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ORIGINAL ARTICLE

The effects of TMJ symptoms on skeletal morphology in orthodontic patients with TMJ disc displacement

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Abstract

Objective. The aim of this study was to investigate the effects of temporomandibular joint (TMJ) symptoms on skeletal morphologies of orthodontic patients with TMJ disc displacement (DD). ***Materials and methods.*** The sample consisted of 197 women seeking orthodontic treatment. The subjects were divided into two groups according to the presence of TMJ symptoms: the presence and absence of TMJ symptoms. Each group was sub-divided into three groups based on magnetic resonance images of bilateral TMJs: bilateral normal disc position (BN), bilateral disc displacement with reduction (DDR) and bilateral disc displacement without reduction (DDNR). Seventeen variables from lateral cephalograms were analyzed by two-way analysis of variance to identify differences in skeletal morphologies with respect to TMJ symptoms and TMJ DD status. ***Results.*** Patients with TMJ DD were more likely to have short ramus height, short mandibular body length and backward positioning of the ramus and mandible. These skeletal morphologies became more severe as TMJ DD progressed to DDNR. However, the skeletal morphologies associated with TMJ DD were not significantly different between symptomatic and asymptomatic patients. As a result, patients with TMJ DD had backward positioning and clockwise rotation compared to those with bilateral normal TMJs, irrespective of the presence of TMJ symptom. ***Conclusions.*** This study suggests that TMJ DD is associated with altered skeletal morphology, but TMJ symptoms do not significantly influence the relationships between TMJ DD and skeletal morphology.

Key Words: *TMJ, symptom, disc displacement, skeletal morphology, orthodontic patients*

Introduction

Disc displacement (DD) of the temporomandibular joint (TMJ) is defined as an abnormal positional relationship of the articular disc to the mandibular condyle and the articular eminence of the temporal bone. TMJ DD is a pathogenetic mechanism of TMJ dysfunction related to symptoms, such as TMJ clicking, crepitus, pain and limitation of jaw movement, because abnormal disc position obstructs the normally smooth sliding movement of the condyle [1,2]. Adult women show the highest prevalence of TMJ DD [3].

Many studies have emphasized the importance of magnetic resonance imaging (MRI) to analyze TMJ DD [2,4]. MRI allows for excellent visualization of both bony and soft tissue anatomies and is considered the gold standard for examination of the soft tissues of the TMJ [5,6]. Tasaki et al. [7] reported that MRI has 95% accuracy in determining disc position and form. In addition, MRI is non-invasive and results in no exposure to ionizing radiation or biologic hazards [8].

With the aid of MRI, TMJ DD has been found to be associated with altered skeletal morphology. The skeletal morphologies of patients with TMJ DD are decreased posterior facial height and ramus height, backward rotation of the ramus and mandible and decreased mandibular length [9–13]. These characteristics become more severe as TMJ DD progresses [14,15].

TMJ DD is usually accompanied by various TMJ symptoms [1,2,16]. However, TMJ DD is also present in symptom-free subjects [6]. MRI studies detected TMJ DD in 77% of symptomatic subjects and 33% of asymptomatic subjects [6]. Although the relationships between skeletal morphologies and TMJ

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DD have been extensively investigated, few studies have addressed the differences in skeletal morphologies between symptomatic and asymptomatic subjects with TMJ DD, especially in orthodontic patients. Because TMJ symptoms may indicate the presence and/or progress of TMJ disorders when symptoms exist [17], the null hypothesis of this study was that there would not be significant difference in skeletal morphologies between symptomatic and asymptomatic orthodontic patients with TMJ DD.

