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Comparative cone-beam computed tomography evaluation of temporomandibular joint position and morphology in female patients with skeletal class II malocclusion

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Abstract

Objective: This study was performed to evaluate the position and morphology of the temporomandibular joint in female patients with skeletal class II malocclusion and to investigate the association between temporomandibular joint disorders and facial types using cone-beam computed tomography.

Methods: A lateral cephalogram was taken to determine the skeletal class of each participant. Sixty female patients aged 16 to 28 years were divided into high-angle, low-angle, and control groups. The shape of the condyle–fossa was measured and assessed on cone-beam computed tomography images of the 120 temporomandibular joints.

Results: Some condylar shape measurements displayed statistically significant differences among the groups. No significant differences were found in the length of the condyle, width of the glenoid fossa, or height of the articular eminence among the three groups. The posterior

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condylar position was more frequently observed in the low-angle group, whereas the anterior condylar position was more prevalent in the high-angle group.
Conclusion: The present study revealed differences in the condyle–fossa morphology and position in female patients with skeletal class II malocclusion with different vertical facial types.

Keywords
Cone-beam computed tomography, temporomandibular joint, osteoarthritis, vertical facial types, skeletal class II females, condylar position

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Introduction

The temporomandibular joint (TMJ) is one of the most complex joints in the human body. This joint is a sophisticated articular system located between the mandibular condyle and the temporal bone.[1,2] The continuous growth and stimulation of the condyle from childhood to adulthood leads to self-remodeling. As a part of the TMJ, the condyle can continually adapt to functional stimulation.

The clinical significance of the condyle–fossa relationship in the TMJ remains controversial.[3] However, the shape of both the condyle and fossa may play a diagnostic role in the accurate prediction and clinical identification of TMJ osteoarthritis (OA), which requires treatment.[4] The spectrum of clinical and pathologic presentations of TMJ OA ranges from structural and functional failure of the joint with disc displacement and degeneration to subchondral bone alterations (erosions), bone overgrowth (osteophytes), and loss of the articular fibrocartilage. Studies have shown an association of abnormal morphology and the position of the condyle with the development of TMJ OA.[5]

The condylar shape and position can be influenced by many dynamically variable factors, such as age, sex, functional matrix activities, increased or decreased masticatory force, occlusion changes, physiological adaptations, and the facial growth pattern.[6,7]

A previous study showed that the condylar position and fossa morphology varied according to the sagittal skeletal features.[8] In addition, some researchers have stated that the condylar position has no association with the vertical skeletal pattern.[9,10]

In the present study, cone-beam computed tomography (CBCT) was employed to study the morphology and position of the condyle. Our aim was to evaluate the morphology and position of the condyle based on established vertical facial types and gain insight into the relationship between TMJ OA and vertical facial types.

Materials and methods

Data collection and patient grouping

This study was performed at the Orthodontic Department of the Stomatological Hospital of Xi'an Jiaotong University (Xi'an, Shaanxi, China). High-resolution CBCT imaging sets of the TMJ were collected from January 2015 to June 2019 at the College of Stomatology, Xi'an Jiaotong University. Female patients were equally divided into a high-angle, low-angle, and control group. Before the study began, we took a lateral cephalogram of each participant who required orthodontic treatment to obtain measurements for the inclusion criteria (ANB angle, Frankfurt horizontal–mandibular plane angle [FH-MP], and sella–nasion to gonion–gnathion angle [GoGn-SN]) before the study. Measurements were performed and assessed by an orthodontist, an arthrologist, and a radiologist.

The inclusion criteria in the control group were individual normal occlusion with a class I molar relationship, $0° < ANB < 5°$, $22° < FH\text{-}MP < 32°$, and $27.3° < GoGn\text{-}SN < 37.7°$. The inclusion criteria in the high-angle group were a class II molar relationship, $ANB > 5°$, $FH\text{-}MP > 32°$, and $GoGn\text{-}SN > 37.7°$. The inclusion criteria in the low-angle group were a class II molar relationship, $ANB > 5°$, $FH\text{-}MP < 22°$, and $GoGn\text{-}SN < 27.3°$.

All three groups comprised female patients with no TMJ disorders (TMDs) (TMJ pain, limited opening, reciprocal clicking, and crepitus). The exclusion criteria in all three groups were a history of pregnancy, orthodontic treatment and maxillofacial trauma, evidence of TMDs in a clinical or imaging examination, history of TMJ treatment, obvious mandibular deviation, congenital craniofacial anomalies, visible facial asymmetry, and systemic diseases such as rheumatic arthritis and rheumatoid arthritis.

