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ORIGINAL RESEARCH

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Condylar asymmetry in patients with mandibular asymmetry assessed by cone-beam computed tomography

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Abstract

Purpose: The study aimed to compare the condylar size of the deviated and non-deviated sides in patients with mandibular asymmetry. The relationship of the condylar size difference between the deviated and non-deviated sides and the involvement of the anteroposterior or vertical skeletal patterns were subsequently examined.

Materials and methods: Cone-beam computed tomography (CBCT) was performed in 47 Japanese, Korean, and Egyptian people over the age of 18 for orthodontic diagnosis. The amount of deviation of Menton (Me) from the reference plane in the middle of the face was targeted at 4 mm or more. The side where Me exists was defined as the deviated side, and the opposite side was defined as the non-deviated side. The measurement items were condylar length, condylar width, and condylar height. The deviated and non-deviated sides were compared.

Results: Statistically significant differences were found in the condylar length and condylar height ($p < 0.05$, $p < 0.000$, respectively). The factors involved in this significant difference were also examined. Condylar length was defined as the anteroposterior skeletal pattern between Class III and Class II.

Conclusion: Patients with mandibular asymmetry have a condylar size difference between the deviated and non-deviated sides. This right – left difference was suggested to be related to the anteroposterior skeletal pattern.

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Introduction

Facial asymmetry seems to be more influenced by the mandible than the maxilla[1]. The condyle plays an important role as the primary centre of growth in the mandible[2]. Mandibular asymmetry is affected by a variety of factors, including the condylar growth centre, which directly or indirectly regulates the size of the condyle and the length of the condylar neck. The Menton (Me) is the most influential landmark and its deviation is crucial in the perception of facial symmetry[1].

Cone beam computed tomography (CBCT) is an appropriate diagnostic imaging method for detecting condyle alterations in the temporomandibular joint (TMJ)[3,4]. Evaluation of the TMJ using CBCT has been reportedly more accurate than evaluation using two-dimensional radiography[5]. CBCT application in

the diagnosis of TMJs in combination with magnetic resonance imaging (MRI) enable the evaluation of the TMJ anatomical structure, condylar position in malocclusion, developmental anomalies, osteoarthritis diagnosis, etc.[6]. CBCT application results in the early diagnosis of TMJ disorders[4].

CBCT can be used to morphologically examine the TMJ in patients with facial asymmetry.[7,8] On the other hand, skeletal patterns are associated with orthodontic diagnosis, treatment, or therapeutic response; for example, controlling hyperdivergence during orthodontic treatment is crucial for patients with hyperdivergence[9]. Therefore, the relationship between condylar characteristics and skeletal patterns has been investigated; anteroposterior skeletal patterns seem to be related to the condylar volume and surface[10]. The anteroposterior or vertical skeletal patterns seem to independently influence the size of the condyle[9,11]. However, the relationship between anteroposterior or vertical skeletal patterns and the size of the condyle in mandibular asymmetry is unknown.

The purpose of this study was to compare the condylar sizes of the deviated and non-deviated sides in patients with mandibular asymmetry. The relationship between the condylar size difference of the deviated and non-deviated sides and the different anteroposterior or vertical skeletal patterns were subsequently examined. We hypothesized the existence of: (1) a difference in the condylar characteristics between the deviated and non-deviated sides in patients with facial asymmetry and (2) the involvement of different anteroposterior or vertical skeletal patterns to the difference.

Materials and methods

Participants

All Japanese, Korean, and Egyptian participants requesting orthodontic treatment visited the Department of Orthodontics. The Japanese participants were patients who visited the Showa University Dental Hospital (Tokyo, Japan). The Korean participants were patients who visited the Pusan National University Dental Hospital (Busan, South Korea). The Egyptian participants were patients who visited the Suez Canal University (Ismailia, Egypt). Ethical approval was granted by the respective ethics committees (Showa University, IRB DH2015-031; Busan National Dental Hospital, IRB PNUDH-2019-025; and Suez Canal University, IRB 8; Kanagawa Dental University, approval numbers 747). CBCT was performed for the orthodontic diagnosis. All the participants had saliva collected for genetic studies. Participants with congenital disorders, such as cleft lip and palate or general physical illnesses, were excluded. Written informed consent was obtained from all participants.

The participants in this study were extracted from the aforementioned participants. All participants were over 18 years old. The midsagittal reference plane, crossing the anatomic landmarks, sella and nasion, perpendicular to the horizontal plane (the plane crossing the bilateral orbitale and right porion points was defined as the horizontal plane), was defined as the facial midline[12]. The participants had a Me deviation of 4 mm or more from the reference plane of the midline of the face[7,11]. The side where the Me was present was defined as the deviated side, and the opposite side as the non-deviated side. The research protocol was approved by the Ethics Committee of Kanagawa Dental University (approval numbers 703).

