

Morphologic Analysis of the Temporomandibular Joint Between Patients With Facial Asymmetry and Asymptomatic Subjects by 2D and 3D Evaluation

A Preliminary Study

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Abstract: Signs and symptoms of temporomandibular joint (TMJ) dysfunction are commonly found in patients with facial asymmetry. Previous studies on the TMJ position have been limited to 2-dimensional (2D) radiographs, computed tomography (CT), or cone-beam computed tomography (CBCT). The purpose of this study was to compare the differences of TMJ position by using 2D CBCT and 3D model measurement methods. In addition, the differences of TMJ positions between patients with facial asymmetry and asymptomatic subjects were investigated.

We prospectively recruited 5 patients (cases, mean age, 24.8 ± 2.9 years) diagnosed with facial asymmetry and 5 asymptomatic subjects (controls, mean age, 26 ± 1.2 years). The TMJ spaces, condylar and ramus angles were assessed by using 2D and 3D methods. The 3D models of mandible, maxilla, and teeth were reconstructed with the 3D image software. The variables in each group were assessed by *t*-test and the level of significance was 0.05.

There was a significant difference in the horizontal condylar angle (HCA), coronal condylar angle (CCA), sagittal ramus angle (SRA), medial joint space (MJS), lateral joint space (LJS), superior joint space (SJS), and anterior joint space (AJS) measured in the 2D CBCT and in the 3D models ($P < 0.05$). The case group had significantly smaller SJS compared to the controls on both nondeviation side ($P = 0.009$) and deviation side ($P = 0.004$). In the case group, the nondeviation SRA was significantly larger than the deviation side ($P = 0.009$). There was no significant difference in the coronal condylar width (CCW) in either group. In addition, the anterior disc displacement (ADD) was more likely to occur on the deviated side in the case group.

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In conclusion, the 3D measurement method is more accurate and effective for clinicians to investigate the morphology of TMJ than the 2D method.

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Abbreviations: 2D = two-dimensional, 3D = three-dimensional, AJS = anterior joint space, CBCT = cone-beam computed tomography, CCA = coronal condylar angle, CCW = coronal condylar width, CT = computed tomography, DICOM = Digital Imaging and Communications in Medicine, HCA = horizontal condylar angle, HU = Hounsfield units, LJS = lateral joint space, MJS = medial joint space, MRI = magnetic resonance imaging, PJS = posterior joint space, SJS = superior joint space, SRA = sagittal ramus angle, TMD = temporomandibular disorders, TMJ = temporomandibular joint.

INTRODUCTION

Facial asymmetry is one of the most common types of jaw deformity.¹ It was reported that the prevalence of facial asymmetry varied from 8.7% to 23.3%.^{1,2} The prevalence of facial asymmetry was 6.3% to 7.5% for Chinese.^{3,4} Temporomandibular joint (TMJ) symptoms and internal derangement are commonly found in patients with facial asymmetry.⁵⁻⁷ The positions of the mandibular condyles, disc, and glenoid fossa in patients with facial asymmetry were proven to be different from those in asymptomatic subjects.^{6,7} These differences can cause joint pain, temporomandibular disorders (TMD), disc displacement, and disc perforation.⁷⁻⁹ The morphologic study of TMJ in patients with facial asymmetry can contribute to the existing knowledge and management strategies of TMJ diseases.⁷

Many studies have investigated the TMJ position of patients with facial asymmetry using different measurement methods.¹⁰⁻¹⁸ Cephalometric radiographs were used to measure the TMJ positions of Malays and Chinese with facial asymmetry for assessing its impact on the TMD.¹⁰ Cephalometric radiographs were also used to evaluate the morphological condylar changes after orthognathic surgery.¹¹ Meanwhile, computed tomography (CT) could be used to examine the morphological aspects of TMJ, to investigate the position of the mandibular canal, and to analyze the influences of complicated mandible reconstruction on a patient's condylar position and TMJ function.¹²⁻¹⁴ In addition, several studies have reported that high accuracy was obtained when using cone-beam computed tomography (CBCT) to evaluate the TMJ position. CBCT was used to measure the volume, metrical size, position of each condyle sample, and the thickness of the roof of the glenoid fossa, and to evaluation the changes of the condylar axis and the anteroposterior condylar position

relative to the glenoid fossa after surgery.^{17,18} Magnetic resonance imaging (MRI) has also been used to assess the relationship of the articular disc and condyle, and to examine the kinematics of the structures of the TMJ under mastication.^{15,16}

