

Does the horizontal condylar angle have a relationship to temporomandibular joint osteoarthritis and condylar position? A cone-beam computed tomography study

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Background: The aim of the study was to evaluate the relationship between the horizontal condylar angle (HCA), temporomandibular joint osteoarthritis (TMJ OA), and condylar position on cone-beam computed tomography (CBCT) images.

Materials and methods: Based on TMJ OA, joints were classified as affected and the unaffected. According to the OA condition of their joints, three groups of patients were formed: control group ($n = 159$, 41.1%), unilateral group ($n = 121$, 31.3%), and bilateral group ($n = 107$, 27.6%). In total, the HCAs of 774 TMJs of 387 patients were measured and their condylar positions were determined as concentric ($n = 184$, 23.8%), posterior ($n = 338$, 43.7%), and anterior ($n = 252$, 32.5%).

Results: The mean HCA of the bilateral group ($22.7 \pm 7.6^\circ$) was greater than those in both the control ($19.5 \pm 6.4^\circ$) and the unilateral ($20.5 \pm 6.5^\circ$) groups ($p < 0.05$). However, the difference was not statistically significant between the control and unilateral group ($p > 0.05$). In total patients, unlike the unilateral group, the affected joints had a greater mean HCA than the unaffected joints ($p < 0.05$). The mean HCAs of the joints according to the condylar position were as concentric: $20.6 \pm 6.7^\circ$, posterior: $21.1 \pm 7.8^\circ$, and anterior: $20.2 \pm 7.9^\circ$ ($p > 0.05$).

Conclusions: While the HCA increased in the presence of TMJ OA, no relationship was found between HCA and three different condylar positions. (Folia Morphol 2022; 81, 3: 723–731)

Key words: horizontal condylar angle, temporomandibular joint osteoarthritis, condylar position, cone-beam computed tomography

INTRODUCTION

Temporomandibular joint osteoarthritis (TMJ OA) is a degenerative joint disease that especially involves osseous structures and is accepted as an important subgroup of temporomandibular disorders (TMDs)

[34]. TMJ OA is more sophisticated than the OA of other joints because of the architecture and composition of the TMJ tissues and the multiple forces the joint is subjected to as well [15]. The radiologically observed osseous changes associated with TMJ OA, in

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both condyle and glenoid fossa are erosion and flattening of articular surfaces, subcortical sclerosis and cyst, osteophyte, generalised sclerosis, and loose joint bodies [1]. It has been claimed that because of the changes in the bone trabecular structure, biomechanical forces and muscle activities following the OA, the morphological structure of TMJ is transformed [15].

In the previous studies that examined the morphological changes of the TMJ related to OA, one of the less-focused parameters has been the horizontal condylar angle (HCA). The HCA is defined as the angle between the long axis of the mandibular condyle and the coronal plane perpendicular to the midsagittal plane on the axial sections [36]. Limited data in the literature suggested that a greater HCA was generally observed in TMJs that presented disc displacement, clinical TMD symptoms, the excessive pulling effect of the lateral pterygoid muscle, and also radiological OA findings [5, 6, 11, 14, 15, 35, 36]. Additionally, it was reported that a greater HCA could be the result of bone formation at the posterior medial pole and resorption at the anterior lateral pole of the condyle [10]. A greater HCA: is it a result of or a reason for TMJ OA? Whether the TMJ OA osseous changes increase the HCA or whether a large HCA contributes to the development of TMJ OA has not been proven yet.

The importance of condylar position on TMJ health is a controversial issue. The predominant opinion is that TMD patients generally have a posterior condylar position [4, 18, 22, 28]. However, some authors have suggested no significant association between condylar position and clinical or radiological findings of TMJ [19, 24].

The value of imaging modality cannot be ignored for establishing the accurate diagnosis of TMJ OA and determining the condylar position [1]. As it provides high resolution and precise three-dimensional images for evaluating the osseous changes and makes reliable linear and angular measurements of maxillofacial hard tissues, cone-beam computed tomography (CBCT) has been accepted as an adequate technique for the assessment of these parameters of TMJ [16, 26].

