Morphological features in patients having bilateral temporomandibular joint disorders depending on overbite

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Abstract

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The temporomandibular joint (TMJ) has the capacity to tolerate a specific level of stress. However, if the stress is above the acceptable threshold, it can lead to temporomandibular joint disorders (TMD). TMD, when accompanied by articular disc displacement (DD) or osteoarthritis (OA), can lead to resorption of the condyle. This can result in alterations in the maxillofacial morphology, such as clockwise rotation of the mandible or an open bite. The majority of previous research has focused on individuals who have either OA or DD, and there have been limited studies conducted on patients who have a TMD with a normal overbite. Thus, this study focuses on patients who have both disc displacement without reduction (DD w/out R) and OA in both condyles.

The goal of this study was to assess the impact of TMD on overbite (OB) by examining the prevalence of open bite, TMJ morphology, and skeletal pattern of patients using cone beam computed tomography (CBCT).

This retrospective analysis included 104 patients diagnosed with DD w/out R and OA in both condyles, as diagnosed by magnetic resonance imaging (MRI) and cone beam computed tomography (CBCT). The age and symptoms of the patient were documented, and CBCT images were utilized to assess 8 parameters related to the TMJ (condylar height, length and width, fossa height and length, joint space at anterior, superior and posterior) as well as 11 parameters (U1-SN, IMPA, SN-MP, Gonial angle, ANB angle, Wits appraisal, ramus height, mandibular body length, and PFH/AFH ratio, overjet, overbite) pertaining to the skeletal pattern.

Specifically, 19 patients with an open bite (OB < 0 mm) and 26 patients with a normal overbite (2 ≤ OB < 4 mm) were selected for a comparative analysis. Initially, we performed a normality test (Shapiro-Wilk test) on all parameters. We performed an independent t-test for the parameters that satisfy normality. On the other hand, we conducted a Mann-Whitney U test for the parameters that did not satisfy normality. Additionally, we conducted a Pearson correlation analysis to identify the parameters associated with overbite. Through the analysis, we obtained the following outcomes.

1. Among patients with both TMD, 18.3% (19 out of 104) exhibited an open bite, while about 70% of patients displayed a shallow overbite (OB < 2mm).

2. Even if TMD is bilateral, overbite varies depending on the patient, with younger patients more likely to have an open bite.

3. When bilateral TMD is present, individuals exhibit skeletal Class II with hyperdivergent facial patterns, regardless of whether they have an open bite or not. The tendency was more evident in cases where an open bite was present.

While TMD can be present on both sides, it does not always result in an open bite. Nevertheless, in the case of a normal overbite, it is important to consider the potential occurrence of TMD if the patient is young and exhibits a skeletal Class II with a hyperdivergent pattern. It is crucial to closely monitor any occlusal alterations that may arise during orthodontic treatment.

Key words: Temporomandibular joint disorders, disc displacement without reduction, osteoarthritis, overbite, open bite, joint space

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I. INTRODUCTION

The condition of the temporomandibular joint (TMJ) has significant impacts on the long-term stability after orthodontic treatment. Various structures of TMJ have the ability to accommodate a certain range of stress. However, when the stress exceeds the range that the TMJ can tolerate, temporomandibular disorder (TMD), such as degenerative joint disease or condylar resorption, may occur (Laskin, 1994).

Osteoarthritis (OA), a common disease in TMJ, is a chronic degenerative joint disease that involves inflammation of the synovial membrane, deterioration of cartilage, and remodeling of subchondral bone (Lei et al., 2017; Nejad et al., 2017; Nitzan et al., 2017; Sperry et al., 2019). OA softens the articular tissues of joints, leading to a dysfunctional remodeling process that indicates the bony surface is absorbed in contact with the joint surface (Arnett et al., 1996a). Condylar resorption could affect the maxillofacial morphology. If bone resorption occurs in both condyles, TMJ undergoes a collapse in its structure and the height of the mandibular ramus decreases, resulting in anterior open bite and mandibular retrognathia (Laskin, 1994). According to a previous study, 19.5% of people with skeletal open bites had bilateral degenerative condyles. More than twice as common in these patients as in normal overbites (Phi et al., 2022).

Bony changes in the condyle are usually assumed to occur as a result of disc displacement (DD), although they may occur on their own (Wilkes, 1989). Anterior DD and subsequent disc deformation would result in the flattening of the articular eminence and the occurrence of degenerative alterations (Katzberg et al., 1983; Schellhas et al., 1992; Xie et al., 2015). A previous study reported that the majority of cases diagnosed with DD without reduction (DD w/out R) exhibited radiologically evident degenerative changes, while in cases of DD with reduction, no significant or only minor degenerative changes were observed, even over a prolonged period (Kurita et al., 2006). Therefore, bony changes in the mandibular condyle are likely evident with DD w/out R. The presence of DD is also related to facial morphology (Byun et al., 2005), particularly for skeletal open bite. A study has demonstrated that individuals with DD w/out R have a reduction in mandible ramus height, a decrease in posterior facial length, and a clockwise rotation of the mandibular plane when compared to individuals without this condition (Ooi et al., 2020). Conversely, patients with skeletal open bite are significantly more likely to experience DD w/out R and condylar resorption compared to patients without maxillofacial deformities (Yura et al., 2010).