Materials and methods

Sample selection

The sample for this study consisted of adult female orthodontic patients who consented to a bilateral high-resolution MRI in the sagittal (opened and closed) and coronal (closed) planes to evaluate the TMJ. All the subjects had a primary complaint of a malocclusion and a routine lateral cephalogram was taken with Asahi CX-90SP II (Asahi Roentgen, Kyoto, Japan). Prior to orthodontic treatment, subjective histories of TMJ symptoms including joint sounds, joint pain and limitation of mandibular movement were recorded using a questionnaire. Findings of clinical examinations of the TMJ, such as the presence of joint sounds, tenderness during joint palpation, the range of maximum opening and deviation of the mandible during jaw opening were evaluated to confirm the presence of TMJ symptoms. Exclusion criteria of the present study were (1) age less than 17 years, (2) any systemic disease, (3) history of orthodontic treatment or TMJ treatment, (4) history of facial cosmetic surgery or orthognathic surgery, (5) history of trauma involving the TMJs and (6) juvenile rheumatoid arthritis. The research protocol was reviewed and approved by the institutional review board of the University Hospital.

TMJ MRI

TMJ MRIs were taken to evaluate TMJ status, mainly due to the presence of TMJ symptoms. Patients with anterior open bite, retrognathic mandible and facial asymmetry reported to be associated with TMJ DD [9,10,18], were also examined by MRI, even if the patients do not complain of any specific TMJ symptoms.

The MRIs were obtained using a Signa Horison (GE, Waukesha, WI, USA) operating at 1.5 T and unilateral 3 inch surface receiver coil (GE). Initially, the axial scout images were obtained at the level of the TMJs in order to identify the long axes of the condyles. Non-orthogonal sagittal sections were obtained perpendicular to the condyles and non-orthogonal coronal oblique sections were also obtained. Closed mouth images were obtained at a maximum dental intercuspation and open mouth images were taken at a maximum unassisted vertical mandibular opening by using a Burnett bidirectional TMJ device (Medrad, Pittsburgh, PA, USA). T1-weighted 600/12 (repetition time [TR] ms/echo time [TE] ms) and proton-density 4000/14 (TR ms/TE ms) pulse sequences were performed in the sagittal plane using a 3-mm slice thickness, a 10-cm field of view, a number of excitations of 2 and an image matrix of 254×192 pixels. T1-weighted 500/12 (TR ms/TE ms) pulse sequence was performed in the coronal plane under the same conditions.

Two radiologists with TMJ MRI experiences over 20 years interpreted the images without associated patient clinical information. TMJ disc position was classified into three categories as follows:

- *Normal disc position*: With the mouth closed, the intermediate zone of the disc was interposed between the condyle and the posterior slope of the articular eminence, with the anterior and posterior bands equally spaced on either side of the condylar load point.
- *Disc displacement with reduction*: The disc was anteriorly displaced relative to the posterior slope of the articular eminence and the head of the condyle with the mouth closed. However, the disc was reduced on mouth opening.
- *Disc displacement without reduction*: The disc was anteriorly displaced relative to the posterior slope of the articular eminence and the condylar head. The disc was not reduced on mouth opening.

The position and form of the disc were evaluated according to classification criteria for disc position. The position and shape of the disc were carefully evaluated according to the classification criteria for disk position. Ambiguous cases such as partial disc displacement or disc displacement with partial reduction were excluded in this study.

Because the skeletal characteristics associated with unilateral DD are obscured by the averaging of the landmarks on both sides [18], only patients with bilateral normal disc status (BN), bilateral TMJ disc displacement with reduction (DDR) and bilateral TMJ disc displacement without reduction (DDNR) were included. Using data collected by questionnaires and clinical examinations, the subjects were subdivided into two groups, symptomatic and asymptomatic, based on the presence of TMJ symptoms.