The first aim of this study was to evaluate the relationship between TMJ OA and HCA; the second aim was to evaluate the relationship between condylar position and HCA by scanning the CBCT images of patients retrospectively in a cross-sectional period.

MATERIALS AND METHODS

This study was approved by the Ethical Committee of Gazi University (date: 26/06/2019, number: 07). The CBCT images of patients who applied to Gazi University Faculty of Dentistry Oral and Maxillofacial Radiology Clinic between January 2015 and December 2019 for various dental reasons were analysed retrospectively. No additional CBCT scan was taken for the study. Informed consent was obtained from all participants included in the study.

The CBCT images were obtained by a Planmeca Promax 3D Mid (Planmeca, Helsinki, Finland) device, and the parameters were 140 × 92 mm² field of view (FOV), 90 kVp, 8 mA, 13.5 s, 0.4 mm³ voxel or 140 × 52 mm² FOV, 90 kVp, 8 mA, 13.5 s, 0.4 mm³ voxel. The original software programme Romexis 4.6.2.R (Planmeca, Helsinki, Finland) of the CBCT device was used to display the images. All images were analysed on the same 24-inch medical monitor (Philips, Luchu Hsiang, Taiwan) with an ideal screen display (resolution: 1920 × 1080 pixels) provided with an NVIDIA QUADRO FX 380 graphics card. All evaluations were made independently by two calibrated investigators who have competence in the CBCT interpretation for maxillofacial diagnosis, including the TMJ region, in a quiet room with subdued ambient lighting, from about 50 cm. The obtained data were recorded in a form that was specially prepared for this study. In cases of disagreement regarding the presence or absence of osseous changes, the observers evaluated the images for the second time and a consensus was reached after a discussion [15].

All the exclusion and inclusion criteria and radiologic findings are based on CBCT reports and images, and health records. The primary inclusion criterion was that both the mandibular condyle and the glenoid fossa could be viewed simultaneously on the same CBCT image. Patients with a history of surgical operation (including orthognathic surgery), trauma, and pathology (including tumours and synovial chondromatosis) in the TMJ area, younger than 18 years (only patients who were aged ≥ 18 years were selected to ensure the TMJ development had been completed), images that had a failure in maximum occlusion position during the scan acquisition, and without sufficient diagnostic quality were excluded. A total of 387 patients' CBCT images were included in the study. Patients were between 18 and 71 years (mean 46.81 ± 13.82 years [standard devi-

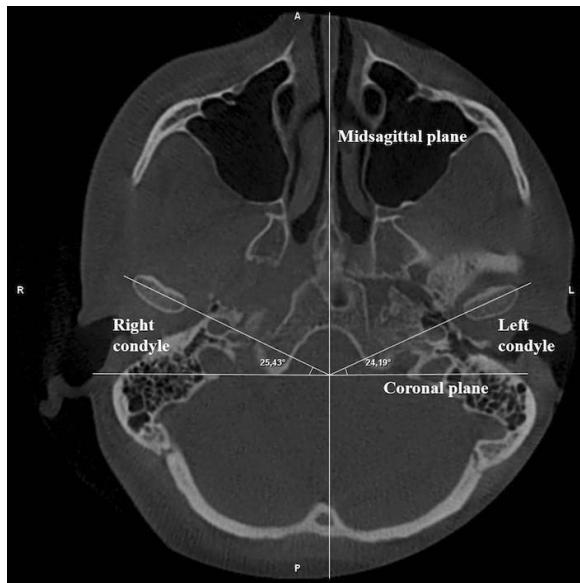


Figure 1. Measurement of horizontal condylar angle on the axial cone-beam computed tomography section.

ation, SD]) and comprised 225 (58.1%) females and 162 (41.9%) males.