These previous studies suggest that DD w/out R and OA in the mandibular condyle are important factors in understanding maxillofacial morphology, particularly skeletal open bite. However, the prevalence of open bite has been barely investigated, which would be an important indicator of the impact of TMDs on specific malocclusion. Furthermore, the comparison between those with an open bite and those with a normal bite can provide different features of TMD for patients who would likely experience an open bite.

Hence, the objective of this study was to assess the impact of bilateral TMDs on overbite by analyzing the prevalence of open bite. In addition, we compared demographic features and measurements from the TMJ morphology and lateral cephalograms between two patient groups: one with an open bite and the other with a normal overbite. To ensure the homogenous influence of TMD, the cases in which both OA and DD w/out R had been confirmed were defined as TMD. OA and DD w/out R were diagnosed by cone-beam computed tomography (CBCT) and magnetic resonance imaging (MRI), respectively.

II. MATERIALS AND METHODS

1. Patients

This study retrospectively included female patients who visited the Department of Oral Medicine at Yonsei University College of Dentistry from January 2019 to April 2023 and were diagnosed with OA and DD w/out R in both TMJs. OA was defined as the presence of erosion on both condyles based on CBCT images, and DD w/out R was confirmed by MRI. Both image modalities were confirmed by a specialist of oral maxillofacial radiology and included when they were taken at intervals of less than 6 months.

A total of 182 patients who met the specified conditions were included, and the final participants were enrolled based on the following exclusion criteria: a history of orthognathic surgery, orthodontic treatment, or prosthetic treatment of the anterior teeth, severe asymmetry with a Menton deviation of 4 mm or more and poor quality of image.

The sample size for each group was determined using the G power program (G* Power 3.1, Dusseldorf, Germany), based on previous research (Ioi et al., 2008). The power analysis was conducted to determine the sample size needed to achieve a statistical power of 80% in order to detect an effect size of 1.029, with a significance level of 0.05 (two-sided). Each group has a minimum sample size of 16.

The study included a total of 104 patients after excluding individuals who met the previous exclusion criteria. To conduct a comparison between patients with an open bite (OB < 0 mm) and those with a normal overbite (2 ≤ OB < 4 mm), individuals with a deep bite (OB ≥ 4 mm) and a shallow overbite (0 ≤ OB< 2 mm) were excluded from the study. Finally, 19 patients with open bite and 26 patients with normal OB were included in this study (Figure 1).

