Original Article

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The three-dimensional temporomandibular joint morphology in a group of Thai skeletal class III openbite patients using Cone-Beam Computed Tomography

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Objectives: The aims of this study were to investigate the temporomandibular joint (TMJ) morphology and to compare the dimensions and ratios between sides and males and females with a skeletal Class III openbite.

Materials and Methods: Cone-Beam Computed Tomography (CBCT) images of 36 TMJs (9 adult males, aged 20–37 years, mean age 23.44±5.41 years and 9 females, aged 22–42 years, mean age 28.78±6.05 years) in Thai patients with a skeletal Class III openbite were analyzed using multiplanar reconstruction images. Measurements were performed comprising the mesiodistal and the anteroposterior condylar width, the condylar height and axis, and the glenoid fossa depth. The differences in dimensions between the left and the right TMJs were analyzed by the Wilcoxon Signed Ranks Test and paired *t*-test. The differences in dimensions and ratios between sexes were analyzed using the Independent *t*-test and Mann-Whitney U test.

Results: The anteroposterior condylar width and the condylar axis were significantly higher on the left side than on the right side (p=0.047 and p=0.006, respectively). The average anteroposterior condylar width was slightly higher in males than females (7.99±1.48 mm in males, 7.26±0.58 mm in females, %difference = 9.57%, p>0.05). Moreover, the condylar anteroposterior width to condylar height ratio was higher in males than females (p=0.043).

Conclusions: The left and the right TMJs were significantly different in their anteroposterior condylar width and the condylar axis. Male Thai skeletal Class III openbite patients demonstrated a significantly higher anteroposterior condylar width to condylar height ratio compared with females.

Keywords: cone-beam computed tomography, openbite, skeletal class III, temporomandibular joint

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Introduction

The temporomandibular joint (TMJ) morphology is influenced by various factors, such as age, sex, ethnicity, or skeletal relationship. Due to the TMJ growth process, the condylar morphology changes from neonate to adulthood [1]. Al-koshab *et al* [2] evaluated 100 Cone-Beam Computed Tomography (CBCT) images of Chinese and Malay subjects. They reported that the condylar height in Chinese was higher compared with Malays. They also found that the mesiodistal condylar width and the condylar height were higher in males compared with females. The CBCT study by Alhammadi *et al* [3] in skeletal Class I, II, and III 18 –25-years-old Egyptians, with 20 samples per group, revealed that the mesiodistal condylar width in the skeletal Class I group was greater than those in the Class II and Class III groups. Moreover, the anteroposterior condylar width in the skeletal Class II was less than those in the Class I and Class III groups, and the condylar height in the

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skeletal Class I was less than the Class II and Class III groups. Park *et al* [4] evaluated 20–40-year-old Koreans with an openbite, normal bite or deepbite, divided into 20 per group. They found that the skeletal openbite had a smaller condylar size and condylar axis compared with the skeletal deepbite group. In a Thai population, Arayapisit *et al* [5] compared mandibular condyle morphology between panoramic radiographs and CBCT images. They found that the angled condylar morphology seen on panoramic radiographs was not present in the CBCT images. Although evaluating TMJ morphology can be performed using various modalities, CBCT has advantages, such as higher resolution multiplanar reconstruction images and lower radiation dose compared with multidetector computed tomography. Panoramic radiographs also have a lower reliability and accuracy to investigate the temporal joint components [6]. Furthermore, CBCT is highly accurate for evaluating the TMJ, and CBCT measurements are not significantly different from the actual TMJ [7]. To the best of our knowledge, there is no previous report on the normal TMJ morphology in Thai skeletal Class III openbite patients investigated using CBCT. Thus, the purposes of this study were to investigate the TMJ morphology using CBCT in a group of Thai skeletal Class III openbite patients and to compare the TMJ dimensions and ratios between sides and in males and females. This useful information can serve as reference data for Thai skeletal Class III openbite patients and be clinically useful in TMJ diagnosis and treatment planning.