Measurement of HCA

First, the maximum mediolateral length of both right and left condyles was determined as the long axis of the condyle on the appropriate axial CBCT section. The coronal plane was determined as a line drawn perpendicular to the midsagittal plane. Then the angle between the long axis and the coronal plane was defined as the HCA (Fig. 1) [36]. Because these images used to measure the HCA did not show indications of OA, all HCA measurements were performed blinded to the knowledge of the OA status of the joints.

Evaluation of TMJ OA

Each patient's right and left TMJ regions were evaluated separately on the reconstructed sagittal CBCT sections in one-millimetre intervals. The TMJ OA was diagnosed radiologically using the method defined by Ahmad et al. [1], in which osseous changes of the joint region were evaluated. The mandibular condyle head changes were gross hypoplasia or hyperplasia, flattening, erosion, subcortical sclerosis and cyst, osteophyte formation, generalised sclerosis, and loose joint bodies. Correspondingly, changes evaluated in the glenoid fossa were flattening of the articular eminence, sclerosis, and surface erosion (Fig. 2).

Joints were categorised as non-OA, indeterminate OA, or OA according to the findings obtained by evaluating the osseous structures on CBCT images. Afterward, the joints with non-OA or indeterminate OA changes were accepted as unaffected, and joints with OA changes were accepted as affected [14]. The patients were divided into three groups according to the presence of unaffected/affected joints as control group (bilaterally unaffected joints), unilateral group (one unaffected joint and one affected joint), and bilateral group (bilaterally affected joints). Furthermore, to evaluate the relationship between the TMJ OA and HCA from another window, only in the unilateral group the value obtained by subtracting the affected joint HCA from the unaffected joint HCA was recorded for each patient [29].

Determination of condylar position

The axial CBCT section where the mandibular condyle has the largest mediolateral diameter was chosen as the reference view for the secondary reconstruction. On this selected axial section, a reconstructed



Figure 2. Osseous changes of temporomandibular joint osteoarthritis observed in the temporomandibular joint region on the reconstructed sagittal cone-beam computed tomography sections; **A.** Flattening of articular eminence and erosion of condyle; **B.** Generalised sclerosis of articular eminence and condyle; **C.** Flattening and subcortical sclerosis of the condyle; **D.** Osteophyte formation; **E.** Subcortical cyst; **F.** Loose joint body and erosion of glenoid fossa.