Existing studies have been limited to 2-dimensional (2D) assessments of the TMJ; however, it has been shown that 2D methods provide less accuracy than 3-dimensional (3D) methods.^{19,20} The aim of this study was to compare the differences of the TMJ position by using 2D CBCT and 3D models measuring methods and to investigate the differences in TMJ morphology between patients with facial asymmetry and asymptomatic subjects.

MATERIALS AND METHODS

Subjects and Data Acquisition

Five patients diagnosed with facial asymmetry were designated as cases (3 women and 2 men, 24.8 ± 2.9 years old) and 5 asymptomatic subjects, designated as controls (3 women and 2 men, 26.0 ± 1.2 years old), were prospectively recruited for this study, with IRB approval. The TMJ clicking sound and joint pain were found in the 5 patients with facial asymmetry. Informed consent was obtained from each subject before the experiment. The patients and asymptomatic subjects were identified and recruited by a single oral surgeon in the Department of Oral and Maxillofacial Surgery, Affiliated Hospital of Stomatology, Chongqing Medical University. The inclusion criteria of patients were as follows: healthy physical condition, the deviations from the facial midline were >5 mm, TMJ clicking sound, and joint pain with no prior TMJ-related procedures. The inclusion criteria of asymptomatic subjects were as follows: healthy physical condition, no facial asymmetry, no TMD symptoms, and no degenerative joint disease.

CBCT for all patients was performed at the Affiliated Hospital of Stomatology, Chongqing Medical University. The maxilla and mandible were scanned using a CBCT machine (Imaging Sciences International Inc. Hatfield) with a complete head view. Each CBCT scan consisted of a total amount of 290 to 330 images with slice thicknesses of 0.4 mm. The CBCT data was reformatted into Digital Imaging and Communications in Medicine (DICOM) format.

3D Modeling

The cortical bone, cancellous bone, and teeth were separated in MIMICS (Materialise, Leuven, Belgium) according to the Hounsfield units (HU). The boundaries of the regions of the

mandible, maxilla, and teeth were accurately distinguished on each slice of CBCT. Subsequently the 3D models of the mandible, maxilla, and teeth were constructed in MIMICS (Figure 1).

2D and 3D TMJ Analysis

In this study, the horizontal condylar angle (HCA), coronal condylar angle (CCA), sagittal ramus angle (SRA), coronal condylar width (CCW), medial joint space (MJS), lateral joint space (LJS), superior joint space (SJS), anterior joint space (AJS), and posterior joint space (PJS) were measured in the 2D CBCT images, as well as in the 3D reconstructed models. The 2D CBCT images were measured in accordance with the method reported by Ueki et al.⁷ A 2D axial slice demonstrating the HCA was selected for each patient (Figure 2A). The HCA was determined as the angle between the RL line and the condylar long axis (the line between the medial and lateral points).⁷ Using 2D coronal slices, measurements of the MJS, SJS, LJS, CCA, and CCW were derived from the condyle and glenoid fossa (Figure 3A and B). The MJS, SJS, and LJS were determined as the distance between the most medial point, superior point, and lateral point of the condyle and the articular fossa, respectively.⁷ The CCA was determined as the angle between the Frankfurt horizontal (FH) plane and the condylar long axis.⁷ The 2D sagittal slices allowed measurements of the SRA, PJS, and AJS (Figure 4A and B). The SRA was determined as the angle between the FH plane and the tangential line to the posterior outline of ramus.⁷ The PJS and AJS were determined as the distance parallel to the FH plane between the posterior point and anterior point of the condyle in the articular fossa and the articular eminence outline, respectively.⁷ In addition, these 9 parameters were also measured in the 3D reconstructed models (Figures 2–4). All samples were re-evaluated thrice within a 1 week interval by 3 authors of this study. The correlation coefficients of the results in each measurement were >0.95 ; therefore, the repeatability of the measurements was acceptable.

