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Joint Space Analysis Using Cone-beam Computed Tomography Imaging in Patients Diagnosed with Temporomandibular Joint Osteoarthritis and Occlusal Changes

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Purpose: This pilot study aimed to evaluate changes in joint space (JS) using cone-beam computed tomography (CBCT) images of patients diagnosed with temporomandibular joint (TMJ) osteoarthritis (OA) and to determine the association between occlusal changes and JS.

Methods: CBCT images were used to measure the anterior, superior, and posterior JSs of the sagittal plane. The differences in JS values over time and between groups were compared. The percentage change in the anteroposterior position of the mandibular condyle between groups was also analyzed.

Results: Thirty-four subjects (mean age=43.91±20.13), comprising eight males (23.5%) and 26 females (76.5%), were divided into 18 patients with no change in occlusion (NCO) and 16 patients with a change in occlusion (CO) during TMJ OA. The JS measurements of the study subjects showed a decrease in anterior joint space (AJS) values over time. There was no difference in JS measurements between the groups at T1 and T2. AJS values measured at T1 were lower in the CO group than in the NCO group, but the difference was not statistically significant. In both groups, a posterior position of the mandibular condyle was initially observed with high frequency. However, there is a statistically significant difference in CBCT images taken after occlusal changes, with an increased frequency of condyles observed in the anterior or central positions.

Conclusions: In conclusion, AJS decreased over time in TMJ OA, and the mandibular condyle became more anteriorly positioned with occlusal changes. Therefore, clinicians should diligently monitor mandibular condyle morphology and JS using CBCT, along with the patient's clinical symptoms, to treat and control TMJ OA effectively.

Keywords: Cone-beam computed tomography; Dental occlusion; Osteoarthritis; Temporomandibular joint

INTRODUCTION

The temporomandibular joint (TMJ) is a complex joint with the mandibular fossa, articular process, and mandibular condyle as its skeletal components [1,2]. As a synovial joint, it performs the most complicated movements of all human joints, creating three-dimensional motion [3]. Due to the complexity of mandibular movements and the constant load on the TMJ, it is a common site for osteoarthritis (OA) [4]. TMJ OA is a condition that involves progressive degenerative changes in the mandibular condyle and surrounding bone tissue [5].

The main clinical manifestations of TMJ OA are joint sounds (characterized by crepitus), pain, and restrictions in mouth opening [3]. An additional symptom is an alteration in occlusion, reflecting a change in the position of the maximum intercuspation (MI). Changes in occlusion due to temporomandibular disorders (TMD) result from changes in the positions of the mandible and mandibular condyle from the associated TMJ and masticatory muscles [6]. Particularly, as TMJ OA progresses, occlusion changes may occur due to the morphological destruction of the TMJ and a subsequent reduction in mandibular height [7]. While certain clinical symptoms of TMJ OA can be ameliorated with treatment, symptoms arising from degenerative changes in bone tissue may be irreversible. Consequently, TMJ OA is considered the most severe type of TMD [4].

The diagnosis of TMD typically involves a comprehensive approach, including history taking, clinical examination, and imaging of the TMJ [8]. Among these, radiological examination of the TMJ is essential for detecting TMJ OA. Currently, cone-beam computed tomography (CBCT) is the preferred imaging tool for diagnosing TMJ OA [9]. Compared to conventional imaging techniques, CBCT can accurately assess the anatomical relationships of the TMJ, with the advantage of significantly lower radiation [8].

TMJ OA is diagnosed following radiographic evidence of cortical bone erosion, condyle flattening, osteophyte formation, subchondral sclerosis, and subcortical cyst formation [3]. However, structural changes in TMJ alone do not indicate disease activity, and there is no direct relationship between radiological findings and clinical symptoms of TMJ OA [10]. In addition to the aforementioned morphological condylar changes, frequent radiographic findings in TMJ OA include joint space (JS) loss [11]. JSs, observed in radiographic images, are located in the temporal bone and mandibular condyle and constitute the spaces in which the disks reside [12]. While studies utilizing JS imaging have compared TMD patients to healthy individuals and different types of TMD [7,12,13], no studies have explored changes in JS over time in patients with TMJ OA. Therefore, this study aimed to evaluate JS changes using CBCT images of patients diagnosed with TMJ OA and determine the association between occlusal changes and JS.