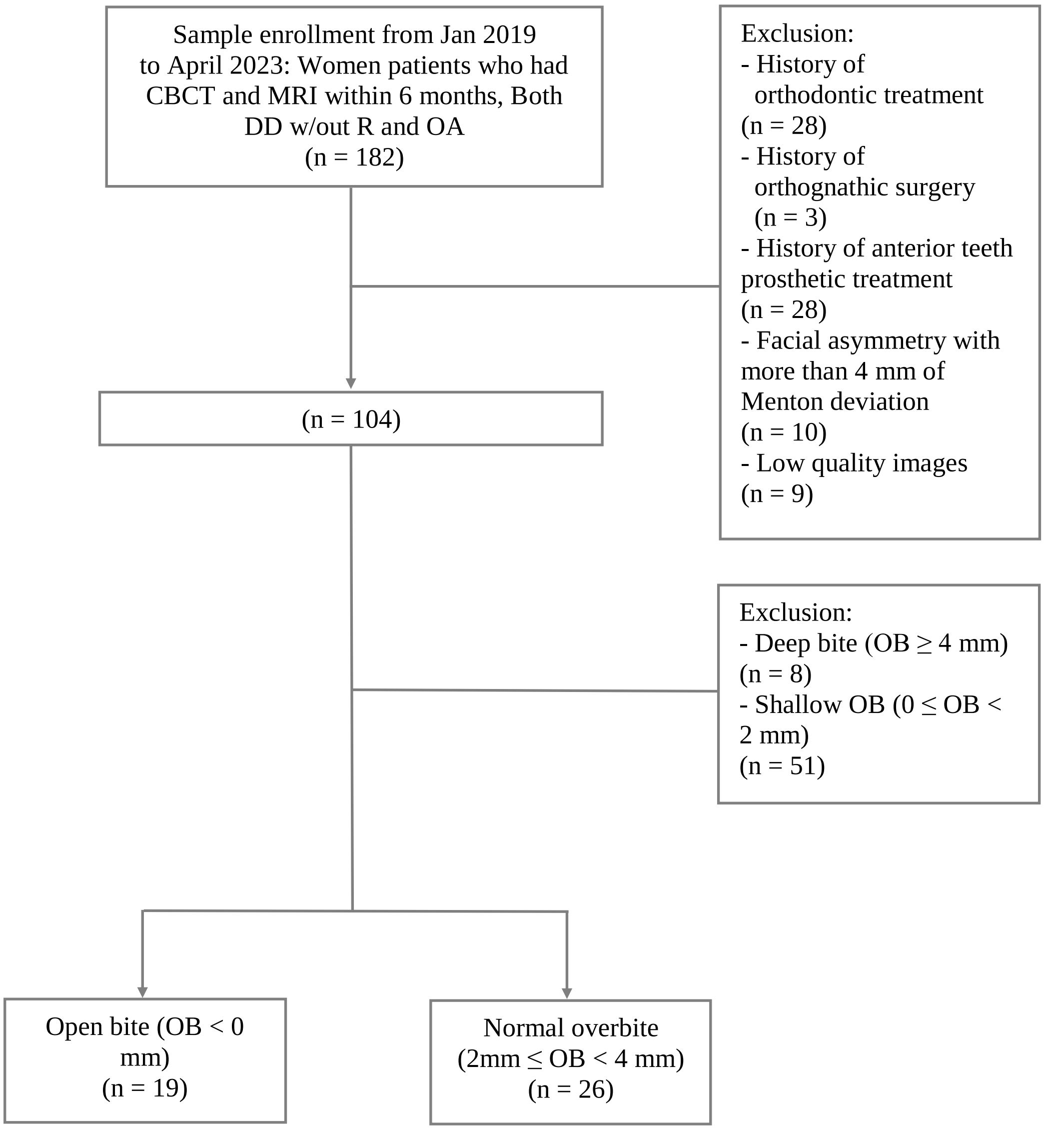

Figure 1. Flow chart of patient selection. CBCT, cone-beam computed tomography; MRI, magnetic resonance imaging; DD w/out R, disc displacement without reduction; OA, osteoarthritis

2. Measurements

The age of the patients and their symptoms of TMD were noted. The symptoms of TMD included subjective pain, limited mouth opening, familiar pain on palpation, and sound during examination. The CBCT images of the patients were converted into DICOM format. Subsequently, 3D tracing and the measurement of various parameters were conducted using an InVivo program (InVivoDental version 5.4.6, Anatomage, Santa Clara, CA, USA). The FH (Frankfort horizontal) plane served as the horizontal reference line, while a line perpendicular to the FH plane and passing through the Nasion served as the vertical reference line.

Measurements were performed for the following variables:

; TMJ parameters (Figure 2) 1) condylar width, 2) condylar length, 3) condylar height, 4) fossa length, 5) fossa height, 6) anterior joint space, 7) superior joint space, 8) posterior joint space ; Condylar width was measured in the coronal section (which contains Cd-med and Cd-lat), while condylar length and height, fossa length and height, as well as superior, anterior, and posterior joint space were measured in the sagittal section (which contains Cd-sup). TMJ measurements were obtained bilaterally from both TMJ, and the mean value of measurements from the left and right sides was used. The landmarks used for the above measurements are defined in the supplementary table.

; Cephalometric parameters (Figure 3) were recorded from 3D tracing in an InVivo program. 1) U1-SN, 2) IMPA, 3) SN-MP, 4) Gonial angle, 5) ANB, 6) Wits, 7) ramus height, 8) mandibular body length, 9) PFH/AFH ratio, 10) overjet, 11) overbite

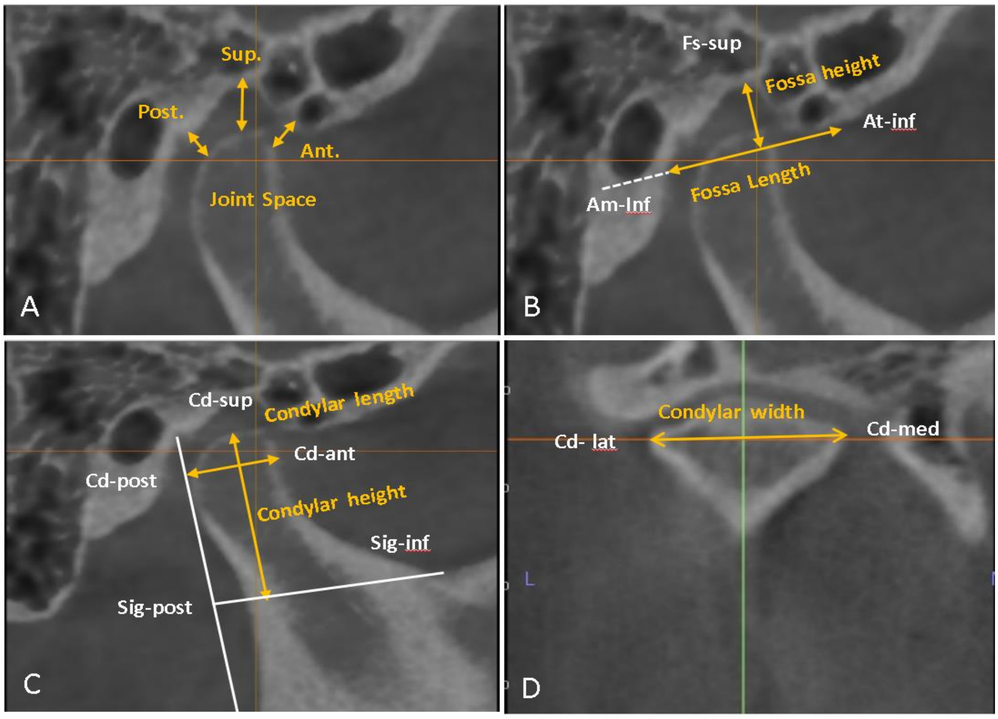

Figure 2. TMJ measurements. Condylar width was measured on the coronal section and other measurements (superior, anterior, and posterior joint spaces, fossa length and height, and condylar length, height, and width) were measured on the same sagittal section. The landmarks used for the measurements are defined in the supplementary Table.