The study was approved by the Ethical Committee of Xi'an Jiaotong University (approval number xjkqll[2017] No. 022). After being informed about the nature of the experiment in detail, all participating individuals were willing to be enrolled in the trial and provided written informed consent. The statutory guardians of minors aged <18 years provided consent.

CBCT imaging

CBCT images of the bilateral TMJs were obtained by the same operator using a KaVo 3D eXam (KaVo Dental GmbH, Biberach, Germany). The image scanning protocol was as follows: field of view, 17 cm × 23 cm; 120 kV; 5 mA; exposure time, 7 seconds; and slice thickness, 0.1 mm. The scanner had sufficient image sharpness and contrast for visualization of the structures to be evaluated (articular eminence and mandibular fossa). The participants were positioned in a seated posture and bit their teeth into maximum intercuspal position. Their heads remained motionless with the Frankfort plane parallel with the ground. The scanner rotated 360° around the participant's head. All images were obtained under the same conditions by the same experienced radiologist using the same device.

Measurements

All patients underwent CBCT scans, and the images were three-dimensionally reconstructed using the third-party design software Invivo Dental 5.2 (KaVo Dental GmbH). Digital reconstruction was then conducted in the maxillofacial region. To correct the coronal and sagittal views, the view in which the bilateral condyles were symmetrical in size and exhibited the maximum area was chosen as the reference view for the secondary reconstruction (Figure 1a). On the corrected sagittal view (Figure 1b), the condylar process showed the maximal long axis, and the sagittal reference line was perpendicular to the long axis and passed through its midpoint. On the corrected coronal view, the condylar process had the maximum long axis, and the coronal reference line was parallel to the long axis and passed through its midpoint.

The measurements were obtained according to the methods established by Yasa and Akgul[11] and Ganugapanta et al.[12] On the axial view, the mediolateral and anteroposterior diameters of the condyle could be measured (Figure 1c).