CBCT images

CBCT images of the Japanese population were obtained using a cone-beam X-ray CT system (CB MercuRay, Hitachi Medico Technology, Tokyo, Japan, and KaVo 3D eXam, KaVo, Biberach, Germany). CBCT images of the Korean population were obtained using a cone-beam X-ray CT system (Zenith 3D, Vatech Co., Seoul, Korea). CBCT images of the Egyptian population were obtained using a cone-beam X-ray CT system (Soredex SCANORA 3D, Nahkeatine 16, TUUSULA, Finland). The data were stored in Digital Imaging and Communications in Medicine format for all populations. It was then imported into Invivo 5 Anatomy imaging software (Anatomage Inc., San Jose, CA, USA) to generate and evaluate the three-dimensional (3D) images. Localizations and reference planes were defined in the 3D CBCT images. The condylar size was measured based on the method reported by Hasebe et al.[9]. The measurement items were condylar length, condylar width, and condylar height (Figure 1). Thirty CBCT images were randomly selected to assess operator error, and separate sessions were measured at 2-week intervals under the same conditions using Darberg's formula[13].

Statistical analysis

The anteroposterior skeletal pattern was defined, according to A point–nasion–B point angle (ANB), into skeletal Class I ($-1° \leq ANB < 4°$), Class II ($ANB \geq 4°$),

and Class III (ANB < -1°)[9,14,15]. The vertical skeletal pattern was defined according to the mandibular plane angle (Mp) as hypodivergent (MP ≤ 23°), normodivergent (23° < MP < 30°), and hyperdivergent (MP ≥ 30°)[9,15]. The three measurements of the condylar length, condylar width, and condylar height were examined using the Wilcoxon signed rank test to determine whether there was a statistical difference between the deviated and non-deviated sides. For those with statistically significant differences among the three measurement items, the association with each factor was subsequently examined. Factors included population, deviated side, sex, anteroposterior skeletal pattern, and vertical skeletal pattern. To determine the difference (⊿ value) in the combination in 2 groups and in 3 groups, the Mann-Whitney U test of nonparametric two-group test and the Kruskal-Wallis test of nonparametric multi-group test were used, respectively. If a significant difference was found as a result of these examinations, the group with a significant difference was further confirmed by multiple comparisons using the Bonferroni method. The significance level was set at $p < 0.05$.

Results

Random measurement errors in the condylar size measurements ranged from 0.00% to 2.28%, which was considered acceptable[16].

Table 1 presents the summary of the participants of the study. These are the age, the gender and the deviated side of the participants. Table 2 shows the distribution of the participants based on the antero-posterio and vertical pattern type.

Statistically significant difference between the deviated and non-deviated sides in the condylar length, condylar width, and condylar height measurements were examined (Table 3). Significant differences were found in condylar length and condylar height ($p < 0.05$, $p < 0.000$, respectively).

The factors involved in these two measurements were also explored (Table 4). The factors examined were population, difference (deviated side-non-deviated side), sex, anteroposterior skeletal pattern, and vertical skeletal pattern. Regarding condylar length, a statistically significant difference was found in the anteroposterior skeletal pattern ($p < 0.05$). A statistically significant difference was found in Class III and Class II group ($p < 0.05$). For condylar height, a statistically significant difference in the population was observed ($p < 0.05$). A statistically significant difference was observed between the Japanese and Korean groups ($p < 0.05$).

Discussion

Mandibular condyle growth and stability are essential for achieving and maintaining mandibular size and morphology[17]. We hypothesized that there exists a difference in the condylar characteristics between the deviated and non-deviated sides in patients with facial asymmetry; our study found a significant difference in the condylar characteristics between the deviated and non-deviated sides in these patients (Table 4). Oh et al.[1] compared the condyle morphology between the facial symmetry and facial asymmetry groups individually on the deviated and non-deviated sides, and found that patients with facial asymmetry had a smaller condyle on the deviated side. Kim et al.[18] also reported smaller condyles on the deviated side. Our study replicated these results. The mechanism leading to condylar size asymmetry is unclear. A positive correlation between masseter muscle weight and condylar size has been reported[19]. However, environmental factors such as potential force differences in crossbite can cause asymmetrical condylar modelling. No consistent conclusions have been reached[20,21]. Genetic background has also been considered[17,22].