A. Joint space Sup.: Distance from Cd-sup to Fs-sup, Joint space Ant.: The shortest distance from Cd-ant to the corresponding glenoid fossa, Joint space Post.: The sh ortest distance from Cd-post to the corresponding glenoid fossa

B. Fossa Length: Distance from At-inf to a point where the line connecting At-inf an d Am-inf meets the posterior wall of the glenoid fossa, Fossa height: perpendicula r distance from Fs-sup to the line connecting At-inf and Am-inf

C. Condyle Length: Distance between Cd-ant and Cd-post, Condyle Height: Perpendic ular distance from Cd-sup to the line between Sig-inf and Sig-post

D. Condyle Width: Distance between Cd-med and Cd-lat

3. Statistical analysis

Tracing and measurements were performed by a single examiner. One month after the initial evaluation, 10 individuals from each group were randomly selected to evaluate the intra-examiner reliability. Re-measurements were taken, and the findings were compared to the initial measurements. Correlation coefficients were > 0.95 or higher.

For comparative analysis between the open bite and normal overbite groups, Shapiro-Wilk's normality test was initially performed on each variable. Subsequently, independent t-tests were performed on variables satisfying a normal distribution, while variables not satisfying a normal distribution were subjected to Mann-Whitney tests. Furthermore, Pearson correlation analysis was conducted to identify variables correlated with overbite. All measurements were performed using Statistical Package for the Social Sciences software (SPSS version 29 from IBM, Chicago, IL, USA).

III. RESULTS

The age of patients and symptoms of TMD are presented in Table 1. The mean age of the open bite group was 35.7 ± 13.1 years, significantly younger than the normal overbite group, which was 44.0 ± 13.4 years ($P < 0.05$). The number and proportion of patients presenting the TMD sub-findings in each group were also described.

The cephalometric measurements of patients are presented in Table 2. Both groups exhibit large ANB and SN-MP angles, as well as a reduced PFH/AFH ratio and U1-SN when compared to standard values. The height of the ramus tended to be slightly shorter in the open bite group compared to the average value reported in previous research (Ilguy et al., 2014). The open bite group exhibited significantly higher values for ANB, SN-MP, and Gonial angle compared to the normal overbite group ($P < 0.01$, $P < 0.05$, and $P < 0.01$, respectively), while the PFH/AFH ratio exhibited significantly lower values in the open bite group ($P < 0.01$).

The TMJ measurements in patients are presented in Table 3. The normal value was determined by referencing previous studies (Al-koshab et al., 2015; Alam et al., 2021; Martins et al., 2015; Noh et al., 2021a). Fossa height was slightly lower than the normal value in both groups, suggesting the presence of a shallow glenoid fossa. The dimensions of the superior, anterior, and posterior joint spaces were comparable to the standard values in the normal overbite group, while the superior and posterior joint spaces in the open bite group exhibited a tendency to be bigger than the standard value. Superior and posterior joint space exhibited significantly higher values in the open bite group compared to the normal bite group ($P < 0.05$, $P < 0.01$, respectively). Conversely, no significant differences were noted between the two groups regarding condyle width, length, and height, fossa length and height, and anterior joint space ($P > 0.05$).

The TMJ morphology and skeletal pattern of patients with an open bite and a normal overbite in patients with bilateral TMD are shown in Figure 3.

Pearson correlation analysis was conducted to identify variables significantly correlated with overbite, as presented in Table 4. ANB, Gonial angle, SN-MP, U1-SN, superior joint space, and posterior joint space exhibited significant negative correlations with overbite, while the PFH/AFH ratio exhibited a significant positive correlation. No significant correlations were observed between age, Wits, mandibular body length, ramus height, IMPA, overjet, condyle width, length, height, fossa length, height, and anterior joint space with overbite ($P > 0.05$).

Table 1. Demographic feature and TMJ symptoms of patients

Variable	Open bite group (n = 19)	Normal overbite (n = 26)	P value
Demographic features			
Age (year)	35.7 ± 13.1	44.0 ± 13.4	0.044 *
TMD sub-finding(number of patients)			
Subjective joint pain (%)	16 (84.2%)	21 (80.8%)	
Mouth opening limitation (%)	1 (5.3%)	13 (50%)	
Familiar pain on palpation (%)	11 (57.9%)	15 (57.7%)	
Sound during examination (%)	17 (89.5%)	18 (69.2%)	

Independent t test was used. * P < 0.05, ** P < 0.01

† P-value indicates the Mann-Whitney test’s results

Table 2. Comparison of cephalometric measurements between the open bite group and the normal overbite group

