41(3):234-240. [CrossRef]
9. Kranjčić J, Vojvodić D, Žabarović D, Vodanović M, Komar D, Mehulić K. Differences in articular-eminence inclination between medieval and contemporary human populations. *Arch Oral Biol*. 2012;57(8):1147-1152. [CrossRef]
10. Schlueter B, Kim KB, Oliver D, Sortiropoulos G. Cone beam computed tomography 3D reconstruction of the mandibular condyle. *Angle Orthod*. 2008;78(5):880-888. [CrossRef]
11. Krisjane Z, Urtane I, Krumina G, Bieza A, Zepa K, Rogovska I. Condylar and mandibular morphological criteria in the 2D and 3D MSCT imaging for patients with class II division 1 subdivision malocclusion. *Stomatologija*. 2007;9(3):67-71.
12. Alexiou K, Stamatakis H, Tsiklakis K. Evaluation of the severity of temporomandibular joint osteoarthritic changes related to age using cone beam computed tomography. *Dento Maxillo Fac Radiol*. 2009;38(3):141-147. [CrossRef]
13. Krisjane Z, Urtane I, Krumina G, Zepa K. Three-dimensional evaluation of TMJ parameters in class II and class III patients. *Stomatologija*. 2009;11(1):32-36.
14. Rodrigues AF, Fraga MR, Vitral RWF. Computed tomography evaluation of the temporomandibular joint in class II division 1 and class III malocclusion patients: condylar symmetry and condyle-fossa relationship. *Am J Orthod Dentofacial Orthop*. 2009;136(2):199-206. [CrossRef]
15. Girardot Jr RA. Comparison of condylar position in hyperdivergent and hypodivergent facial skeletal types. *Angle Orthod*. 2001;71(4):240-246. [CrossRef]

16. Katsavrias EG, Halazonetis DJ. Condyle and fossa shape in class II and class III skeletal patterns: a morphometric tomographic study. *Am J Orthod Dentofacial Orthop*. 2005;128(3):337-346. [CrossRef]
17. Kikuchi K, Takeuchi S, Tanaka E, Shibaguchi T, Tanne K. Association between condylar position, joint morphology and craniofacial morphology in orthodontic patients without temporomandibular joint disorders. *J Oral Rehabil*. 2003;30(11):1070-1075. [CrossRef]
18. Saccucci M, D'Attilio M, Rodolfino D, Festa F, Polimeni A, Tecco S. Condylar volume and condylar area in class I, class II and class III young adult subjects. *Head Face Med*. 2012;8(1):34. [CrossRef]
19. Fraga MR, Rodrigues AF, Ribeiro LC, Campos MJ, vitral RWF. Anteroposterior condylar position: a comparative study between subjects with normal occlusion and patients with class I, class II division 1, and class III malocclusions. *Med Sci Monit*. 2013;19:903-907. [CrossRef]
20. Vitral RWF, Telles Cde S, Fraga MR, de Oliveira RSMF, Tanaka OM. Computed tomography evaluation of temporomandibular joint alterations in patients with class II division 1 subdivision malocclusions: condyle-fossa relationship. *Am J Orthod Dentofacial Orthop*. 2004;126(1):48-52. [CrossRef]
21. Pullinger AG, Hollender L, Solberg WK, Petersson A. A tomographic study of mandibular condyle position in an asymptomatic population. *J Prosthet Dent*. 1985;53(5):706-713. [CrossRef]
22. Paknahad M, Shahidi S, Abbaszade H. Correlation between condylar position and different sagittal skeletal facial types. *J Orofac Orthop*. 2016;77(5):350-356. [CrossRef]
23. Serra MD, Gavião MB. Evaluation of condylar position from transcranial projections in primary dentition. *Dento Maxillo Fac Radiol*. 2006;35(2):110-116. [CrossRef]
24. Major PW, Kinniburgh RD, Nebbe B, Prasad NG, Glover KE. Tomographic assessment of temporomandibular joint osseous articular surface contour and spatial relationships associated with disc displacement and disc length. *Am J Orthod Dentofacial Orthop*. 2002;121(2):152-161. [CrossRef]
25. Jasinevicius TR, Pyle MA, Nelson S, Lalumandier JA, Kohrs KJ, Sawyer DR. Relationship of degenerative changes of the temporomandibular joint (TMJ) with the angle of eminentia. *J Oral Rehabil*. 2006;33(9):638-645. [CrossRef]
26. Okur A, Ozkiris M, Kapusuz Z, Karaçavus S, Saydam L. Characteristics of articular fossa and condyle in patients with temporomandibular joint complaint. *Eur Rev Med Pharmacol Sci*. 2012;16(15):2131-2135.
27. Ikeda K, Kawamura A. Assessment of optimal condylar position with limited cone-beam computed tomography. *Am J Orthod Dentofacial Orthop*. 2009;135(4):495-501. [CrossRef]
28. Ichikawa W, Laskin DM, Rosenberg HM. Transcranial radiographic and tomographic analysis of the lateral and midpoint inclined planes of the articular eminence. *Oral Surg Oral Med Oral Pathol*. 1990;70(4):516-522. [CrossRef]
29. Keller DC, Carano A. Eminence-posterior occlusal plane angle in patients with temporomandibular disorders. *Cranio*. 1991;9(2):159-164. [CrossRef]
30. Kerstens HC, Tuinzing DB, Golding RP, Van der Kwast WA. Inclination of the temporomandibular joint eminence and anterior disc displacement. *Int J Oral Maxillofac Surg*. 1989;18(4):228-232. [CrossRef]
31. Song J, Cheng M, Qian Y, Chu F. Cone-beam CT evaluation of temporomandibular joint in permanent dentition according to Angle's classification. *Oral Radiol*. 2019;36(3):261-266.
32. Chaukse A, Jain S, Dubey R, Maurya R, Shukla C, Sthapak A. Computed tomographic analysis of condyle-fossa relationship in skeletal class I and skeletal class II vertically growing males. *J Orthop*. 2015;3(3):170-170.
33. Droel R, Isaacson RJ. Some relationships between the glenoid fossa position and various skeletal discrepancies. *Am J Orthod*. 1972;61(1):64-78. [CrossRef]
34. Park IY, Kim JH, Park YH. Three-dimensional cone-beam computed tomography based comparison of condylar position and morphology according to the vertical skeletal pattern. *Korean J Orthod*. 2015;45(2):66-73. [CrossRef]