Cephalometric analysis

A single investigator traced all cephalograms. A digitizer with a desktop computer was used to evaluate cephalometric measurements using a commercial software (V-ceph, Osstem, Seoul, Korea). Fifteen landmarks were digitized on each radiograph. Seventeen variables were recorded using these

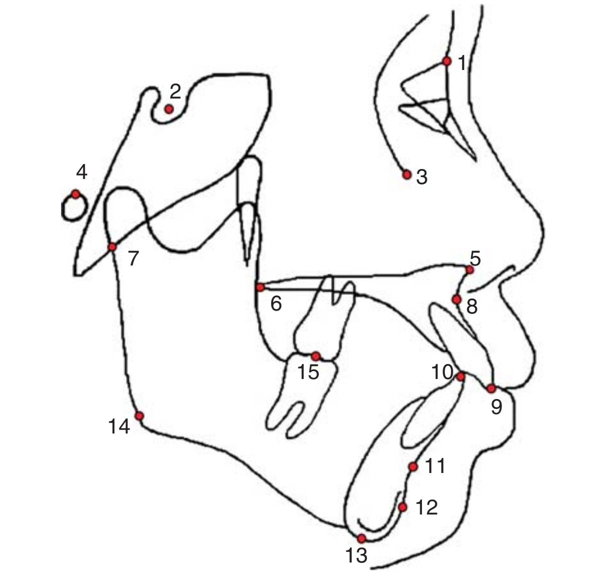

Figure 1. Landmarks used in this study: (1) nasion; (2) sella; (3) orbitale; (4) porion; (5) anterior nasal spine; (6) posterior nasal spine; (7) articulare; (8) point A; (9) incisal end of maxillary incisor; (10) incisal end of mandibular incisor; (11) point B; (12) pogonion; (13) menton; (14) gonion; (15) articulation of maxillary and mandibular molars.

landmarks and classified into four categories for convenience: maxillo-mandibular morphology, vertical skeletal morphology, size and form of mandible and dental morphology. The locations of all landmarks are shown in Figure 1 and measurements are shown in Figures 2 and 3.

Statistical analysis

Thirty subjects were randomly chosen from the total sample and their lateral cephalograms were measured

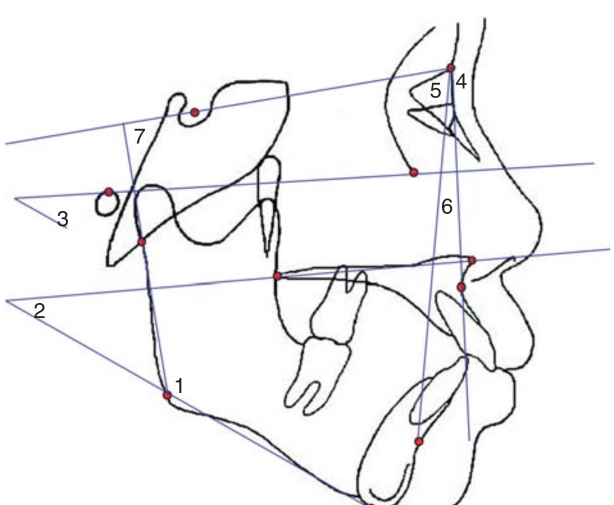

Figure 2. Angular measurements used in this study: (1) gonial angle (articulare-gonion-menton); (2) maxillo-mandibular plane angle; (3) FH to mandibular plane angle; (4) SNA angle; (5) SNB angle; (6) ANB angle; (7) ramus inclination (N-S to Ar-Go).