Variable	Normal	Open bite group (n = 19)	Normal overbite (n = 26)	P value
ANB (º)	2.8 ± 2.3	7.2 ± 2.2	5.1 ± 1.6	< .001 **
Wits (mm)	-1.3 ± 1	-0.43 ± 2.26	-0.67 ± 3.33	0.797
Gonial angle (º)	122.2 ± 4.2	128.4 ± 3.8	124.9 ± 22.1	0.01 *
SN-MP (º)	34.8 ± 3.1	46.8 ± 4.1	40.5 ± 5.1	< .001 **
PFH/AFH ratio	0.65 ± 0.04	0.57 ± 0.03	0.61 ± 0.61	0.009 **
Mandibular body length[a] (mm)	67.7 ± 5.7	67.2 ± 4.6	68.9 ± 5.0	0.248
Ramus height [a] (mm) †	54.7 ± 4.9	49.8 ± 4.0	52.2 ± 5.9	0.129
U1-SN (º)	107.0 ± 2.0	99.0 ± 7.3	95.8 ± 6.4	0.121
IMPA (º)	90.0 ± 5.8	93.0 ± 6.5	91.9 ± 6.2	0.557
OJ(mm)	2.5 ± 2.5	3.7 ± 1.2	4.1 ± 0.8	0.166

ANB, A–point–Nasion–B-point angle; SN, Sella-Nasion; MP, mandibular plane; PHF, posterior facial height (Sella-Gonion); AFH, anterior facial height (Nasion-Menton); Mandibular body length (Gonion-Menton); Ramus height (Condylion-Gonion); U1, maxillary central incisor; IMPA, mandibular incisor to mandibular plane angle

Independent t test was used. * $P < 0.05$, ** $P < 0.01$
† P-value indicates the Mann-Whitney test's results
[a] Normal value of mandibular body length, ramus height were determined with reference to previous research (Ilguy et al., 2014).

Table 3. Comparison of temporomandibular joint measurements between the open bite group and the normal overbite group

Variable		Normal	Open bite group (n = 19)	Normal overbite (n = 26)	P value
Condyle	Width [a] (mm)	17.0 ± 2.4	17.5 ± 1.9	17.4 ± 2.2	0.963
	Length [b] (mm) †	8.6 ± 0.9	9.7 ± 3.4	8.5 ± 1.4	0.131
	Height [a] (mm)	17.2 ± 3.3	17.1 ± 2.6	17.6 ± 2.7	0.504
Fossa	Length [c](mm) †	20.3 ± 2.2	19.7 ± 3.4	20.4 ± 1.5	0.463
	Height [c] (mm) †	9.3 ± 1.7	8.1 ± 1.2	8.3 ± 0.8	0.491
Joint space	Superior [d] (mm) †	2.36 (CI 1.99 - 2.72)	2.8 ± 0.9	2.1 ± 0.7	0.014 *
	Anterior [d] (mm)	1.86 (CI 1.62 - 2.10)	1.8 ± 0.8	1.9 ± 0.7	0.601
	Posterior [d] (mm)	2.22 (CI 2.00 - 2.45)	3.6 ± 1.2	2.1 ± 0.50	< .001**

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

[a] Normal value of condylar width, height (Al-koshab et al., 2015), [b] condylar length (Alam et al., 2021), [c] fossa length and height (Noh et al., 2021a), [d] joint space (Martins et al., 2015) were determined with reference to previous research.

Table 4. Pearson's Correlation of overbite and other variables

Variable	r [a]	P value
Age (year)	0.29	0.052
ANB (º)	-0.45	0.002 **
Wits (mm)	-0.002	0.989
Gonial angle (º)	-0.36	0.017*
SN-MP (º)	-0.53	< .001 *
PFH/AFH ratio	0.39	0.009 **
Mandibular body length (mm)	0.10	0.514
Ramus height (mm)	0.21	0.160
U1-SN (º)	-0.34	0.023 *
IMPA (º)	-0.20	0.198
OJ (mm)	0.23	0.132

Variable		r [a]	P value
Condyle	Width (mm)	-0.04	0.778
	Length (mm)	-0.20	0.200
	Height	0.03	0.825
Fossa	Length	0.07	0.644
	Height (mm)	0.02	0.910
Joint space	Superior (mm)	-0.31	0.037 *
	Anterior (mm)	0.07	0.654
	Posterior (mm)	-0.58	< .001 *