Materials and Methods

The study protocol was approved by the Ethics Committee (HREC-DCU 2020-114). The patients CBCT images were taken using the standard method from 3D Accuitomo 170 (J. Morita, Kyoto, Japan) with 90 kVp, 5–10 mA, 17.5 sec scanning time, 17x12 mm field of view (FOV), and 0.25 mm voxel size and i-CAT (Imaging Sciences International, Hatfield, PA, USA) with 120 kVp, 3–8 mA, 7.4 sec scanning time, 23x17 mm FOV, and 0.25 mm voxel size were collected between January 2013–March 2021. In our study, we classified skeletal Class III openbite using Wits appraisal [8] and the Palatal plane-Mandibular plane (PP-MP) angle [9]. The sampling was random with a purposive requirement. The sample inclusion criteria were: 1) Thai adult ≥20-years old, 2) No history of surgery, trauma, or pathology of the TMJ and mandible, 3) Skeletal Class III categorized by Wits appraisal (value less than -5 mm) [8], 4) Skeletal openbite was categorized using the PP-MP angle (>25.4° in males and more than 27.4° in females) [9]. The sample exclusion criteria were: 1) Skeletal transverse asymmetry >3 mm and 2) History of orthodontic treatment. Based on these criteria, the CBCT images of 9 males (18 TMJs) and 9 females (18 TMJs) were obtained. The CBCT images were oriented and measured using Infinitt® PACS software (Version 1.0 Infinitt Healthcare Co., Ltd., Seoul, Korea). The linear and angular measurements were performed using multiplanar reconstruction images when each plane was perpendicular to the other planes. The structures on the left and right sides were measured separately. In the axial slice, the mesiodistal and anteroposterior condylar widths were measured after the maximum width was determined in the sagittal and coronal slices. The sagittal slice measurements were made after adjusting the Frankfort horizontal plane parallel to the floor. The measurement landmarks are shown in Figure 1.

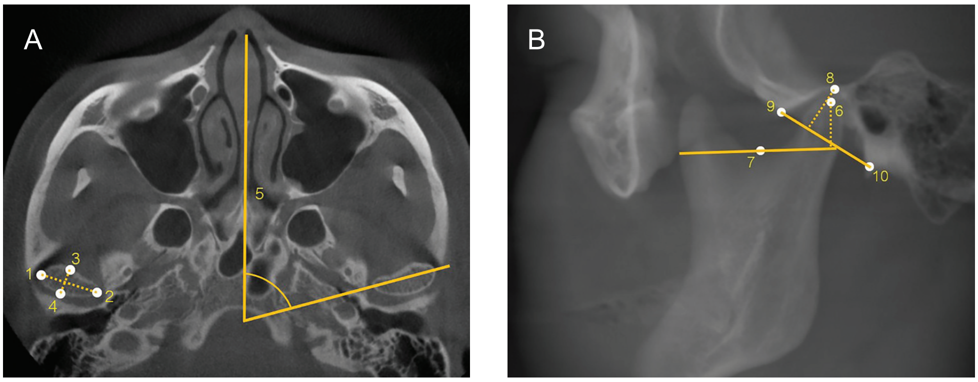

Figure 1 A) Landmarks and measurements in the axial plane: No.1 to 4 as Lateral, Medial, Anterior, and Posterior condylar points, consequently. No.5 Midsagittal plane.
B) Landmarks and measurements in the sagittal plane: No.6 Superior condylar point, No.7 Deepest point of the sigmoid notch, No.8 Deepest point of the glenoid fossa, No.9 Articular eminence, No.10 Post glenoid tubercle.
The definitions of the measurements were as follows: *Mesiodistal condylar width*; The distance between points 1 and 2, *Anteroposterior condylar width*; The distance between points 3 and 4, *Condylar axis*; Angle of the line passed through points 1 and 2 intersect with the line 5, *Condylar height*; The distance from point 6 perpendicular to the line passed through point 7 and paralleled to Frankfort horizontal plane, *Glenoid fossa depth*; The distance from point 8 perpendicular to the line connected points 9 and 10.