Statistical Analysis

2D and 3D TMJ morphological measurements were analyzed for differences using Student's *t* test for each patient to determine the accuracy of the measurements. In addition, we performed comparisons: (1) between the cases and controls, (2) between the deviation and nondeviation sides for asymmetric TMJ in the case group, and (3) between the left and right sides for symmetric TMJ in the control group. The *t* test was performed and statistical significance was achieved when

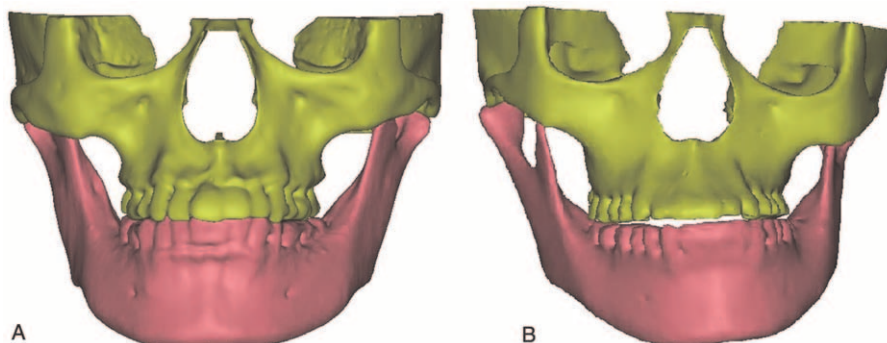


FIGURE 1. The 3D models of mandible, maxilla, and teeth of (A) asymptomatic subject, (B) patient with facial asymmetry. 3D = three-dimensional.

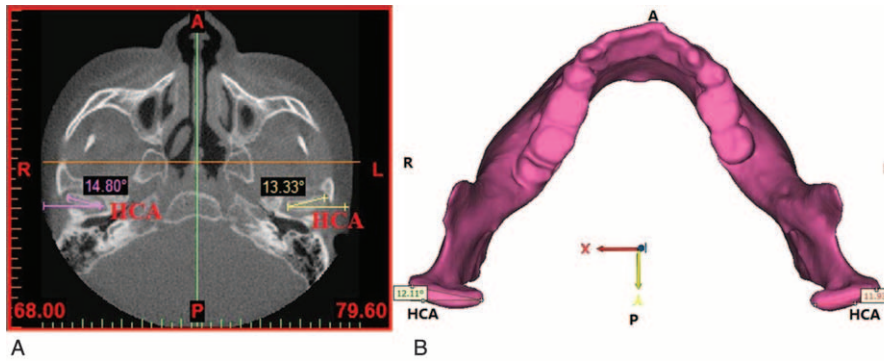


FIGURE 2. Measurements of the HCA: (A) on the horizontal CBCT image; (B) in the 3D model. 3D = three-dimensional; A = the anterior direction; CBCT = cone-beam computed tomography; HCA = horizontal condylar angle; L = the left direction; P = the posterior direction; R = the right direction.

$P < 0.05$. SPSS 20.0 (SPSS, Inc, Chicago, IL) was used for the analysis.

RESULTS

The mandibles of all the patients with facial asymmetry deviated toward the left, shown as Figure 1B. The right and left sides were defined as the deviation side and the nondeviation side, respectively.

For the asymptomatic subjects, the HCA measured from the 2D CBCT images showed statistical significance between

the left and right sides. However, all the 9 parameters measured from 3D models indicated no statistical significance between the left and right sides. The HCA, SRA, MJS, LJS, SJS, and AJS in the 2D CBCT images and 3D models were found to be statistically significant (Table 1). The SRA, MJS, LJS, SJS, and AJS in the 2D group were significantly smaller than in the 3D group (Table 1). However, the HCA on the right side in the 2D group was significantly larger than that in the 3D group ($P = 0.009$).