[a] Correlation coefficient value

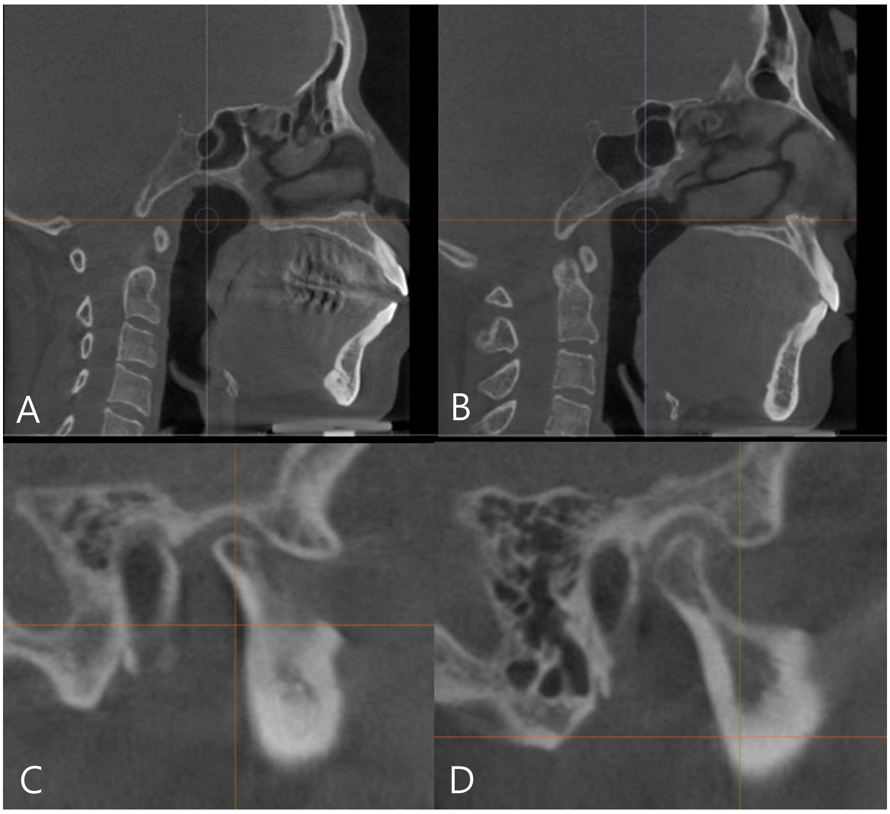

Figure 3. TMJ morphology and skeletal pattern of patients: A. skeletal pattern of a patient in the open bite group, B. skeletal pattern of a patient in the normal overbite group, C. TMJ morphology of a patient in the open bite group, D. TMJ morphology of a patient in the normal overbite group; A patient with an open bite exhibits larger sup. and post. joint spaces compared to a patient with a normal overbite.

IV. DISCUSSION

The objective of this study was to assess the impact of TMD on overbite by comparing the features of patients with open bite and patients with normal overbite, specifically those with bilateral TMD, characterized by both DD w/out R and OA. OA and DD w/out R were diagnosed by cone-beam computed tomography (CBCT) and magnetic resonance imaging (MRI), respectively. CBCT offers precise information for detecting issues related to the bony TMJ (Hintze et al., 2007; Honey et al., 2007) and changes in the condition and position of the condyle (Kristensen et al., 2017; Nah, 2012; Rodrigues et al., 2009). MRI is beneficial for evaluating the soft tissue of the TMJ and can verify the precise position of the disc (Alkhader et al., 2010; Liedberg et al., 1996).

In 104 patients with bilateral TMD, the overbite range was -3.94 to 8.6 mm. Among the 104 patients, 19 exhibited open bite (OB < 0 mm), 51 exhibited shallow overbite (0 ≤ OB < 2 mm), 26 exhibited normal overbite (2 mm ≤ OB < 4 mm), and 8 exhibited deep OB (OB ≥ 4 mm). The number of patients with open bite in this study was 18.3% (19 of 104), significantly higher than the prevalence of open bite (2.5 (Iftikhar et al., 2017) ~4% (Burford and Noar, 2003)) in adults without considering TMD. Approximately 70% of patients (70 of 104) had a shallow overbite (OB < 2 mm), while the proportion of patients with a deep bite (OB ≥ 4 mm) was minimal (8 of 104).

The age of patients and symptoms of TMD are shown in Table 1. The majority of patients (above 80%) in both groups experienced subjective pain, while around 50% of patients in each group experienced familiar pain on palpation. The open bite group had a higher prevalence of TMJ noise compared to the normal overbite group. Additionally, 50% of patients in the normal overbite group experienced limited mouth opening, whereas just one patient in the open bite group had this limitation. This result yields a comparable outcome to the previous research, indicating that DD and

OA are TMD characterized by restricted mouth opening accompanied by functional TMJ pain (Arnett et al., 1996a, 1996b; Bertram et al., 2001; Dimitroulis, 2002; Kristensen et al., 2017). It is notable that the open bite group exhibits a significantly low number of patients with mouth opening limitation.

The mean age of all 104 patients was 41.54 ± 15.6 years. The mean age of the open bite group (35.7 ± 13.1 years) was significantly younger than that of the normal bite group (44.0 ± 13.4 years). The mean overbite in 45 patients (open bite patients 19, normal overbite patients 26) for different age groups was as follows: -0.41mm for individuals under 30 years old (n = 13), 0.85mm for individuals between 31 and 40 years old (n = 8), and 1.8mm for individuals over 41 years old (n = 24). The tendency for open bite increased in younger people. This suggests that, although OA is exhibited more frequently in older patients (Alexiou et al., 2009), the disease progressed rapidly in younger people, or that it is probable that young patients had idiopathic condylar resorption (ICR), also known as progressive condylar resorption (PCR), a condition that primarily affects young female patients (Arnett et al., 1996a).