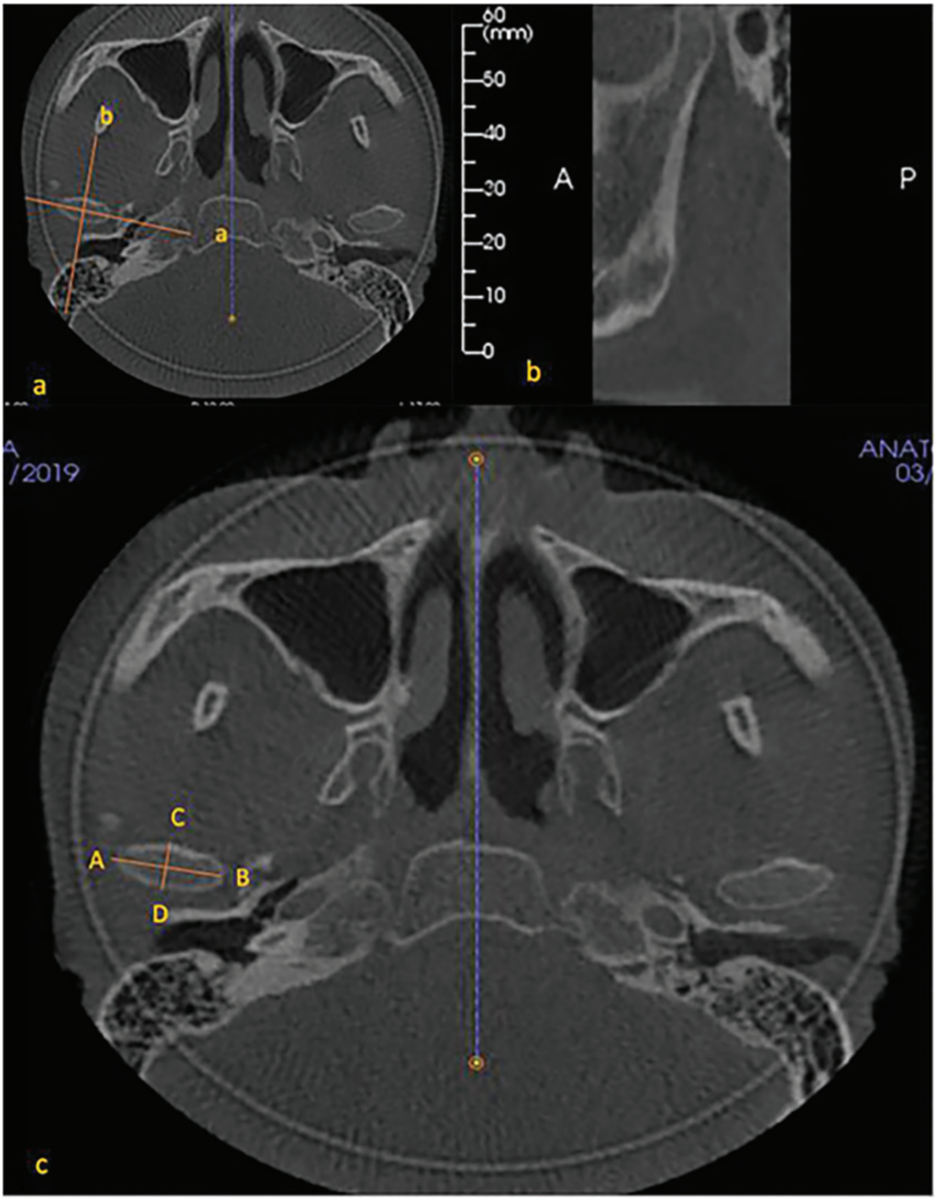

Figure 1. (a) Axial view shows the maximum condylar area as the reference for the secondary reconstruction. a: Coronal reference line. b: Sagittal reference line. (b) Sagittal cross-sectional image corresponding to line b shown in (a). (c) AB: Mediolateral diameter of the condyle. CD: Anteroposterior diameter of the condyle.

On the standardized sagittal plane, we measured the depth and width of the glenoid fossa (Figure 2a), the width and height of the condylar head (Figure 2b), the length of the condyle (Figure 2c), the inclination (Figure 2d) and height of the articular eminence (Figure 2e), and the anterior, superior, and posterior joint spaces (Figure 2f).

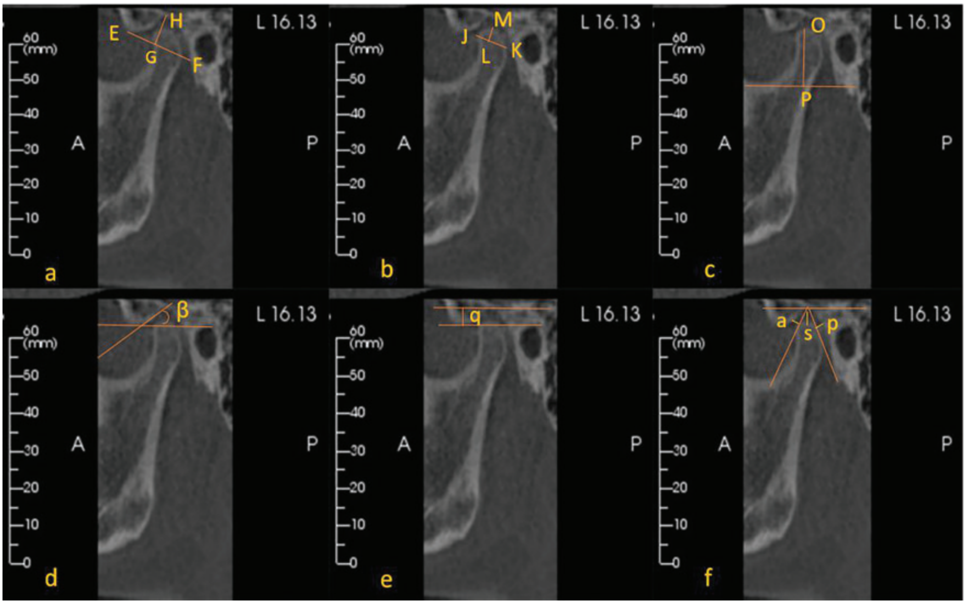

Figure 2. (a) GH: Depth of the glenoid fossa. EF: Width of the glenoid fossa. (b) ML: Height of the condylar head. JK: Width of the condylar head. (c) OP: Length of the condyle. (d) β: Inclination of the articular eminence. (e) q: Height of the articular eminence. (f) a: Anterior joint space. s: Superior joint space. p: Posterior joint space.

The definitions of these measurements are listed in Table 1.