For the patients with facial asymmetry, the LJS measured from the 2D CBCT images showed statistical significance

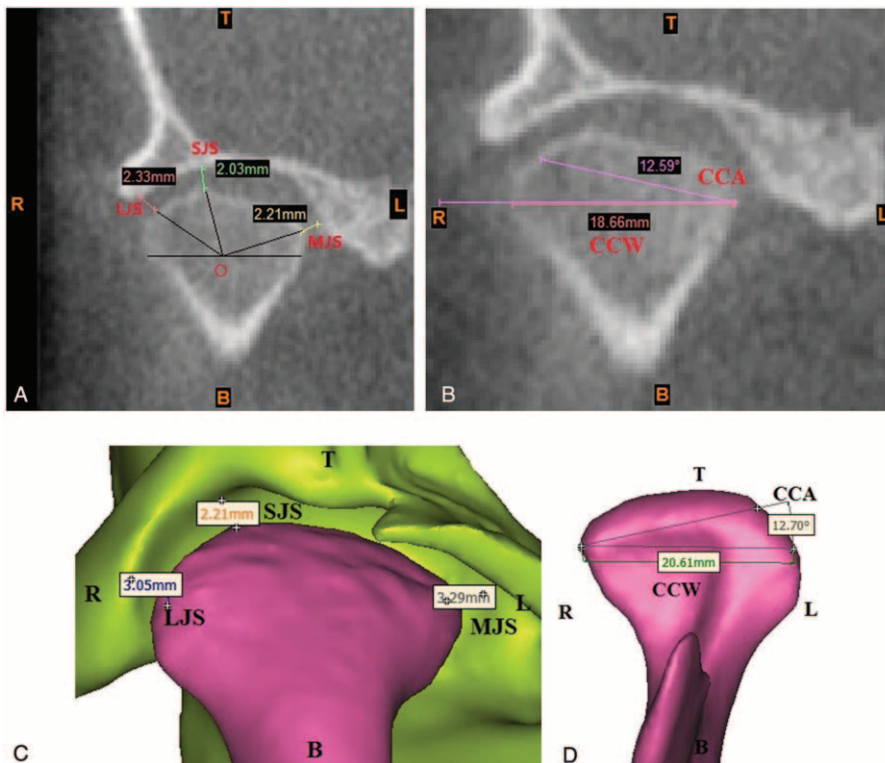


FIGURE 3. Measurements of MJS, SJS, LJS, CCA, and CCW: (A and B) on the coronal CBCT image; (C and D) in the 3D model. 3D = three-dimensional; B = the bottom direction; CBCT = cone-beam computed tomography; CCA = coronal condylar angle; CCW = coronal condylar width; L = the left direction; LJS = lateral joint space; MJS = medial joint space; R = the right direction; SJS = superior joint space; T = the top direction.