Cephalometric measurements of patients are shown in Table 2. Both groups showed a large ANB, a steep SN-MP, and a small PFH/AFH ratio compared to the standard value. This finding indicates that individuals with bilateral TMD are more likely to have a skeletal Class II with a hyperdivergent profile (Rodrigues et al., 2009), regardless of the presence of an open bite. Additionally, this suggests that if a patient has a small, retruded, clockwise rotated mandible and a steep mandibular plane before initiating orthodontic treatment, clinicians could be cautious about the potential TMD (Byun et al., 2005).

In the open bite group, the ANB, SN-MP, and Gonial angles measured 7.2 º, 46.8 º, and 128.4 º, respectively, which were significantly greater than those observed in the normal bite group, which measured 5.1 º, 40.5 º, and 124.9 º. Additionally, the PFH/AFH ratio was 0.57 in the open bite group, significantly smaller compared to the normal bite group's ratio of 0.61. In short, skeletal class II with a hyperdivergent tendency was more prominent in the open bite group (Ellis III and McNamara Jr, 1984).

Furthermore, the ramus height in the open bite group was shorter than the normal value, possibly due to a decrease in ramus height caused by condyle resorption (Laskin, 1994). In addition, the U1-SN angle measured 99.0 º in the open bite group and 95.8 º in the normal overbite group. There were no significant differences observed between the two groups; however, the measurements were smaller than the standard value, which might be attributed to dentoalveolar compensation in individuals with skeletal Class II (Anwar and Fida, 2009).

The TMJ measurements of patients are shown in Table 3. The ant. joint space exhibited comparable measurements to the standard value in both groups, whereas the sup. and post. joint spaces demonstrated a higher measurement than the standard value in the open bite group, and a comparable measurement to the standard value in the normal overbite group. In comparison of two groups, the sup. and post. joint spaces were significantly larger in the open bite group (sup. 2.8 mm, post. 3.6 mm) than in the normal overbite group (sup. and post. 2.1 mm), which indicates that the condyle in the open bite group is displaced forward (Ari-Demirkaya et al., 2004). This is contrary to previous findings that, in cases of disc displacement, the condyle typically shifts to the back, resulting in a widening of the anterior joint space and a narrowing of the posterior joint space (Ikeda and Kawamura, 2013; Incesu et al., 2004). Thus, this finding suggests that if both DD and OA are present together and the resorption of the condyle continues, there may be a forward migration of the condyle from the back, leading to the development of an open bite.

Pearson correlation analysis (Table 4) revealed that ANB, Gonial angle, SN-MP, U1-SN, superior and posterior joint space exhibited a significant negative correlation with overbite (OB), whereas the PFH/AFH ratio exhibited a significant positive correlation with OB. Consequently, as the mandibular condyle moves forward, the mandible rotates clockwise, and the Gonial angle increases, the overbite becomes shallower.

Out of the total of 104 patients, only 5 individuals had a low Gonial angle (< 115 º) or a low mandibular plane angle (< 30 º). This suggests that individuals with a skeletal Class II with a hyperdivergent profile are more susceptible to TMD incidence, and they are more likely to develop an open bite when they experience TMD, compared to individuals with different skeletal patterns.

The majority of patients visiting the Department of Oral Medicine complained about subjective pain. Among 19 open bite patients, 7 patients visited the hospital owing to occlusal changes. For the remaining 12 patients, it's possible that either they didn't exhibit a noticeable occlusal change, or the open bite wasn't a result of TMD. Instead, the patients may have had an open bite prior to the development of TMD.

In this study, 18.3% of patients with bilateral TMD exhibited an open bite, indicating that if bilateral TMD may be present, not all individuals would experience an open bite. On the basis of a previous study that found condylar degeneration was observed in 15% of patients with normal overbite (Phi et al., 2022)**,** the presence or absence of TMD does not have an absolute influence on the development of an open bite but is influenced by multiple factors such as skeletal pattern, degree of condylar resorption, and degree of alveolar bone adaptation.

Nevertheless, this study had several limitations. Firstly, since this is not a longitudinal study on patients with open bite, it remains uncertain whether the anatomical characteristics observed in these patients are a result of changes due to TMD or pre-existing conditions. Secondly, the study only included patients who visited the oral medicine department, leaving out a control group of normal, healthy individuals. Therefore, this study referenced standard values from previous studies. Third, this study did not include measurements of condyle volume, so it is insufficient to confirm how much the condyle size has been reduced due to bone resorption. Measuring and comparing the 3D volume of the condyle could confirm the effect of condylar resorption on an open bite.

V. CONCLUSION

This study aimed to investigate the effect of TMD on the overbite. Although DD w/out R and OA are present bilaterally, the overbite varies depending on the patient, with younger patients showing a tendency towards an open bite. Of the patients diagnosed with bilateral TMD, 18.3% exhibited an open bite, while almost 70% displayed a shallow overbite. Regardless of the presence or absence of an open bite, patients with bilateral TMD had a skeletal Class II with hyperdivergent patterns. Moreover, this tendency was more evident in patients with open bite. Furthermore, as the degree of overbite decreased, an increase in the size of the superior and posterior joint spaces was noted. These findings indicate that it is important to closely monitor occlusal changes in young patients undergoing orthodontic treatment, particularly those with skeletal class II with hyperdivergent facial patterns, due to the potential risk of TMD.