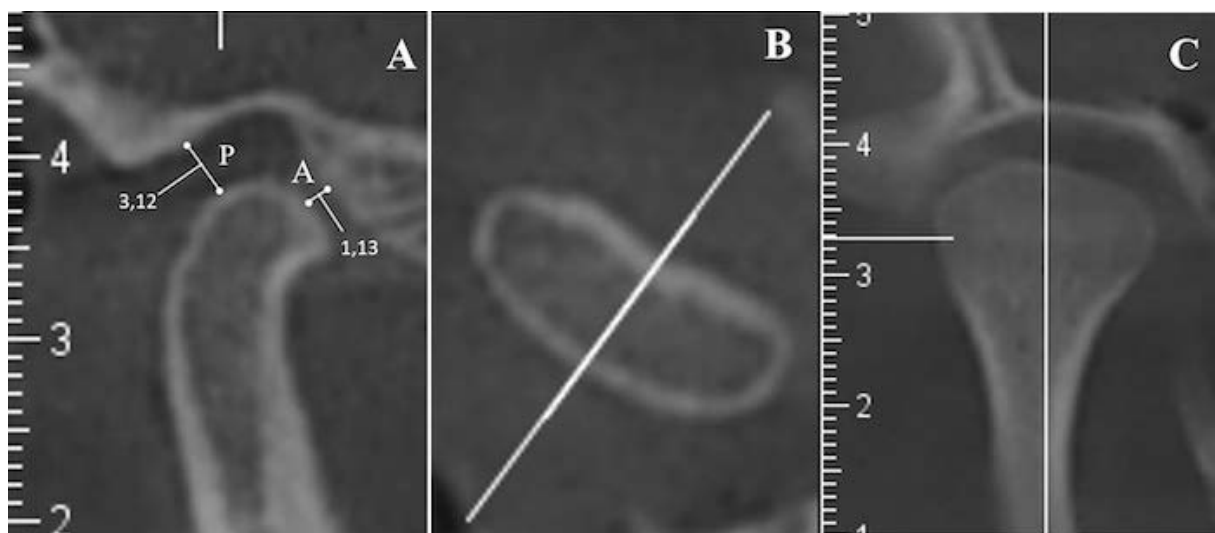


Figure 3. Measurements for determining the condylar position; **A.** Linear measurement of posterior (P), and anterior (A) joint spaces on the reconstructed sagittal cone-beam computed tomography sections with the axial (**B**) and coronal (**C**) cone-beam computed tomography sections as reference.

sagittal CBCT section was obtained by drawing a line parallel to the long axis of the condyle. The narrowest posterior (P) and anterior (A) joint spaces were measured linearly on this sagittal section (Fig. 3). The condylar position was determined according to the Pullinger and Hollender method: Condylar ratio = $(P - A) / (P + A) \times 100$ [21]. The condyle was accepted to be located in the concentric position if the calculated ratio was within $\pm 12\%$, in the posterior position if it was less than -12% , and in the anterior position, if it was greater than $+12\%$.

Statistical analysis

The Kolmogorov-Smirnov test was used to examine whether the data were compatible with the normal distribution. Because the dimensions in the scale were from a population with a normal distribution, the independent sample t-test was used to compare two groups, and one-way analysis of variance (one-way ANOVA) was used to compare more than two groups. If the difference between the groups was statistically significant because of the variance analysis, the Tukey test (one of the multiple comparison tests) was applied to determine which groups were different from each other. The assumption of variance homogeneity in the tests related to the comparison of the groups was examined with Levene's test, and the results were used to decide which test statistics should be considered. The χ^2 test was used to examine categorical variables. The results obtained for the analysis were interpreted

at a significance level of 0.05, and IBM SPSS 20.0 programmes were used.

RESULTS

A total of 387 patients were divided into three groups according to the radiological OA findings of their 774 TMJs examined by CBCT:

- the control group consisted of 159 patients with two unaffected joints ($n = 88$, 55.3% females and $n = 71$, 44.7% males);
- the unilateral group consisted of 121 patients with one unaffected joint and one affected joint ($n = 69$, 57% females and $n = 52$, 43% males);
- the bilateral group consisted of 101 patients with two affected joints ($n = 68$, 63.6% females and $n = 39$, 36.4% males).

The mean ages of the patients for the three groups were similar (control group: 44.9 ± 13.7 years, unilateral group: 49.6 ± 13.1 years, bilateral group: 46.5 ± 14.5 years). When the mean HCAs of the TMJ OA groups were compared, the difference was statistically significant ($p < 0.05$). According to the results of the multiple comparison test, the bilateral group had a greater mean HCA than both the control and unilateral group, and the difference was statistically significant ($p = 0.001 < 0.05$) (Table 1). However, the difference was not statistically significant between the control and unilateral group ($p = 0.199 > 0.05$).

The mean HCA of the total 774 joints was $20.7 \pm 7.7^\circ$. The difference between the mean HCAs of all joints in the control group (both unaffected) and

Table 1. Distribution of mean horizontal condylar angles (HCA) of temporomandibular joint osteoarthritis (TMH OA) groups, number (%) and the statistical analysis results

TMJ OA-HCA (patients)	N (%)	Mean HCA of right and left condyle ± SD (degree)	P
Control group	159 (41.1)	19.5 ± 6.4 ^a	} 0.199 } } 0.001*
Unilateral group	121 (31.3)	20.5 ± 6.5 ^a	
Bilateral group	107 (27.6)	22.7 ± 7.6 ^b	
Total	387 (100)	20.7 ± 6.9	

^{a,b}The letters next to the mean angles indicate groups that differ according to the Tukey HSD test; *p < 0.05, statistically significant; SD — standard deviation

Table 2. Distribution of mean horizontal condylar angles (HCA) of affected and unaffected joints in terms of temporomandibular joint osteoarthritis (TMJ OA), number (%) and the statistical analysis results