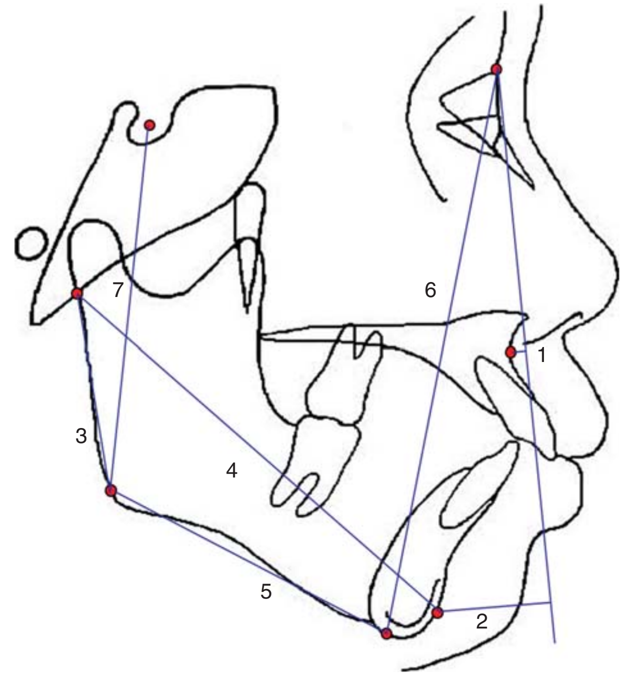

Figure 3. Linear measurements used in this study: (1) N perpendicular to point A; (2) N perpendicular to pogonion; (3) ramus height (articulare-gonion); (4) effective mandibular length (articulare-pogonion); (5) Mandibular body length (gonion-menton); (6) total anterior facial height (nasion-menton); (7) total posterior facial height (sella-gonion).

again to estimate the measurement error in the present study. The reliabilities of tracing, landmark identification and analytical measurements all had intra-class correlation coefficients greater than 0.98.

Descriptive statistics for each variable were calculated. Differences in skeletal morphologies with respect to TMJ DD status and TMJ symptom were analyzed using two-way factorial analysis of variance and Scheffe's multiple comparisons were performed to analyze between-group comparisons at a significance level of 0.05.

Results

A total of 197 adult female patients were included in this study (Table I). Although there were more patients with TMJ DD than with BN, there were no significant differences in age distributions according to TMJ DD status or TMJ symptom.

Table II summarizes the relationships between TMJ symptoms and TMJ status. Generally, patients with TMJ DD were more likely to show TMJ symptoms than those with BN. Clinical TMJ symptoms were observed in 124 of the patients. TMJ DD (DDR and DDNR) were observed in 95 (76.6%) of these symptomatic patients, while 40 (54.8%) of 73 asymptomatic patients had TMJ DD.

Tables III and IV show differences in cephalometric characteristics according to TMJ DD status and TMJ symptom. Only main factors were considered

Table I. Ages of asymptomatic or symptomatic subjects with bilateral normal disc position (BN), bilateral disc placement with reduction (DDR) and bilateral disc displacement without reduction (DDNR).

	BN (n = 62)	DDR (n = 56)	DDNR (n = 79)	Significance*
Asymptomatic	22.7 ± 3.6	26.0 ± 7.3	24.3 ± 6.0	Asymptomatic = Symptomatic
Symptomatic	24.3 ± 7.3	24.1 ± 4.2	24.4 ± 4.9	BN = DDR = DDNR

*Two-way factorial analysis of variance was done at a significance level of 0.05.

Table II. Number and proportion of asymptomatic or symptomatic subjects with respect to TMJ status (bilateral normal disc position [BN], bilateral disc placement with reduction [DDR] and bilateral disc displacement without reduction [DDNR]).

	BN	DDR	DDNR	Total
Total	62 (100%)	56 (100%)	79 (100%)	197 (100%)
Asymptomatic	33 (53.2%)	18 (32.1%)	22 (27.8%)	73 (37.0%)
Symptomatic	29 (46.8%)	38 (67.9%)	57 (72.2%)	124 (63.0%)

because the interactions between TMJ DD status and TMJ symptom were not significant for any of the cephalometric variables ($p > 0.05$).

TMJ DD status has significant effects on cephalometric variables. Twelve of the 17 cephalometric variables showed significant differences among different TMJ DD statuses. The differences were mainly associated with mandibular position, specifically antero-posterior position. The patients with TMJ DD showed increased SNB, ANB and ramus

Table III. Cephalometric variables of symptomatic or asymptomatic subjects with bilateral normal disc position (BN), bilateral disc displacement with reduction (DDR) and bilateral disc displacement without reduction (DDNR).