MATERIALS AND METHODS

1. Subjects

This retrospective study was approved by the Institutional Review Board of Chosun University Dental Hospital (CUDH IRB-2202 001), and the committee waived the requirement for written informed consent. The study subjects comprised patients diagnosed with bilateral TMJ OA at the Department of Oral Medicine, Chosun University Dental Hospital, between 2018 and 2022, who underwent CBCT at one-year intervals. During CBCT, the patients were positioned upright, with their teeth in MI.

Inclusion criteria encompassed healthy adults with complete dentition who were over 20 years old. Exclusion criteria included patients with abnormal deformities or condyle tumors, such as osteochondromatosis. Additionally, individuals with a history of trauma to the face and jaw or a history of orthodontic treatment were excluded. Therefore, our study was conducted using CBCT images obtained during the initial diagnosis (T1) and one-year follow-up (T2) of the study subjects. By evaluating the patients' medical records, the study subjects were categorized into two groups (no change in occlusion [NCO] and change in occlusion [CO]) based on the presence or absence of occlusal changes during follow-up.

2. Image Analysis

CBCT images were obtained using the CS9300 system (Carestream Health Inc.) and Planmeca Viso G7 (Planmeca) at 80-120 kVp, 5-11 mA, and a voxel size of 0.25-0.3 mm. Image reconstruction was conducted using OnDemand3D software (Cybermed Co.), and the reconstruction of the left and right mandibular condyles followed the method in our previous study [14]. Each image was edited with a slice thickness of 0.5 mm. All CBCT image reconstructions were performed by an experienced oral and maxillofacial radiologist (YSS) with over 10 years of experience in the field.

3. Data Analysis of CBCT Images

CBCT images were sent to the picture-archiving and communication system (PACS) (ZETTA PACS; Taeyoung Soft Co.). The image with the highest roof of the glenoid fossa of the temporal bone in the sagittal plane was selected for JS measurement. To enhance reproducibility, two experts (HJP and JWR) with over 10 years of clinical experience in oral medicine selected the assessment images from sagittal images. Subsequently, the experts measured the anterior joint space (AJS), superior JS (SJS), and posterior JS (PJS) using anatomical landmarks [15,16]. In brief, AJS measured the shortest perpendicular distance to the glenoid fossa from the tangent of the most anterior–superior point of the condyle. Additionally, SJS measured the shortest perpendicular distance to the glenoid fossa from the tangent of the most superior point of the condyle, and PJS measured the shortest perpendicular distance to the glenoid fossa from the tangent of the most posterior–superior point of the condyle (Fig. 1). Each JS value was measured three times, and the average value was used for analysis. Measurements were taken using a digital ruler provided by the PACS.

Among the JS measurements, AJS and PJS were used to calculate information about the anteroposterior position (APP) of the mandibular condyle in the glenoid fossa. The APP is defined as the position obtained by dividing AJS by PJS (AJS/PJS ratio) and is considered a central condylar position when the calculated value is 1 (±0.09), a posterior condylar position when it is greater than 1, and an anterior condylar position when it is less than 1 [17,18].

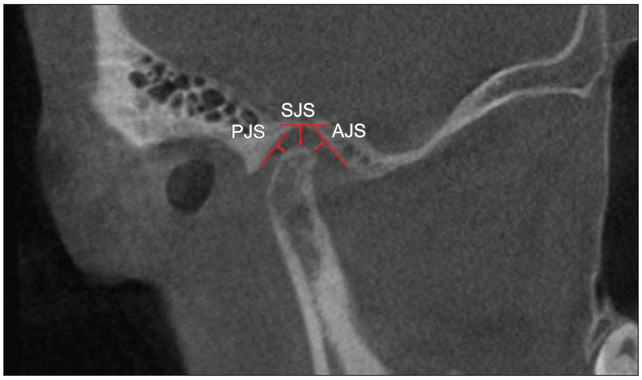

Fig. 1. Joint space measured in the sagittal plane of a cone-beam computed tomography image of the temporomandibular joint. AJS, anterior joint space; SJS, superior joint space; PJS, posterior joint space.

4. Statistical Analysis

All statistical analyses were conducted using IBM SPSS Statistics for Windows, Version 27.0 (IBM Co.). All quantitative variables are expressed as mean±standard deviations. The normal distribution of data was analyzed using the Shapiro–Wilk test. Mean age differences between groups were compared using independent t-tests, and sex distribution was compared using chi-square tests. Given that this study involved CBCT of patients diagnosed with bilateral TMJ OA, changes in JS measurements over time were analyzed using a paired t-test. An independent t-test was conducted to compare the differences in JS values between the groups based on occlusal changes over time. Additionally, a chi-square test was conducted to analyze the percentage change in the APP of the mandibular condyle. Intraexaminer reliability was measured using intraclass correlation coefficients (ICCs) with 95% confidence intervals. All statistical analyses were considered statistically different when $p<0.05$.