TMJ OA-HCA (joints)	N (%)	Mean HCA ± SD (degree)	P	
Unaffected joints	Control group	318 (41.1)	19.5 ± 6.4	} 0.852 } } 0.0001*
	Unilateral group's unaffected joint	121 (15.6)	19.7 ± 7.0	
	Total	439 (56.7)	19.6 ± 6.6	
Affected joints	Bilateral group	214 (27.6)	22.7 ± 7.6	} 0.155 } } 0.0001*
	Unilateral group's affected joint	121 (15.6)	21.3 ± 7.5	
	Total	335 (43.3)	21.0 ± 7.6	
Total	774 (100)	20.7 ± 7.2		

*p < 0.05, statistically significant; SD — standard deviation

Table 3. Relationship between condylar position, temporomandibular joint osteoarthritis (TMH OA) groups, and mean horizontal condylar angle (HCA), number (%) and the statistical analysis results

Condylar position: TMJ OA groups and HCA (joints)	Control group, n (%)	Unilateral group, n (%)			P	Bilateral group, n (%)	Mean HCA ± SD (degree)	
		Affected joints	Unaffected joints	Total				
Condyar position	Concentric	84 (26.4)	22 (18.2)	24 (19.8)	46 (19)	0.942 ^e	54 (25.2)	20.6 ± 6.7
	Posterior	111 (34.9)	62 (51.2)	60 (49.6)	122 (50.4)		105 (49.1)	21.1 ± 7.8
	Anterior	123 (38.7)	37 (30.6)	37 (30.6)	74 (30.6)		55 (25.7)	20.2 ± 7.9
P		0.023 ^{a*}	0.000 ^{b**}	0.000 ^{c**}	0.000 ^{d**}		0.000 ^{f**}	0.408 ^g
				0.000 ^{h**}				

*p < 0.05, **p < 0.01, statistically significant; SD — standard deviation; ^acomparison of condylar position frequencies in the control group; ^bcomparison of condylar position frequencies of affected joints in the unilateral group; ^ccomparison of condylar position frequencies of unaffected joints in the unilateral group; ^dcomparison of condylar position frequencies in the unilateral group; ^ecomparison of condylar position frequencies and OA status in the unilateral group; ^fcomparison of condylar position frequencies in the bilateral group; ^gcomparison of mean HCAs according to condylar positions; ^hcomparison of condylar position frequencies according to TMJ OA groups

the unaffected joints in the unilateral group was not statistically significant (p = 0.852 > 0.05) (Table 2). Similarly, the difference between the mean HCAs of all joints in the bilateral group (both affected) and the affected joints in the unilateral group was not statistically significant (p = 0.155 > 0.05) (Table 2). However, while in total patients the difference between the mean HCAs of the unaffected joints and the affected joints was statistically significant (p = 0.0001 < 0.001) (Table 2), in the unilateral group, the difference between the mean HCAs of the unaffected joints and the affected joints was not statistically significant (p = 0.085 > 0.05).

The distribution of joints according to condylar positions and their mean HCAs were n = 184 (23.8%) in the concentric position with 20.6 ± 6.7° mean HCA, n = 338 (43.7%) in the posterior position with 21.1 ± 7.8° mean HCA, and n = 252 (32.5%) in the anterior position with 20.2 ± 7.9° mean HCA. The difference between the mean HCAs of the three condylar positions was not statistically significant (p = 0.408 > 0.05) (Table 3).