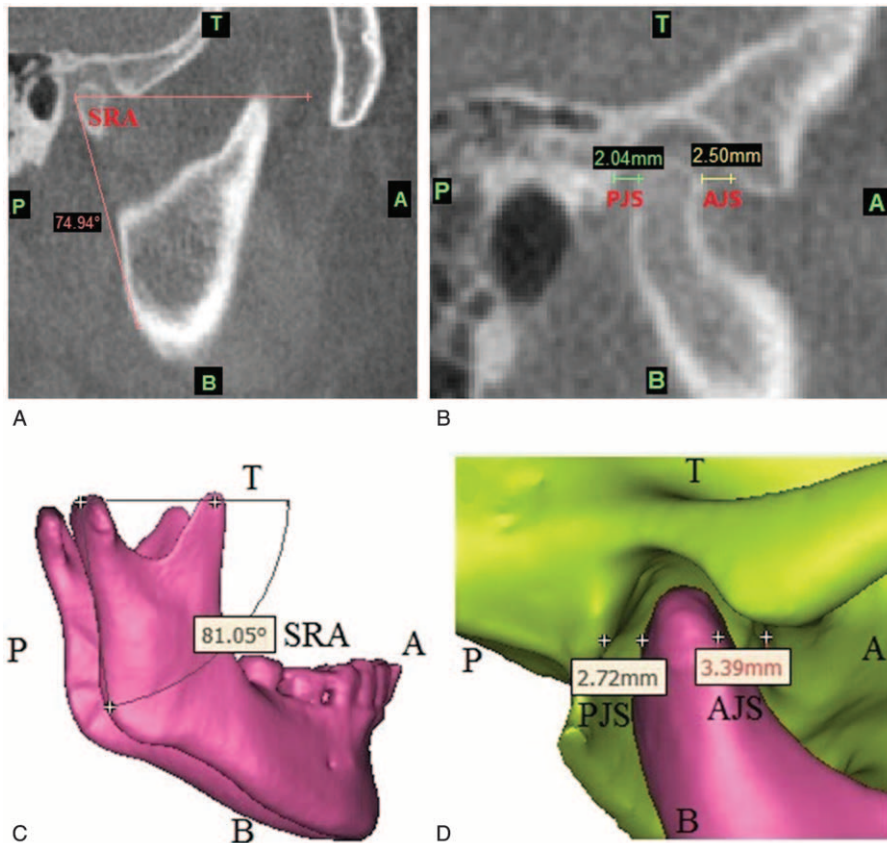


FIGURE 4. Measurements of SRA, PJS, and AJS: (A and B) on the sagittal CBCT image; (C and D) in the 3D model. 3D = three-dimensional; A = the anterior direction; AJS = anterior joint space; B = the bottom direction; CBCT = cone-beam computed tomography; P = the posterior direction; PJS = posterior joint space; SRA = sagittal ramus angle; T = the top direction.

between the left and right sides. However, the CCA, SRA, MJS, and AJS measured from 3D models had statistical significance between the left and right sides. The CCA in the 2D group was significantly smaller than that in the 3D group on the nondeviation side ($P=0.009$) and the deviation side ($P=0.000$). The CCA of patients with facial asymmetry were also observably larger than for asymptomatic subjects (Tables 1 and 2). The SRA and LJS on the deviation side in the 2D group were significantly smaller than in the 3D group (Table 2). The MJS on the nondeviation side in the 2D group was significantly larger than that in the 3D group ($P=0.000$). The LJS and SJS of patients with facial asymmetry were observably larger than for asymptomatic subjects (Tables 1 and 2).

The HCA and CCA in the patients group were significantly larger than those in the asymptomatic subjects group, no matter on the nondeviation/left side or the deviation/right side (Table 3). The SRA in the patients group was also significantly larger than that in the control group on the nondeviation/left side ($P=0.024$), but there was no significant difference for the SRA in the 2 groups on the deviation/right side (Table 3). Meanwhile, the MJS and SJS in the patients group were significantly smaller than those in the control group on both sides (Table 3). Moreover, the LJS on the deviation/right side in the patients group was also significantly smaller than that in the asymptomatic subjects group ($P=0.022$). The other variables were not significantly different in the 2 groups (Table 3).

In the measurements from the 3D models, the CCA, SRA, MJS, and AJS for the patients with facial asymmetry had statistical significance between the left and right sides, but all the 9 parameters for the asymptomatic subjects had no statistical significance between the left and right sides. For the patients with facial asymmetry, the CCA, MJS, and AJS on the nondeviation side were significantly smaller than those on the deviation side (Table 3). However, the SRA on the nondeviation side was significantly larger than that on the deviation side ($P=0.009$).

DISCUSSION

Comparison of the TMJ position between the 2D CBCT slices and the 3D space models has not been studied previously. The measurement method on the 2D CBCT scans has been validated in the literature.^{7,21} Gonçalves et al and Yang and Hwang measured the changes in the condylar position after SSRO in 3D space.^{6,22} However the changes in disc, glenoid fossa, and articular eminence were not measured. This is the first study to investigate the differences of the TMJ position between the patients with facial asymmetry and asymptomatic subjects by using 2D CBCT and 3D models methods. The results indicated that there were significant differences between the cases and controls, and between the deviation and nondeviation sides.