Statistical analysis

All data were analyzed with SPSS ver. 18 (SPSS Inc., Chicago, IL, USA). The data of the left and right TMJs in the three groups were analyzed using the paired t-test. The statistical analysis was performed using the independent t-test to compare the differences among the three groups.

The condylar position was calculated by the following formula according to the method described by Pullinger et al.:[13]

$$\text{Condylar ratio} = \frac{P - A}{P + A} \times 100\%$$

where A is the anterior joint space and P is the posterior joint space.

At a ratio smaller than −12%, the condyle was considered to be in a posterior position. At a ratio greater than +12%, the condyle was considered to be in an anterior position. At a ratio within ±12%, the condylar position was considered concentric.

To avoid error, all images were remeasured by the same operator after 1 week. A P value of <0.05 was considered statistically significant.

Results

A total of 60 high-resolution CBCT imaging sets of the TMJ were collected from 60 female patients aged 16 to 28 years (mean age, 22.46 ± 3.57 years). The patients were equally divided into a high-angle, low-angle, and control group of 20 patients each. All TMJ measurements in the three groups are summarized in Tables 2 and 3.

Table 1. Definitions of measurements.

Parameter	Definition
Mediolateral diameter of the condyle	Distance between the outermost point and innermost point of the condyle.
Anteroposterior diameter of the condyle	Distance between the foremost point and backmost point of the condyle.
Width of glenoid fossa	Distance between the lowermost point of the articular eminence and the lowermost point of the internal acoustic meatus.
Depth of glenoid fossa	A vertical line is drawn from the uppermost point of the glenoid fossa to the full width of the glenoid fossa. The distance between the uppermost point and the vertical point is the depth of the glenoid fossa.
Width of condylar head	Distance between the foremost point and backmost point of the condylar head.
Height of condylar head	A vertical line is drawn from the uppermost point of the condylar head to the full width of the condylar head. The distance between the uppermost point and the vertical point is the height of the condylar head.
Length of the condyle	A tangent line is drawn from the mandibular ramus to the sigmoid notch. The perpendicular distance between the uppermost point of the condyle and the tangent line is the length of the condyle.
Inclination of the articular eminence	A tangent line is drawn from the uppermost point of the glenoid fossa to the anterior inclination of the articular eminence. The angle between this line and a true horizontal line is the inclination of the articular eminence.
Height of the articular eminence	A tangent line is drawn from the uppermost point of the glenoid fossa. The perpendicular distance between the lowermost point of the articular eminence and the tangent line is the height of the articular eminence.
Superior joint space	Distance between the uppermost point of the condyle and the uppermost point of the glenoid fossa.
Anterior and posterior joint spaces	Two tangent lines are drawn from the most superior point of the articular cavity on the most prominent part of the anterior and posterior condylar surfaces. The shortest distances between these lines to the opposite glenoid fossa wall are the anterior and posterior joint spaces.

Among the measurements revealing the condylar morphology, the mediolateral and anteroposterior diameters of the condyle were longest in the low-angle group and shortest in the high-angle group ($P < 0.05$). The height of the condylar head was lowest in the low-angle group ($P < 0.05$), whereas no statistically significant difference was observed between the high-angle and control groups. The width of the condylar head was significantly different only between the high-angle and

Table 2. Temporomandibular joint measurements in the three groups.

Variable	Groups	n	Mean ± SD
Mediolateral diameter of condyle, mm	High-angle	40	16.89 ± 0.79
	Control	40	18.18 ± 1.12
	Low-angle	40	19.03 ± 0.73
Anteroposterior diameter of condyle, mm	High-angle	40	7.18 ± 0.73
	Control	40	8.13 ± 0.34
	Low-angle	40	8.97 ± 0.57
Width of glenoid fossa, mm	High-angle	40	18.43 ± 0.98
	Control	40	18.03 ± 1.18
	Low-angle	40	17.89 ± 1.23
Depth of glenoid fossa, mm	High-angle	40	7.28 ± 0.88
	Control	40	7.98 ± 1.13
	Low-angle	40	8.08 ± 0.93
Width of condylar head, mm	High-angle	40	6.78 ± 1.01
	Control	40	6.98 ± 0.93
	Low-angle	40	7.33 ± 0.78
Height of condylar head, mm	High-angle	40	4.01 ± 0.47
	Control	40	3.89 ± 0.74
	Low-angle	40	3.25 ± 0.66
Length of condyle, mm	High-angle	40	25.58 ± 2.38
	Control	40	25.45 ± 2.11
	Low-angle	40	25.66 ± 1.97
Height of articular eminence, mm	High-angle	40	6.13 ± 1.00
	Control	40	6.15 ± 0.59
	Low-angle	40	6.24 ± 0.69
Superior joint space, mm	High-angle	40	2.38 ± 0.21
	Control	40	2.97 ± 0.18
	Low-angle	40	2.91 ± 0.43
Anterior joint space, mm	High-angle	40	1.88 ± 0.19
	Control	40	1.84 ± 0.31
	Low-angle	40	2.51 ± 0.27
Posterior joint space, mm	High-angle	40	2.45 ± 0.57
	Control	40	2.07 ± 0.26
	Low-angle	40	1.73 ± 0.17
Inclination of the articular eminence, degrees	High-angle	40	40.18 ± 6.51
	Control	40	45.21 ± 5.77
	Low-angle	40	51.03 ± 7.01