	Asymptomatic			Symptomatic		
Variables	BN Mean ± SD	DDR Mean ± SD	DDNR Mean ± SD	BN Mean ± SD	DDR Mean ± SD	DDNR Mean ± SD
Maxillo-mandibular morphology						
SNA angle (°)	81.3 ± 3.1	81.1 ± 3.1	80.2 ± 3.5	81.2 ± 3.2	81.7 ± 2.9	81.9 ± 3.6
SNB angle (°)	78.7 ± 5.3	76.9 ± 3.0	73.5 ± 4.1	80.4 ± 4.2	76.5 ± 3.0	74.1 ± 4.3
N perpendicular to point A (mm)	2.2 ± 2.9	1.2 ± 1.8	0.5 ± 3.5	1.5 ± 3.1	2.8 ± 2.9	2.0 ± 3.5
N perpendicular to pogonion (mm)	−1.3 ± 10.7	−6.7 ± 5.3	−13.8 ± 7.8	−2.2 ± 8.7	−5.9 ± 7.5	−13.4 ± 8.5
ANB angle (°)	2.6 ± 4.5	4.2 ± 2.0	6.8 ± 2.8	0.8 ± 4.1	5.2 ± 2.4	7.8 ± 2.8
Vertical skeletal morphology						
FH to mandibular plane angle (°)	30.0 ± 5.9	31.2 ± 6.3	34.3 ± 7.3	27.4 ± 6.1	30.1 ± 7.4	35.6 ± 6.5
Maxillo-mandibular plane angle (°)	40.6 ± 5.8	41.1 ± 5.9	44.5 ± 7.4	37.5 ± 6.8	40.8 ± 7.0	45.5 ± 6.9
Total anterior facial height (mm)	135.4 ± 6.1	134.5 ± 6.3	133.0 ± 5.7	132.2 ± 4.6	134.1 ± 6.5	133.0 ± 5.8
Total posterior facial height (mm)	83.8 ± 6.5	83.1 ± 6.7	78.4 ± 6.3	84.9 ± 6.5	83.0 ± 7.2	77.9 ± 6.7
Total anterior facial height/total posterior facial height (%)	62.0 ± 4.5	61.8 ± 4.9	59.1 ± 5.2	64.3 ± 5.3	61.9 ± 5.6	58.6 ± 4.9
Size and form of mandible						
Ramus height (mm)	50.9 ± 5.3	50.2 ± 5.1	46.1 ± 5.2	52.8 ± 4.4	49.6 ± 6.8	45.3 ± 4.9
Ramus inclination (°)	96.5 ± 6.7	97.7 ± 6.0	104.0 ± 5.9	94.3 ± 6.5	98.5 ± 5.9	103.0 ± 5.9
Mandibular body length (mm)	78.9 ± 4.4	77.0 ± 4.5	75.4 ± 6.0	77.9 ± 4.4	77.4 ± 4.1	74.4 ± 4.6
Effective mandibular length (mm)	115.9 ± 7.4	113.2 ± 5.5	106.8 ± 6.1	116.5 ± 6.6	113.0 ± 6.6	106.5 ± 6.1
Gonial angle (°)	124.1 ± 7.0	123.4 ± 6.7	120.5 ± 8.1	123.2 ± 8.7	122.3 ± 6.6	122.5 ± 5.4
Dental morphology						
Overbite (mm)	−0.4 ± 2.4	−0.4 ± 2.2	0.3 ± 3.7	−0.2 ± 2.9	−0.4 ± 3.3	−0.4 ± 3.3
Overjet (mm)	1.9 ± 3.3	4.8 ± 2.0	6.0 ± 2.7	1.1 ± 3.2	4.7 ± 2.2	5.8 ± 2.9

Table IV. Results of cephalometric variable comparisons with respect to TMJ status (bilateral normal disc position [BN], bilateral disc placement with reduction [DDR] and bilateral disc displacement without reduction [DDNR]) and TMJ symptom (asymptomatic and symptomatic).