TABLE 1. Mean (SD) of the Variables for Asymptomatic Subjects Measured in the 2D CBCT and 3D Model

		Mean (SD) of the Variables for Asymptomatic Subjects		
		2D CBCT	3D Model	P Value
HCA, °	Left side	12.39 (0.63) [†]	12.54 (0.33)	0.646
	Right side	14.29 (1.10)	12.93 (0.31)	0.009*
CCA, °	Left side	11.80 (0.89)	12.71 (1.10)	0.187
	Right side	12.05 (1.40)	13.21 (0.77)	0.145
SRA, °	Left side	75.54 (4.04)	80.87 (1.33)	0.016*
	Right side	75.40 (4.44)	81.02 (1.25)	0.028*
CCW, mm	Left side	18.99 (2.53)	17.87 (2.28)	0.480
	Right side	17.60 (1.55)	17.34 (2.69)	0.855
MJS, mm	Left side	2.23 (0.38)	2.96 (0.51)	0.034*
	Right side	2.41 (0.25)	2.81 (0.52)	0.154
LJS, mm	Left side	2.69 (0.16)	3.34 (0.92)	0.175
	Right side	2.66 (0.20)	3.21 (0.41)	0.028*
SJS, mm	Left side	1.99 (0.09)	2.20 (0.12)	0.014*
	Right side	2.03 (0.18)	2.37 (0.29)	0.057
AJS, mm	Left side	2.73 (0.78)	2.73 (0.68)	0.990
	Right side	2.49 (0.47)	3.20 (0.34)	0.025*
PJS, mm	Left side	2.47 (0.42)	2.33 (0.95)	0.765
	Right side	2.82 (1.07)	2.44 (0.68)	0.518

The data in the brackets indicate standard deviation (SD). $P > 0.05$: not significant. 2D = two-dimensional; 3D = three-dimensional; AJS = anterior joint space; CBCT = cone-beam computed tomography; CCA = coronal condylar angle; CCW = coronal condylar width; HCA = horizontal condylar angle; LJS = lateral joint space; MJS = medial joint space; PJS = posterior joint space; SJS = superior joint space; SRA = sagittal ramus angle.

* Statistically significant difference between the 2D CBCT measurement group and the 3D model measurement group ($P < 0.05$).

[†] Statistically significant difference between the left and right sides ($P < 0.05$).

The condylar angle could be an etiological factor for disc displacement and degenerative joint disease.^{7,23,24} The joint space and ramus angle would determine the disc position and the asymmetry of mandible.^{7,24} Therefore, the above 9 parameters were used to investigate the TMJ morphology. Ueki et al measured both TMJs using the 2D CBCT images and found that the mean angles of CCA were 11.9 and 12.7° on the left side and right side and the mean distances of SJS and PJS were 1.8 mm and 2.5 mm, respectively.⁷ In this study, the CCA for asymptomatic subjects measured in the 2D CBCT images were 11.80 ± 0.89 and 12.05 ± 1.40° on the left and right sides, respectively. The mean distances of SJS and PJS for asymptomatic subjects were 1.99 mm and 2.47 mm, respectively. The mean distance of the CCW for asymptomatic subjects was 17.60 mm in this study, consistent with Al-Koshab et al's result of 17.80 mm.¹⁷ The measurement method in the 3D models was also similar to other previous studies.^{6,22,25,26} In this study, the mean angle of CCA for patients with facial asymmetry was 19.17° measured from the 3D models, close to Kim et al's results of 19.81°.²⁶ These results indicated that the methods and results were reliable in our study.

Tables 1 and 2 indicated that the HCA, CCA, SRA, MJS, LJS, SJS, and AJS measured in the 2D CBCT and 3D models were statistically significantly different, no matter in the case

TABLE 2. Mean (SD) of the Variables for Patients With Facial Asymmetry Measured in the 2D CBCT and 3D Model