SD, standard deviation.

low-angle groups ($P < 0.05$). No significant differences were detected in the length of the condyle, the width of the glenoid fossa, or the height of the articular eminence among the three groups. The depth of the glenoid fossa was significantly smaller in the high-angle group than in the control and low-angle groups ($P < 0.05$). The inclination of the articular eminence was highest in the low-angle group and lowest in the high-angle group ($P < 0.05$). The posterior joint space was significantly different among the three groups (highest in the high-angle group and lowest in the

Table 3. Comparison of measurements among the three groups with independent t-test.

Variable	*P* value		
	High-angle vs. Control	High-angle vs. Low-angle	Control vs. Low-angle
Mediolateral diameter of condyle	0.000	0.000	0.000
Anteroposterior diameter of condyle	0.000	0.000	0.000
Width of glenoid fossa	0.260	0.089	0.846
Depth of glenoid fossa	0.005	0.001	0.893
Width of condylar head	0.590	0.022	0.203
Height of condylar head	0.675	0.000	0.000
Length of condyle	0.961	0.985	0.901
Inclination of articular eminence	0.002	0.000	0.000
Height of articular eminence	0.993	0.804	0.864
Superior joint space	0.000	0.000	0.634
Anterior joint space	0.773	0.000	0.000
Posterior joint space	0.000	0.000	0.000

low-angle group) ($P < 0.05$). The superior joint space was significantly lower in the high-angle group than in the control and low-angle groups ($P < 0.05$). The anterior joint space was significantly greater in the low-angle group than in the control and high-angle groups ($P < 0.05$).

The distribution of the condylar position in the high-angle, low-angle, and control groups is summarized in Table 4. As shown in the table, the anterior (42.5%) and concentric (45.0%) condylar positions were significantly more prevalent in the high-angle group, the concentric (75.0%) condylar position was significantly more prevalent in the control group, and the posterior (50.0%) and concentric (32.5%) condylar positions were significantly more prevalent in the low-angle group.

Table 4. Distribution of condylar position in the three groups.

Groups	Condylar position		
	Posterior	Concentric	Anterior
High-angle	5 (12.5%)	18 (45.0%)	17 (42.5%)
Control	3 (7.5%)	30 (75.0%)	7 (17.5%)
Low-angle	20 (50.0%)	13 (32.5%)	7 (17.5%)

Discussion

In the present study, CBCT images were collected to obtain measurements of the condyle–fossa. The anatomical structure of the TMJ is complex; thus, clinical examinations cannot precisely reveal its internal environment. Taking this obstacle into account, various radiographic methods have been used in previous studies to examine the TMJ morphology, such as CT magnetic resonance imaging (MRI), conventional/plain CT, plain film radiography, and CBCT. Conventional two-dimensional projections of the TMJ cannot show its three-dimensional shape accurately and thus have limited clinical utility. MRI is considered the gold standard diagnostic method for TMDs. Many cases of disc displacement without reduction develop from disc displacement with reduction. Such patients often have a history of joint clicking, limitation of mouth opening, and pain. All participants in the present study were investigated through a case history inquiry to exclude those with disc displacement without reduction. However, we were unable to use MRI for all participants in this study because of the limitations of the research conditions. CBCT is a new imaging method for the diagnosis of TMDs. Nakajima et al.[14] found that CBCT can provide a three-dimensional image of the TMJ in which the bone structure can be clearly observed. Additionally, Lascala et al.[15] evaluated the accuracy of TMJ measurements using CBCT and concluded that CBCT images have high reliability, repeatability, and accuracy. CBCT has obvious advantages in terms of its high space resolution, low radiation dose, and clear display of the bone trabecular structure of the condyle.