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Supplementary table. Definitions of the landmarks used in this study

Landmark		Definition
Condyle	Medial (Cd-med)	The most medial point of the condylar head on the coronal section
	Lateral (Cd-lat)	The most lateral point of the condylar head on the coronal section
	Superior (Cd-sup)	The most superior point of the condylar head identified on the axial and sagittal sections
	Anterior (Cd-ant)	The most anterior point of the condylar head within a 5 mm-radius from Cd-sup on the sagittal section
	Posterior (Cd-post)	The most posterior point of the condylar head within a 5 mm-radius from Cd-sup on the sagittal section
Sigmoid	Inferior (Sig-inf)	The most inferior point of the sigmoid notch
	Posterior (Sig-post)	Perpendicular point from Sig-inf to the tangent line of the ramal posterior surface on the sagittal section
Fossa superior (Fs-sup)		The point showing the shortest distance from Cd-sup to the superior wall of the glenoid fossa
Articular tubercle (At-inf)		The most inferior point of the articular tubercle
Auditory meatus (Am-inf)		The most inferior point of the auditory meatus

Landmarks were determined with reference to previous research (Noh et al., 2021b).

국문요약

양측성 측두하악관절장애를 가진 환자의 수직피개에 따른 형태적 특징

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측두하악관절의 구조물은 일정 범주의 스트레스를 수용할 수 있는 능력을 가지고 있으나, 스트레스가 수용 범주를 넘어서면 과두의 퇴행성변화나 과두 흡수와 같은 측두하악관절장애가 발생할 수 있다. 관절원판변위나 골관절염을 동반하는 측두하악관절장애의 경우 과두의 흡수가 발생하여 하악골의 후방회전이나 개방교합과 같은 악안면형태의 변화를 야기할 수 있다. 기존 연구는 대부분 골관절염 또는 과두원판변위 중 한가지 요소만을 가진 환자군을 연구하였고, 측두하악관절장애가 존재하는 상태에서 정상피개교합을 보이는 환자에 대한 연구는 거의 없었다. 따라서 본 연구는 양측 과두에 비정복성 관절원판변위와 골관절염이 모두 존재하는 환자를

대상으로 하며, 환자들의 수직피개, 과두-측두와의 상태, 골격패턴을 3 차원 cone-beam computed tomography (CBCT)를 통해 관찰하여 측두하악관절장애가 수직피개에 미치는 영향을 확인하고자 한다.

본 연구는 후향적으로 진행되었으며, Magnetic resonance imaging (MRI) 및 CBCT 판독결과 양측 과두에 비정복성 관절원판변위와 골관절염이 존재하는 환자 104 명을 등록하였다. 환자의 나이와 증상을 기록하고, CBCT 이미지를 사용해서 측두하악관절에 대한 8 가지 항목[과두의 높이, 길이, 폭, 측두와의 높이, 길이, 관절강 크기(전방, 상방, 후방)]과 및 측모두부규격에 대한 11 가지 항목(U1-SN, IMPA, SN-MP, Gonial angle, ANB angle, Wits appraisal, ramus height, mandibular body length, PFH/AFH ratio, overjet, overbite)에 대해 측정을 시행하였다. 104 명의 환자 중 개방교합(OB < 0 mm, 19 명)를 보이는 환자와 정상피개교합(2≤ OB <4 mm, 26 명)를 보이는 환자를 선정하여 결과에 대한 비교분석을 시행하였다. 두 그룹간 각 항목을 비교하기 위해 모든 측정항목에 대한 정규성 검정(Shapiro-Wilk test)을 시행했고, 정규성을 만족하는 항목에 대해서는 independent t-test 를, 정규성을 만족하지 않는 항목에 대해서는 Mann-Whitney U test 를 시행하였다. 또한 overbite 과 상관관계를 보이는 항목을 확인하기 위해서 Pearson 상관분석을 시행하였다. 분석을 통해 다음과 같은 결과를 얻었다.

1. 비정복성 관절원판변위와 골관절염이 양측 턱관절에 존재할 때 개방교합을 보이는 환자는 18.3%(104 명 중 19 명)였고, 전체의 약 70% 정도에서 수직피개가 얕은 경향(OB < 2 mm)을 보였다.

2. 양측성으로 측두하악관절장애가 존재하더라도 환자에 따라 수직피개가 달라지고, 젊은 사람일수록 개방교합 경향을 보였다.

3. 비정복성 디스크 변위와 골관절염이 양측 턱관절에 존재하는 경우 개방교합 유무와 상관없이 골격성 II 급 및 발산형 안모를 보였고, 개방교합이 존재하는 경우 그 경향이 더 심해졌다.

4. 개방교합이 커질수록 상관절강 후관절강이 더 크게 관찰되었다.

양측에 TMD 가 존재하더라도 모두 개방교합이 발생하는 것은 아니다. 그러나 정상 수직피개를 보이더라도 환자의 나이가 어리고, 골격성 II 급 및 발산형인 안모를 가진 경우 TMD 가능성을 염두에 두고 교정치료 중 교합변화를 주의 깊게 관찰하여 치료를 진행해야 한다.

핵심이 되는 말: 측두하악관절장애, 비정복성 디스크 변위, 골관절염, 수직피개, 개방교합, 관절강