		Mean (SD) of the Variables for Patients With Facial Asymmetry		
		2D CBCT	3D Model	P Value
HCA, °	Nondeviation side	20.61 (3.53)	20.05 (0.40)	0.602
	Deviation side	19.60 (3.65)	19.90 (0.22)	0.602
CCA, °	Nondeviation side	16.90 (1.07)	19.17 (0.60) [†]	0.009*
	Deviation side	17.41 (0.72)	21.24 (0.99)	0.000*
SRA, °	Nondeviation side	78.49 (6.09)	85.18 (3.20) [†]	0.061
	Deviation side	74.67 (2.69)	81.45 (0.89)	0.001*
CCW, mm	Nondeviation side	16.09 (2.21)	16.44 (4.44)	0.879
	Deviation side	16.27 (2.14)	16.45 (3.87)	0.930
MJS, mm	Nondeviation side	2.29 (0.33)	1.31 (0.19) [†]	0.000*
	Deviation side	2.17 (0.71)	1.97 (0.58)	0.649
LJS, mm	Nondeviation side	2.41 (0.38) [†]	2.81 (0.77)	0.330
	Deviation side	1.72 (0.31)	2.50 (0.38)	0.008*
SJS, mm	Nondeviation side	1.64 (0.22)	1.57 (0.37)	0.704
	Deviation side	1.65 (0.22)	1.66 (0.27)	0.920
AJS, mm	Nondeviation side	2.10 (0.44)	1.97 (0.28) [†]	0.572
	Deviation side	2.52 (0.47)	2.84 (0.70)	0.427
PJS, mm	Nondeviation side	2.62 (0.94)	2.20 (0.39)	0.382
	Deviation side	2.18 (0.61)	2.26 (0.77)	0.864

The data in the brackets indicate standard deviation (SD). $P > 0.05$: not significant.

2D = two-dimensional; 3D = three-dimensional; AJS = anterior joint space; CBCT = cone-beam computed tomography; CCA = coronal condylar angle; CCW = coronal condylar width; HCA = horizontal condylar angle; LJS = lateral joint space; MJS = medial joint space; PJS = posterior joint space; SJS = superior joint space; SRA = sagittal ramus angle.

* Statistically significant difference between the 2D CBCT measurement group and the 3D model measurement group ($P < 0.05$).

[†] Statistically significant difference between the nondeviation side and deviation side ($P < 0.05$).

group or in the control group. These distances and angles measured in the 2D CBCT were significantly less than that measured in the 3D model, which suggested that the 2D method may lead to smaller measured values. Because the lines of CCW and PJS measured in the 2D CBCT almost coincided with the coronal and sagittal projection of the 2 lines measured in the 3D model, the CCW and PJS were not significantly different between the 2 measurement methods. In other words, these results suggest that the distances and angles of TMJ measured in the 3D model were closer to the real value.

From the results measured in the 3D models, significant differences of HCA, CCA, SRA, MJS, SJS, and LJS were found between the patients with facial asymmetry and the asymptomatic subjects. The HCA and CCA for patients with facial asymmetry were significantly larger than those for the asymptomatic subjects on both sides. The increase of the condylar angle for the patients may probably cause the rise of the condylar ridge, and then it may lead to the aggravation of the squeezing in the disc and other soft tissues in the TMJ. The disc displacement and other TMJ diseases were also widely reported to be associated with mandibular asymmetry in related research.^{7,23,24,27} The SRA on the nondeviation side for the patients with facial asymmetry was significantly larger than that for the asymptomatic subjects. However, there was no

TABLE 3. Mean (SD) of the Variables for Patients With Facial Asymmetry and Asymptomatic Subjects Measured in the 3D Model