	Significance*	
Variables	TMJ status	Symptom
Maxillo-mandibular morphology		
SNA angle (°)	NS	NS
SNB angle (°)	(BN > DDR > DDNR)***	NS
N perpendicular to point A (mm)	NS	NS
N perpendicular to pogonion (mm)	(BN > DDR > DDNR)***	NS
ANB angle (°)	(BN < DDR < DDNR)***	NS
Vertical skeletal morphology		
FH to mandibular plane angle (°)	(BN = DDR < DDNR)***	NS
Maxillo-mandibular plane angle (°)	(BN = DDR < DDNR)***	NS
Total anterior facial height (mm)	NS	NS
Total posterior facial height (mm)	(BN = DDR > DDNR)***	NS
Total anterior facial height/total posterior facial height (%)	(BN = DDR > DDNR)***	NS
Size and form of mandible		
Ramus height (mm)	(BN = DDR > DDNR)***	NS
Ramus inclination (°)	(BN < DDR < DDNR)***	NS
Mandibular body length (mm)	(BN = DDR > DDNR)***	NS
Effective mandibular length (mm)	(BN > DDR > DDNR)***	NS
Gonial angle (°)	NS	
Dental morphology		
Overbite (mm)	NS	NS
Overjet (mm)	(BN < DDR = DDNR)***	NS

*Two-way factorial analysis of variance was done at a significance level of 0.05; NS, not significant; *** $p < 0.001$.

inclination and decreased N perpendicular to pogonion and effective mandibular length compared to those with BN, indicating that the mandible was positioned more posteriorly in patients with TMJ DD than with BN. In addition, these cephalometric variables became more evident as TMJ DD progressed to DDNR, the most severe stage of TMJ DD.

Vertical skeletal morphology was also associated with TMJ DD status (Tables III and IV). FMA, maxillo-mandibular plane angle, total posterior facial height and total posterior facial height to total anterior facial height ratio were significantly different between BN and DDNR or between DDR and DDNR, whereas there were no significant differences in these variables between BN and DDR (Tables III and IV). This means that patients with DDNR showed steeper mandibular planes than did patients with BN or DDR. Among variables related to dental morphology, overjet showed significant differences among different TMJ statuses and subjects with DDR or DDNR had larger overjet than those with BN (Tables III and IV).

Interestingly, there were no significant differences in skeletal morphologies according to TMJ symptoms (Tables III and IV). This means that skeletal morphologies were not significantly different between symptomatic and asymptomatic patients and patients with TMJ DD, specifically DDNR had backward positioning and clockwise rotation compared to those with BN, regardless of TMJ symptom.

Discussion

Many studies have shown that TMJ DD is one of the main causes of TMJ symptoms [2,4]. The breakdown of joint structure originating from TMJ DD results in a loss of normal articular surface, creating pain in the sub-articular bone, TMJ clicking or crepitus and limitation of mandibular movement [14,19]. Our results indicate that subjects with TMJ DD have a high probability of exhibiting TMJ symptoms. Among a total of 124 patients with TMJ symptoms, 95 patients (76.6%) had TMJ DD and 29 patients (23.4%) had bilateral normal TMJs (Table II).

Although direct comparisons are not possible, the prevalence of TMJ DD in asymptomatic patients (54.8%, 40 of 74 asymptomatic patients) is higher than those observed in previous studies (up to 34%) [6,20]. The higher prevalence of TMJ DD in asymptomatic patients is mainly due to differences in sample selection. In contrast to previous studies that included symptomatic patients and asymptomatic volunteers of various ages [11,12,20], this study included only adult female orthodontic patients with TMJ symptoms or skeletal malocclusions that have been reported to be associated with TMJ DD, such as anterior open bite, retrognathic mandible and facial asymmetry [9–11,13]. TMJ symptoms may result from TMJ disorders other than TMJ DD such as synovitis, capsulitis and retrodiscitis, although these disorders commonly exist alongside TMJ DD [21]. In addition, general conditions, such as emotional condition, and hormonal factors can be associated with TMJ symptoms. Finally, there may be different responses and adaptations to TMJ DD between individuals. Although TMJ symptoms are commonly accompanied by TMJ DD in the general population, our results suggest that adult female patients with specific skeletal malocclusions may have a high possibility of exhibiting TMJ DD, irrespective of the presence of TMJ symptom.