The anteroposterior skeletal pattern was extracted as a factor related to the condylar length (Table 4). This left-right difference was large in Class II and small in Class III. Fraga et al.[23] compared the anteroposterior position of the mandibular condyle in the mandibular fossa between patients with normal occlusion and those with Class I, Class II division 1, and Class III malocclusions. They found that the greatest condylar decentralization was observed in the Class II group, whereas the least condylar decentralization was observed in the normal occlusion group. There are still few reports comparing mandibular condyles between adult participants with and without facial asymmetry. Further studies need to consider the surface area and volume of the mandibular condyle

Saccucci et al.[10] reported that patients with Class III patterns also tended to show a higher condylar volume and surface than those with class I and class II. Hasebe et al.[9] reported that patients with Class II patterns had small condylar sizes, and those with Class III

Table 1 Summary of Participants

Population	n (total)	Ave (years)	SD (years)	Min (years)	Max (years)	Male: n (%)	Female: n (%)	Deviated side in right: n (%)	Deviated side in left: n (%)
Japanese	27	26.5	6.5	18	44	9 (33.3)	18 (66.7)	8 (29.6)	19 (70.4)
Korean	8	21.5	4.8	18	30	5 (62.5)	3 (37.5)	5 (62.5)	3 (37.5)
Egyptian	12	22.8	3.7	19	33	5 (41.7)	7 (58.3)	3 (25.0)	9 (75.0)
Total	47	24.7	5.9	18	44	19 (40.4)	28 (59.6)	16 (34.0)	31 (66.0)

n, number; Ave, Average; SD, standard deviation; Min, minimum; Max, maximum

Table 2 Distribution of participants based on antero-posterio and vertical type, n (%)

		Anteroposterior skeletal pattern			Vertical skeletal pattern		
Population	n (total)	Class I	Class II	Class III	hypo	norm	hyper
Japanese	27	10 (37.0)	6 (22.2)	11 (40.7)	4 (14.8)	10 (37.0)	13 (48.1)
Korean	8	4 (50.0)	2 (25.0)	2 (25.0)	1 (12.5)	2 (25.0)	5 (62.5)
Egyptian	12	6 (50.0)	6 (50.0)	0 (0.0)	3 (25.0)	7 (58.3)	2 (16.7)
Total	47	20 (42.6)	14 (29.8)	13 (27.7)	8 (17.0)	19 (40.4)	20 (42.6)

n, number

Table 3 The differences of three condylar sizes between deviated side and non-deviated side

	condylar length			condylar width		condylar height		
	deviated side	non-deviated side		deviated side	non-deviated side	deviated side	non-deviated side	
ave (mm)	6.6	6.9		17.0	17.5	23.1	25.7	
SD	0.6	0.4		3.3	2.8	4.4	5.1	
min (mm)	4.7	5.9		10.0	11.4	12.8	15.1	
max (mm)	7.7	7.7		25.5	25.8	32.0	35.5	
p value	0.015		*	0.151		0.000		***

ave, Average; SD, standard deviation; min, minimum; max, maximum
*: $p < 0.05$, ***: $p < 0.005$

skeletal patterns had large condylar sizes. We found a statistically significant difference between patients with skeletal Class II and Class III; however, the patients in our study possessed merely mandibular asymmetry. Moreover, Vitral et al.[24] reported the mean values for the Class I and Class II sides in patients with Class II Division 1 subdivision, malocclusions were compared in the evaluation of anteroposterior symmetry or in the mediolateral symmetry of the condylar processes, and no statistically significant difference was found. This result is consistent with our results. However, Minich et al.[25] and Huang et al.[26] reported that there were significant differences in condylar size between the Class I and Class II sides. Minich et al.[25] and Huang et al.[26] did not consider any differences from the results of Vitral et al.[24].

In patients without an asymmetrical mandible, patients with hyperdivergence had short condylar widths, whereas those with hypodivergence had large widths[9,11,27]. In a study of mice with alternating hard and soft diets, one week later, the hard diet group had a significantly larger condylar width than the soft diet group[28]. In a study of patients with asymmetrical mandibles, there was no significant difference in condylar widths between the deviated and non-deviated sides.

Table 4 Factors involved in the difference between deviated side and non-deviated side