The relationship between the TMJ OA groups and the condylar position was statistically significant (p = 0.000 < 0.01) (Table 3). However, in the unilateral group, the relationship between the joints' OA

Table 4. Distribution of mean horizontal condylar angles (HCA) of temporomandibular joint osteoarthritis (TMJ OA) groups by sexes, number (%) and the statistical analysis results

Variables		Sexes				P
		Female		Male		
		N (%)	Mean HCA ± SD (degree)	N (%)	Mean HCA ± SD (degree)	
TMJ OA groups	Control	88 (39.1)	19.3 ± 6.4	71 (43.8)	19.8 ± 6.4	0.659
	Unilateral	69 (30.1)	21.5 ± 6.3	52 (32.1)	19.1 ± 6.5	0.039*
	Bilateral	68 (30.2)	22.9 ± 7.9	39 (24.1)	22.4 ± 7.2	0.711
Total		225 (100)	21.1 ± 6.9	162 (100)	20.2 ± 6.7	0.196

*p < 0.05, statistically significant; SD — standard deviation

status and the condylar positions was not statistically significant ($p = 0.942 > 0.05$) (Table 3). That is, the condylar positions distribution of the affected and unaffected joints in the unilateral group was similar. When we analysed each TMJ OA group independently according to the condylar position, mostly the posterior (except for the control group) and least the concentric condylar position was observed, and the differences were statistically significant ($p < 0.05$) (Table 3).

In the unilateral group, the mean value of the difference between the affected joints' HCAs and the unaffected joints' HCAs was positive, as $1.6 \pm 6.5^\circ$. It was positive ($5.7 \pm 4.8^\circ$) in 70 (57.9%) patients, while negative ($-3.9 \pm 4.1^\circ$) in 51 (42.1%) patients, and the difference was statistically significant ($p = 0.000 < 0.001$).

According to TMJ OA groups, the mean HCAs of the sexes were close to each other in the control group, bilateral group, and in total patients, and the difference was not statistically significant ($p > 0.05$) (Table 4). Only in the unilateral group, the mean HCA of the females was greater than the males', and the difference was statistically significant ($p = 0.039 < 0.05$) (Table 4). Additionally, the correlation between the HCA and age was negatively and not statistically significantly ($r_s = -0.054$, $p = 0.436 > 0.05$).

DISCUSSION

In the present study, the relationship between HCA, TMJ OA, and condylar position was evaluated by CBCT. The authors observed that HCA increased in the presence of TMJ OA, but no relationship between HCA and different condylar positions. In literature, various radiological imaging modalities such as submentovertex projection radiography (SPR) [3, 8, 25, 36, 38], magnetic resonance imaging (MRI) [6, 12, 13, 29, 32, 35], computed tomography (CT) [5, 9, 15, 23, 27, 33], and CBCT [2, 14] have been used alone or

combined in studies for measuring the HCA to date. In studies that used SPR, the HCA was found associated with disc position while not associated with osseous changes [8, 25, 36, 38]. In MRI studies, generally, a greater mean HCA was reported in TMJs with disc displacement and osseous changes [6, 13, 27, 29, 31, 35, 36]. Considering that TMJ OA was more common with initial and prolonged disc displacement [37], the findings of the present study overlapped these studies. Although the osseous structures of TMJ could be evaluated with MRI, it is superior in evaluating the soft tissues [17]. Additionally, in the context of HCA measurement, MRI has a low spatial resolution and few available axial sections and is not suitable for the secondary image reconstruction like CBCT [14]. In studies that used CT to evaluate the osseous structures or disc position in addition to HCA measurements, it was reported that the mean HCA increased in the case of osseous changes and disc displacement in TMJ [5, 15, 27]. In their prospective longitudinal study, Lee et al. [15] observed a mean 2.83° increase of the HCA in joints that developed OA over time and the increase did not regress even in rare cases where morphological osseous changes were reversed. They stated TMJ OA may cause a greater HCA, but an initially great HCA did not affect the development of TMJ OA [15]. Seo et al. [27] claimed the joints with greater HCAs could be explained by OA changes that were thought to be associated with disc displacement. The results authors reached in the present study showed similarity to the studies that examined the osseous changes of TMJ radiologically on CT.