In this study, we found no significant associations between TMJ symptoms and skeletal morphology; therefore, the null hypothesis is accepted. There are several reasons why the presence of TMJ symptoms does not significantly influence skeletal morphology. TMJ DD symptoms progress as follows: joint clicking, locking and pain and then released pain with joint sounds, followed by normal range of painless movement with reduced sounds [22]. When patients with TMJ DD reach a level of adaptation, further disease progress stops and symptoms are reduced or disappear [23]. Osteoarthritis (or destructive bony changes on the articular surfaces of the TMJ) is commonly accompanied by TMJ DD, which is associated with various symptoms and skeletal morphologic changes such as backward rotation of the mandible. However, osteoarthritis is a reversible joint disorder and its signs and symptoms are self-limiting, despite frequently appearing considerable radiographic changes [23–25]. Once etiologic factors are removed or loading force is decreased, the arthritic condition becomes adaptive and bony remodeling occurs. As a result, the form and shape of the TMJ remain abnormal, but symptoms disappear [26]. Therefore, patients who show altered skeletal morphologies associated with TMJ DD may be asymptomatic. Furthermore, TMJ symptoms may be caused by various other factors and individual adaptability during the progressive events may vary, which partly explains why there are no significant differences in skeletal morphologies between symptomatic and asymptomatic patients with TMJ DD.

We observed that TMJ DD status significantly influences differences in skeletal morphology, regardless of TMJ symptoms (Tables III and IV). In particular, variables associated with mandibular position and morphology, such as decreased ramus height, decreased mandibular body length, decreased effective size of the mandible and backward rotation of the ramus were significantly influenced by TMJ DD status. Mandibular changes related to TMJ DD may result from osseous changes on the articular surface of the condylar head. Previous studies have reported bony changes on the articular surface of the mandibular condyle in patients with TMJ DD, such as decreased condylar height with a distally inclined condylar head and these condylar shape changes become more severe as TMJ DD progresses in severity [27,28].

Because there were few differences in variables (SNA and point A to N perpendicular) related to the maxilla according to TMJ DD status, we hypothesize that altered mandibular morphology may contribute greatly to sagittal and vertical skeletal changes. Differences in maxillo-mandibular morphology in patients with TMJ DD, manifested as decreased SNB and pogonion to N perpendicular, and increased ANB angle, may be explained by altered mandibular morphology, such as decreased mandibular body length and effective mandibular length. Backward rotation and decreased size of the ramus and mandible may explain changes in vertical skeletal morphology, such as increased FH to mandibular plane angle, increased maxillo-mandibular plane angle, decreased total anterior facial height to total posterior facial height ratio and increased overjet in patients with TMJ DD.

Generally, TMJ DD is characterized by various clinical symptoms which can be used as indicators of TMJ DD [17,29]. As noted above, however, adult orthodontic patients with various skeletal malocclusions may have a high possibility of exhibiting TMJ DD without any specific TMJ symptoms. These patients can unexpectedly present with TMJ symptoms during and/or after orthodontic treatment or orthognathic surgery, which may be interpreted as a result of the orthodontic treatment or surgery. In addition, patients with TMJ DD may not respond normally to conventional orthodontic treatments [30]. Therefore, it is important to identify patients with TMJ DD before commencing orthodontic treatments. Our results suggest that clinicians should carefully examine TMJ status of adult patients with short mandible and backward rotation of the ramus, even if they do not have any specific TMJ symptoms.

In conclusion, we compared skeletal morphologies in symptomatic and asymptomatic adult orthodontic patients with TMJ DD using MRI as a gold standard. We observed that orthodontic patients with TMJ DD exhibit decreased posterior facial height and ramus height, backward rotation of the ramus and mandible and decreased mandibular length, irrespective of the presence of TMJ symptoms.

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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