Data analysis

To determine the intra-examiner reliability, ten samples were randomly selected and re-measured after 2 weeks and analyzed using the Intraclass Correlation Coefficient (ICC). The inter-examiner reliability was evaluated by measuring 10 randomly selected samples and compared between the investigator and an experienced radiologist. The means, standard deviations (SD), minimums, and maximums of the parameters were calculated. The normality of the data distribution was determined by the Shapiro Wilk test. The differences between the left and the right TMJ measurements were analyzed by the Wilcoxon Signed Ranks Test and paired *t*-test. The difference between sexes was analyzed by the Independent *t*-test and Mann-Whitney U test. The statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS 22.0; SPSS Inc., Chicago, IL, USA). Significance was defined at $p<0.05$.

Results

The ICC results were good to excellent for both intra-examiner reliability (0.843–0.993) and inter-examiner reliability (0.833–0.980). We separated the left and the right sides of TMJ for measurement evaluation. The left side anteroposterior condylar width ($p= 0.047$) and the condylar axis ($p= 0.006$) was significantly higher compared with the right side (Table 1). Although there was no significant difference in these parameters between males and females (Table 2A), the mean anteroposterior condylar width in males was slightly higher than in females (7.99 ± 1.48 mm in males, 7.26 ± 0.58 mm in females, %difference = 9.57%). Furthermore, we found a significantly higher anteroposterior condylar width to condylar height ratio compared with females ($p= 0.043$) (Table 2B).

Table 1 Comparison of the TMJ dimensions between left and right sides

Measurement	Side	Minimum - Maximum	Mean ± SD	*p*-value
Mesiodistal condylar width (mm)	L	15.54 - 24.85	17.60 ± 2.15	0.878†
	R	13.86 - 22.28	17.63 ± 1.86	
Anteroposterior condylar width (mm)	L	6.58 - 12.48	7.80 ± 1.32	0.047†*
	R	5.90 - 10.21	7.45 ± 1.00	
Condylar axis (degree)	L	53.15 - 87.51	74.22 ± 8.11	0.006‡*
	R	50.17 - 82.40	70.77 ± 8.74	
Condylar height (mm)	L	16.35 - 28.02	21.07 ± 3.19	0.052‡
	R	12.72 - 28.00	20.43 ± 3.56	
Glenoid fossa depth (mm)	L	9.36 - 14.12	11.83 ± 1.15	0.369‡
	R	10.24 - 13.95	11.94 ± 0.99	

† Wilcoxon test, ‡ Paired *t*-test, *Statistical significance (p<0.05), L; left, R; right

Table 2A Comparison of the TMJ dimensions between males and females

Measurement	Sex	Minimum - Maximum	Mean ± SD	*p*-value
Mesiodistal condylar width (mm)	M	14.27 - 24.85	18.01 ± 2.53	0.635†
	F	13.86 - 18.87	17.22 ± 1.15	
Anteroposterior condylar width (mm)	M	5.90 - 12.48	7.99 ± 1.48	0.066†
	F	6.58 - 8.37	7.26 ± 0.58	
Condylar axis (degree)	M	50.17 - 87.51	72.75 ± 10.38	0.862‡
	F	55.81 - 82.32	72.24 ± 6.36	
Condylar height (mm)	M	12.72 - 27.84	20.42 ± 3.61	0.612†
	F	16.92 - 28.02	21.09 ± 3.12	
Glenoid fossa depth (mm)	M	10.34 - 14.12	11.81 ± 1.11	0.664‡
	F	9.36 - 13.68	11.96 ± 1.03	