In some studies, age- and sex-related differences were found in the bone structure of TMJs.[16] Ribeiro-Dasilva et al.[17] suggested that female patients were at higher risk of developing TMDs than male patients. Thus, selection of female patients as study participants is very representative. Severt and Proffit[18] and Haraguchi et al.[19] found that some patients with malocclusion p had craniofacial asymmetry. However, the present study showed no significant differences in any TMJ measurements between the left and right sides among the three groups. Because the participants were females with facial symmetry and an age of 16 to 28 years, the effects of the facial form, sex, and age on the joint abnormalities were eliminated.

Kurita et al.[20] found that both the mediolateral and anteroposterior diameters of the condyle were decreased mainly in patients with disc displacement. Gomes et al.[21] reported that the size of the condyle in patients with OA was clearly decreased in the presence of pathological changes in the bone. Thus, the mediolateral and anteroposterior diameters of the condyle may be important factors in TMDs. In the present study, measurement of the mediolateral diameter of the condyle, anteroposterior diameter of the condyle, height of the condylar head, and width of the condylar head showed that the condylar head was narrow and long in the high-angle group but wide and short in the low-angle group. Such changes are associated with bone density, masticatory muscle strength, condylar stress, and adaptive remodeling. We assumed that the patients in the low-angle group had larger masticatory muscles and greater masticatory force that contributed to the adaptive reconstruction of the condyle. Arnett and Gunson[22] suggested that a larger condyle is associated with more stable masticatory function. The degree of matching between the condyle and fossa would be better, contributing to greater stability of the condyle. Different concepts concerning the depth and width of the glenoid fossa have been proposed. For instance, Alkhader et al.[23] speculated that the width of the glenoid fossa decreased because of changes in the bone. In another study, however, the opposite opinion was expressed (i.e., that the depth and width of the glenoid fossa were higher in patients with TMDs than in asymptomatic individuals) as established through comparison of the joint form between the TMD group and control group.[24] In the present study, the depth of the glenoid fossa was significantly smaller in the high-angle group than in the control group and low-angle group. The risk of TMD is likely higher in the high-angle group than in the other groups because of the depth of the glenoid fossa. Earlier reports provided evidence that a high inclination of the articular eminence might be a pathogenic factor for TMD,[25] which is contrary to the findings obtained by Sümbüllü et al.[26] and Ren et al.[27] The inclination of the articular eminence was highest in the low-angle group and lowest in the high-angle group. This indicates that the glenoid fossa was low and flat in the high-angle group but high and steep in the low-angle group. Some authors have reported that most patients with skeletal class II malocclusion with a low angle have a deep overbite and require a greater occlusal dimension when opening the mouth, which contributes to excessive development of the articular eminence.[28] In addition, the glenoid fossa of patients with a low angle has undergone adaptive reconstruction because the masticatory force must match the more sturdy condyle. Paknahad and Shahidi[29] reported that the condyles were more anteriorly positioned in patients with a high-angle vertical pattern than in those with a normal and low-angle vertical pattern. Moreover, Bjork[30] found that the condyle of patients with a high angle often grew backward, which led to the occurrence of an anterior condylar position to some extent. The condyle often grew backward along with clockwise rotation of the mandible in patients with a high angle, which contributed to the tendency of the posterior condyle to rotate forward. The situation in patients with a low angle was the opposite, which is consistent with our results. In the control group, most condyles were in the concentric position, which is consistent with the findings reported by Madsen[31] and Weinberg.[32]

Conclusions

In conclusion, the present study demonstrated some significant differences in the condyle–fossa morphology and position in female patients with skeletal class II malocclusion with different vertical facial types. We conclude that patients with skeletal class II malocclusion with a high angle have an unstable structure of the TMJ. We assume that the risk of TMDs in such patients is much higher than that in other people. The possible relationship between orthodontic treatment and TMDs is a topic of great research interest. Increasingly more investigations are being focused on this field. The present study will be helpful in the diagnosis of TMDs and provide orthodontic specialists with valuable clinical guidance.

Declaration of conflicting interest

The authors declare that there is no conflict of interest.

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