RESULTS

A total of 34 subjects (mean age 43.91±20.13 years; eight males [23.5%] and 26 females [76.5%]) were categorized into two groups: 18 patients with NCO and 16 patients with a CO during TMJ OA (Table 1). In total, 68 TMJs were included in the study. Analyses of age and sex differences between the two groups revealed no significant differences. All measurements underwent normality validation using the Shapiro–Wilk test. The ICC for interrater agreement was 0.94, indicating excellent reliability. Consequently, we used the average of the two examiners' measurements to perform the analysis.

When comparing JS measurements in the sagittal plane between T1 and T2 across all study subjects, a significant

Table 1. Demographic characteristics of the subjects

Sex/group	NCO	CO	p-value
Male	5 (27.8)	3 (18.8)	0.536[a]
Female	13 (72.2)	13 (81.3)	
Age (y)	43.61±21.52	44.25±19.15	0.928[b]

NCO, no change in occlusion; CO, change in occlusion.
Values are presented as number (%) or mean±standard deviation.
[a]Chi-square test; [b]Independent t-test.

Table 2. Comparison of AJS, SJS, and PJS for the entire study population across time and between groups at each time

JS measurements	T1			T2			Difference in measurements between time (T1-T2)	p-value[b]
	NCO (N=36)	CO (N=32)	p-value[a]	NCO (N=36)	CO (N=32)	p-value[a]		
AJS (mm)	3.09±1.14	2.60±0.93	0.054	2.82±1.32	2.51±0.96	0.276	0.19±0.73	0.036*
SJS (mm)	3.11±0.86	3.19±1.15	0.737	3.28±1.22	3.24±0.89	0.893	–0.12±0.97	0.318
PJS (mm)	2.05±0.62	2.29±1.13	0.256	2.23±1.00	2.42±0.93	0.421	–0.16±0.95	0.175

JS, joint space; AJS, anterior joint space; SJS, superior joint space; PJS, posterior joint space; NCO, no change in occlusion; CO, change in occlusion; T1, initial assessment; T2, one-year follow-up.

Values are presented as mean±standard deviation.

[a] Independent t-test; [b] Paired t-test.

*p<0.05, paired t-test.

Table 3. Frequency distribution of the APP of the condyle by group and time

APP	NCO (N=36)			CO (N=32)		
	T1	T2	p-value	T1	T2	p-value
Anterior	10 (27.8)	7 (19.4)	0.718	8 (25.0)	12 (37.5)	0.025*
Center	6 (16.7)	6 (16.7)		2 (6.3)	8 (25.0)	
Posterior	20 (55.6)	23 (53.5)		22 (68.8)	12 (37.5)	

APP, anteroposterior position; NCO, no change in occlusion; CO, change in occlusion; T1, initial assessment; T2, one-year follow-up.

Values are presented as number (%).

*p<0.05, chi-square test.

change in AJS was observed (Table 2). Differences in AJS, SJS, and PJS between the NCO and CO groups were examined at different time points. There was no difference in JS measurements between the groups at T1 and T2 (Table 2). AJS values at T1 were lower in the CO group than in the NCO group, although the difference was not statistically significant.

Table 3 shows the frequency distribution of categorical judgments for APP in the mandibular condyle for each group over time. In the NCO group, the mandibular condyle was observed in the posterior position with a high frequency, regardless of the measurement time. Conversely, in the CO group, a predominant posterior condyle position was observed on T1 measurements. However, the frequency of the condyle observed in the anterior or central position increased on T2 measurements, indicating a statistically significant difference.

DISCUSSION

This study quantitatively analyzed JS values in CBCT images of patients with TMJ OA. The JS observed in TMJ imaging suggests the disk space between the mandible and temporal bone, and the interplay of these three structures makes the TMJ a complex joint system. A combination of rotational and translational movements of the disk–condyle complex within the glenoid fossa facilitates mouth opening [19]. Therefore, narrowing of the JS can increase the friction between articular surface structures during mandibular opening and closing movements, leading to pain and TMJ dysfunction [12].