† Mann-Whitney U test, ‡ Independent *t*-test, M; male, F; female

Table 2B Comparison of the TMJ ratio between males and females

Ratio	Sex	Minimum - Maximum	Mean ± SD	*p*-value
Anteroposterior condylar	M	0.27 - 0.57	0.39 ± 0.08	0.043†*
width to Condylar height ratio	F	0.24 - 0.41	0.35 ± 0.04	
Mesiodistal condylar width to	M	0.66 - 1.39	0.90 ± 0.18	0.486†
Condylar height ratio	F	0.50 - 1.02	0.84 ± 0.14	
Anteroposterior condylar width to	M	0.33 - 0.57	0.45 ± 0.06	0.207‡
Mesiodistal condylar width ratio	F	0.38 - 0.51	0.42 ± 0.03	
Glenoid fossa depth to	M	0.39 - 0.91	0.59 ± 0.10	0.612†
Condylar height ratio	F	0.33 - 0.67	0.58 ± 0.09	

† Mann-Whitney U test, ‡ Independent *t*-test, *Statistical significance (p<0.05), M; male, F; female

Discussion

The present study evaluated the TMJ morphology using CBCT in a group of Thai skeletal Class III openbite patients and compared the TMJ dimensions and ratios between sides and males and females. We found that among the parameters evaluated there was a significantly higher anteroposterior condylar width and the condylar axis on the left side compared with the right side. Moreover, there was a significantly anteroposterior condylar width to condylar height ratio in males compared with females. The Intra-examiner reliability and Inter-examiner reliability of this study were almost perfect [10]. The comparison between the left anteroposterior condylar width and the condylar axis were significantly higher compared with the right side, which was similar to a study in Chinese and Malays where the right mesiodistal and anteroposterior condylar width was significantly higher compared with the left side, and the left condylar height was significantly higher compared with the right side [2]. The glenoid fossa depth in our study was similar between sides and similar to that found in normal occlusion [11]. However, these results differed from a study in skeletal Class III Brazilians that found no significant difference in the mesiodistal condylar width, anteroposterior condylar width, or condylar axis between the left and the right sides [12]. In our study, the means of the mesiodistal condylar width, the anteroposterior condylar width, and the condylar axis were higher in males compared with females, especially the anteroposterior condylar width (p=0.066), which the p-value was nearly 0.05. These findings suggest that the anteroposterior condylar width tended to be a significant difference. If a larger sample size was used, it would be statistically significant. We found only a significantly higher anteroposterior condylar width to condylar height ratio in males compared with females. This significantly higher ratio might be due to the mean anteroposterior condylar width in males being higher compared with females and/or that the mean condylar height was lower in males than females. However, a study in Chinese and Malays revealed that the mesiodistal condylar width and condylar height were higher in males compared with females [2]. The difference between males and females in this study might be due to factors that were not controlled, such as the skeletal relationship. In adolescents, the mesiodistal condylar width and the anteroposterior condylar width were similar between sexes. In contrast, the glenoid fossa depth was significantly higher in males compared with females [13]. However, a study of the TMJ in Saudi Arabian patients corresponded with our study, finding that there was no significant difference in the mesiodistal condylar width or the anteroposterior condylar width between males and females [14]. Noh *et al* found that the mesiodistal condylar width and the glenoid fossa depth were influenced by the sagittal and vertical skeletal relationship and the condylar height was also influenced by the sagittal skeletal relationship [15]. The present study could be a reference for evaluating TMJ morphology in Thai population. The normal TMJ values could be used for evaluating the pathological changes of the TMJ and assessing the outcomes after orthognathic surgery. A limitation of our study was its small sample size due to the limited FOV of the CBCT images that did not include the TMJ. Based on the ALARA (As Low As Reasonably Achievable protocol) the FOV size was used to minimize radiation exposure. Thus, we could obtain the TMJ images only from orthognathic patients and those with deeply embedded teeth.

Conclusions

Comparing the left and the right TMJs demonstrated that the anteroposterior condylar width and the condylar axis were higher on the left side than on the right side. In a group of Thai skeletal Class III openbite patients, the anteroposterior condylar width to condylar height ratio in males was significantly higher compared with females.

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