Because it is an effective imaging modality for evaluating structural changes in the osseous morphology of TMJ, for both determination of the TMJ OA and the measurement of the HCA the CBCT was used in the current study [7]. In terms of TMJ OA groups, the mean HCA of the patients in the bilat-

eral group was greater than both the control and unilateral groups, and the difference was statistically significant. However, although the mean HCA of the patients in the unilateral group was greater than those in the control group, the difference was not statistically significant. When focused on the unilateral group, the mean HCA of the affected joints was greater than the unaffected joints, and the difference was statistically significant. In addition, the difference between the mean HCAs of total affected joints and total unaffected joints was also statistically significant. However, when the mean HCAs of similar joints in terms of OA in different groups were compared, the difference was not statistically significant. The results of the present study, which showed TMJ OA was associated with increased HCA, were consistent with each other and similar studies. In a CBCT study, Lee et al. [14] found the mean HCA was greater in OA-affected joints than the contralateral OA-unaffected joints, in the TMJ OA unilateral group, and the difference was statistically significant. However, the difference between the mean HCA of both joints of the control subjects and the mean HCA of the unaffected joints of the unilateral OA patients was not statistically significant [14]. These findings were exactly consistent with the present study. A clinical TMD study that used CBCT only to measure the HCA found a greater mean HCA in the control group [2], unlike the present study findings. That result may have arisen because there is no correlation between osseous changes in TMJ and clinical symptoms, including pain [20].

Another parameter examined was the relationship between condylar position and both TMJ OA and HCA. The authors did not find any studies in the literature investigating the relationship between condylar position and HCA. However, some studies found the posterior condylar position was associated with any TMD [18, 22, 28]. Cho et al. [4] concluded the posterior condylar position was more common in joints with osseous changes. The results obtained showed that the frequency of posterior condyle position was higher in the unilateral and bilateral TMJ OA groups compared to the control group. As the posterior condylar position was generally accepted as associated with disc displacement, OA, and clinical TMDs, these results were expected. In addition, although it was not addressed previously, the mean HCAs of three condylar positions were found close to each other.

Hüls et al. [11] reported a greater mean value for the difference between the right and left joints HCAs in TMD patients compared to the asymptomatic group. Taylor et al. [30] investigated the difference between the right and left joints HCAs only in asymptomatic adults. Sulun et al. [29] also indicated this difference was greater in patients with internal derangement than in the asymptomatic volunteers. From a different perspective, in the present study for each patient in the TMJ OA unilateral group the difference between the HCAs of the affected and unaffected joints, not the right and left joints, were examined. In the unilateral group, the mean value of this difference was found positive. Additionally, in the same group, the frequency of patients with positive value was higher than the patients with negative value, and the difference was statistically significant.

In many studies, like the present study, the relationship between the HCA and sexes and age was not found statistically significant [6, 15, 29, 35]. Contrary to these studies, Al-Rawi et al. [2] found a greater mean HCA for males both in TMD and control groups, but interestingly, the statistical difference was only in the control group. Christiansen et al. [5] found the HCA was positively significantly correlated with age.

Limitations of the study

This study had limitations. The dentition status of the patients and the presence or absence of mandibular asymmetry were not considered. Theoretically, the HCA could be affected by both parameters. In addition, due to the lack of clinical information, the HCA changes in the presence or absence of clinical signs of TMD could not evaluate.

CONCLUSIONS

The mean HCA of the bilateral group was statistically significantly greater than the control and unilateral groups. Unlike in the unilateral group, when all patients were considered, the mean HCA of the affected joints was greater than the unaffected joints. There was no statistically significant difference between the mean HCA values of the joints with the concentric, posterior, and anterior condylar positions. Posteriorly located condyles were observed more in the bilateral and unilateral TMJ OA groups, and anteriorly located condyles were observed more often in the control group. The mean HCAs of females and males were close. The results showed TMJ OA-related osseous changes positioned the condyle posteriorly in

the anteroposterior direction and rotated its position relative to the cranium resulting in an increase in HCA. While an undeniably strong relationship between the TMJ OA and the greater HCA was demonstrated, it is not easy to make a full judgment in the context of a cause-effect relationship. Although several studies investigated the HCA of patients with TMD and TMJ OA findings, the diagnostic value of this phenomenon has still been unclear because of various HCA values reported.

Conflict of interest: None declared

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