		Mean (SD) of the Variables for Patients With Facial Asymmetry and Asymptomatic Subjects		
		Patients	Asymptomatic Subjects	P Value
HCA, °	Nondeviation/left side	20.05 (0.40)	12.54 (0.33)	0.000*
	Deviation/right side	19.90 (0.22)	12.93 (0.31)	0.000*
	P value	0.490	0.089	
CCA, °	Nondeviation/left side	19.17 (0.60)	12.71 (1.10)	0.009*
	Deviation/right side	21.24 (0.99)	13.21 (0.77)	0.000*
	P value	0.004†	0.436	
SRA, °	Nondeviation/left side	85.18 (3.20)	80.87 (1.33)	0.024*
	Deviation/right side	81.45 (0.89)	81.02 (1.25)	0.548
	P value	0.009†	0.864	
CCW, mm	Nondeviation/left side	16.44 (4.44)	17.87 (2.28)	0.540
	Deviation/right side	16.45 (3.87)	17.34 (2.69)	0.684
	P value	0.997	0.745	
MJS, mm	Nondeviation/left side	1.31 (0.19)	2.96 (0.51)	0.000*
	Deviation/right side	1.97 (0.58)	2.81 (0.52)	0.042*
	P value	0.028†	0.669	
LJS, mm	Nondeviation/left side	2.81 (0.77)	3.34 (0.92)	0.345
	Deviation/right side	2.50 (0.38)	3.21 (0.41)	0.022*
	P value	0.447	0.770	
SJS, mm	Nondeviation/left side	1.57 (0.37)	2.20 (0.12)	0.009*
	Deviation/right side	1.66 (0.27)	2.37 (0.29)	0.004*
	P value	0.651	0.261	
AJS, mm	Nondeviation/left side	1.97 (0.28)	2.73 (0.68)	0.175
	Deviation/right side	2.84 (0.70)	3.20 (0.34)	0.326
	P value	0.032†	0.465	
PJS, mm	Nondeviation/left side	2.20 (0.39)	2.33 (0.95)	0.785
	Deviation/right side	2.26 (0.77)	2.44 (0.68)	0.703
	P value	0.885	0.839	

The data in the brackets indicate standard deviation (SD). $P > 0.05$: not significant. 3D = three-dimensional; AJS = anterior joint space; CCA = coronal condylar angle; CCW = coronal condylar width; HCA = horizontal condylar angle; LJS = lateral joint space; MJS = medial joint space; PJS = posterior joint space; SJS = superior joint space; SRA = sagittal ramus angle.

* Statistically significant difference between the patients group and asymptomatic subjects group ($P < 0.05$).

† Statistically significant difference between the non-deviation side and deviation side ($P < 0.05$).

significant difference of SRA on the deviation side between the patients with facial asymmetry and the asymptomatic subjects. This result suggested that the sagittal ramus angles for patients with facial asymmetry were increased on the nondeviation side rather than the deviation side comparing to the asymptomatic subjects. The MJS, SJS, and LJS for the patients with facial asymmetry were significantly smaller than those for the asymptomatic subjects. The results indicated that the spaces between the condyle and glenoid fossa were reduced for the patients with facial asymmetry. The decrease of the joint space for the patients with facial asymmetry may lead to the articular disc suffering severely squeezing. Furthermore, the severely squeezing of disc may lead to the joint pain, disc perforation, or other TMJ dysfunctions, which were the symptoms of the TMD. This finding was also consistent with Yang and Hwang and Ueki et al's studies.^{22,28}

In our study, there was no significant difference of the TMJ positions measured in the 3D models for asymptomatic subjects between the left side and right side. However, for the patients with facial asymmetry, the SRA on the deviation side was significantly smaller than that on the nondeviation side. This result indicated that facial asymmetry may lead to the increase of the sagittal ramus angle on the nondeviation side

rather than the deviation. On the contrary, the CCA, MJS, and AJS on the deviation side were significantly larger than those on the nondeviation side. The increase of the coronal condylar angle indicated that facial asymmetry may lead to the rise of condylar ridge on the deviation side. The increase of the joint space at the medial and anterior sides of TMJ on the deviation side may induce the disc move to forward, known as anterior disc displacement (ADD). Related research reported that ~14% to 49.3% of the patients with jaw deformities had TMJ symptoms.^{29–32} In Ueki et al's study, the incidence of disc displacement was 56.8% in the asymmetry group.²⁴ The results in this study also suggested that the patients with facial asymmetry may had ADD. Furthermore, this study indicated that the ADD was more likely to occur on the deviated side for the patients with facial asymmetry.

One major limitation of the present study is that the sample size of each group is relatively small. This is mainly due to that this study is a methodological inquiry between the 2D and 3D measurement of TMJ, which could provide the theoretical guidance on the methodology for future studies. Certainly, a multicentric study with a larger sample should be necessary to confirm our findings.

CONCLUSIONS

The 3D measurement method is more accurate and effective for clinicians to investigate the morphology of TMJ than the 2D method.

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