		comparison	ave (mm)¶	SD	*p* value		Comparison in 2 groups	*p* value†	
condylar length	Population	Japanese	0.15	0.64					
		Korean	0.33	0.54	0.110				
		Egyptian	0.51	0.64					
	right and left	right	0.19	0.48	0.779				
		left	0.32	0.70					
	Gender	male	0.31	0.72	0.845				
		female	0.25	0.58					
	anteroposterior skeletal pattern	Class I	0.26	0.65			Class III - Class I	0.833	
		Class II	0.54	0.71	0.049	*	Class III - Class II	0.045	*
		Class III	0.01	0.41			Class I - Class II	0.346	
	vertical skeletal pattern	hypodivergent	0.20	0.62					
		normodivergent	0.32	0.71	0.844				
		hyperdivergent	0.26	0.59					
condylar height	Population	Japanese	-3.44	3.31			Japanese - Egyptian	0.547	
		Korean	-0.49	1.53	0.016	*	Japanese - Korean	0.015	*
		Egyptian	-2.10	1.43			Egyptian - Korean	0.429	
	right and left	right	-3.31	3.85	0.221				
		left	-2.23	2.21					
	Gender	male	-2.62	2.52	0.897				
		female	-2.58	3.14					
	anteroposterior skeletal pattern	Class I	-1.91	1.79					
		Class II	-2.59	3.02	0.269				
		Class III	-3.66	3.85					
	vertical skeletal patter	hypodivergent	-2.50	3.41					
		normodivergent	-2.39	1.96	0.717				
		hyperdivergent	-2.83	3.47					

ave, average; SD, standard deviation

¶: deviated side - non-deviated side

†: adjusted significance

The population was extracted as a factor related to the condylar height (Table 4). No study has discussed variations in condylar morphology within the same ethnicity and between ethnicities[29]. Interestingly, Hasebe et al.[9] reported that there are no data obtained on another population using the same measuring method, and the observation in different ethnicities would be interesting as well. Hasebe et al.[9] verified that the similarity in measurements for Malays[5] and Chinese[29] may be due to their common origin similar to Japanese. The patients in the present study were Japanese, Korean, and Egyptian, and previous reports on modern and ancient Egyptians indicated that the specific common characteristics that are similar to those of Northeast African, Mediterranean Asian, and European[30,31]. The condyles of patients with asymmetric mandible have a greater variations in condylar characteristics than patients with no facial asymmetry[32]. Nevertheless,

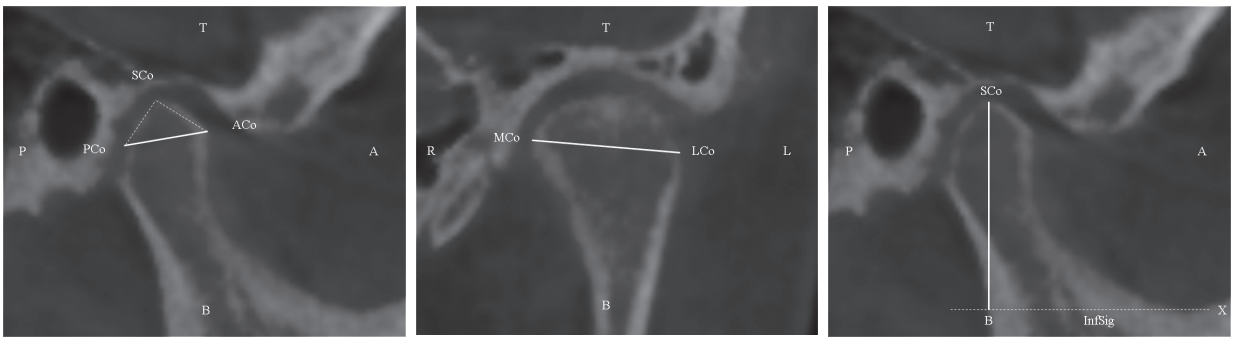


Figure 1. The condylar length on the sagittal cone-beam computed tomography (CBCT) image is shown on the left. A = anterior direction, P = posterior direction, T = top direction, B = bottom direction. The condylar length is a line in the sagittal plane that connects the anterior mandibular condyle point (ACo) to the posterior mandibular condyle point (PCo). ACo and PCo are located 4 mm below the most superior mandible condyle point (SCo). The condylar width on the coronal CBCT image is shown in the middle. T = top direction, B = bottom direction, L = left direction, R = right direction. The condylar width is a line in the coronal plane, from the medial (MCo) and lateral (LCo) mandible poles, which are located in the largest dimension of the condyle. The condylar height on the sagittal CBCT image is shown on the right. A = anterior direction, P = posterior direction, T = top direction, B = bottom direction, X = tangent of the most inferior point of the sigmoid notch parallel to the true horizontal line. The condylar height was measured as the distance from the SCo to the point where the tangent of the most inferior point of the sigmoid notch (InfSig) intersects the rearmost line of the ramus in the sagittal plane.

there was no significant difference between Egyptians and Japanese and between Egyptians and Koreans. This may be due to the small sample size of the Korean population (Table 1).

A previous study reported that the condyle size was larger in men than in women[29], and that mandibular volume had sex differences[15]. Hasebe et al.[9] also reported that condylar sizes were smaller in women than in men. No statistical differences due to gender were found in this study. Gender differences may have been camouflaged because the condyles of patients with asymmetric mandible have greater variations in condylar characteristics than patients with no facial asymmetry[32].

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