When we compared the JS measurements from T1 and T2, we observed that the AJS values decreased over time (Table 2). While several studies have quantitatively assessed JS in TMD studies [1,8,12], to our knowledge, this study is the sole longitudinal study of TMJ OA. A previous study highlighted a significant reduction in AJS in the chronic TMD group compared to the acute TMD group, with bilateral TMJ OA being more frequent in the chronic TMD group [12]. In this study, we selected CBCT images of patients diagnosed with bilateral TMJ disorders to reduce the distinction between the affected and unaffected sides. Therefore, this is consistent with the findings mentioned above. Additionally, a previous study analyzing the TMJs of patients with rheumatoid arthritis using CBCT reported a reduction in the JS, which was interpreted as a result of increased joint contact surface due to the destruction of bone on the superior surface of the mandibular condyle [1]. Therefore, the gradual decrease in AJS in the mandibular condyle affected by TMJ OA implies progressive degenerative changes in TMJ OA.

TMJ OA affects a unique and anatomically complex joint, making it very complicated to diagnose and treat [20]. Conventionally, clinicians treating TMJ OA have used regular TMJ CBCT imaging for morphological assessment of the mandibular condyle and evaluation of disease progression. However, radiographic abnormalities often do not reflect active TMJ OA presence [21,22]. When TMJ OA is active, bone tissue resorption reduces the vertical dimension of the mandible, resulting in occlusal disharmony and excessive stress on the ipsilateral molar region during CO [23]. Although TMJ OA can cause relatively minor bite changes fairly slowly [7], predicting when occlusal changes will occur remains challenging.

In this study, we categorized the groups based on whether or not occlusal changes occurred and evaluated whether JS measurements differed between before and after these changes. The results showed no differences in JS measures over time or between groups (Table 2). These findings align with previous studies, emphasizing the absence of a direct relationship between radiological findings and the clinical symptoms of TMJ OA [10,22]. Although the AJS values measured at T1 were lower in the CO group compared to the NCO group, this difference was not statistically significant. These results extend the study main findings, which showed that mandibular condyles affected by TMJ OA progressively decrease in AJS measurements over time. However, considering changes in the position of the mandibular condyle can be accomplished not only by anteroposterior movement but also by lateral movement. Future studies should simultaneously evaluate the sagittal and coronal images of CBCT.

We also assessed the relationship between occlusal changes and mandibular condyle position using categorical variables (Table 3). The APP criteria used in this study were primarily used to assess the position of the mandibular condyle in relation to the skeleton [17] or changes in the position of the mandibular condyle after bimaxillary surgery [18,24]. Although condylar position may not be a determinant of TMJ pathophysiology [24,25], frequency analysis of condylar position over time may provide helpful information for clinicians diagnosing and treating TMJ OA. In both groups, a posterior position of the mandibular condyle was initially observed with high frequency. These results are consistent with research results showing that TMJ OA accompanied by functional overload causes joint tissue collapse, shortening mandibular condyle length, and posterior displacement of the mandible [7,26]. However, a statistically significant difference emerged in CBCT images taken after occlusal changes, with an increased frequency of condyles in the anterior or central positions. This suggests a potential association between occlusal changes related to osteoarthritis and changes in mandibular condyle position.

Despite the contributions of this study, several limitations exist. First, to evaluate the association between JS and TMJ OA, CBCT images taken at one-year intervals among patients with bilateral TMJ OA were selected as study subjects, which limited the study subjects, precluding a precise determination of sample numbers related to TMJ OA. Second, our study did not correlate various clinical parameters associated with TMJ OA. Lastly, only sagittal images were evaluated for mandibular condyle assessment with CBCT. Therefore, future large-scale, long-term follow-up studies that prospectively supplement the evaluation variables should be conducted.

In conclusion, we observed that AJS decreased over time in TMJ OA, and the mandibular condyle became more anteriorly positioned as occlusal changes occurred. Therefore, clinicians should carefully monitor mandibular condyle morphology and JS using CBCT and the patient's clinical symptoms to effectively treat and manage TMJ OA. We hope that further studies will discover imaging markers that can predict the activation of TMJ OA.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

DATA AVAILABILITY STATEMENT

The datasets used in this study are available from the corresponding author upon reasonable request.

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AUTHOR CONTRIBUTIONS

Conceptualization: JWR. Data curation: JWK. Formal analysis: YSS. Funding acquisition: JWR. Methodology: HJP, JWR. Project administration: JWR. Visualization: SKY, JWR. Writing - original draft: HJP, JWR. Writing - review & editing: HJP, JWR.

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