Clinical relationship between maxillomandibular characteristics and temporomandibular disc conditions in female patients with a skeletal class III pattern

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Abstract

Objectives: To analyze the relationship between maxillomandibular characteristics and the severity of temporomandibular disc displacement in female patients with a skeletal class III (SKIII) pattern.

Materials and Methods: Fifty-seven samples were included. Articular disc conditions were evaluated by magnetic resonance imaging, and 25 cephalometric variables on lateral and postero-anterior cephalograms were measured to determine their maxillomandibular characteristics. The samples were classified into three groups based on the articular disc conditions: (1) normal disc position (NDP), (2) disc displacement with reduction (DDwR), and (3) disc displacement without reduction (DDwoR). The relationship between the maxillomandibular characteristics according to disc condition was examined in both a basic statistical analysis and a multivariate analysis known as principal component analysis.

Results: Kruskal-Wallis and Dunn-Bonferroni tests indicated a significant between-group difference in the deviation of mandibular characteristics seen on the postero-anterior cephalogram. The menton deviation, ramal height asymmetry index, and total mandibular length asymmetry index were significantly larger in the DDwoR group than in the NDP and DDwR groups. Furthermore, using principal component analysis, it was possible to extract all of the cephalometric variables into eight principal components. Only the principal component related to mandibular asymmetry could distinguish the SKIII samples with DDwoR from those in the other groups.

Conclusions: There is a significant relationship between mandibular asymmetry and the severity of disc displacement, particularly DDwoR, in female patients with a SKIII pattern.

Clinical Relevance: Etiologic relationship between SKIII patients with asymmetric mandible and the severity of articular disc conditions was significantly indicated in this study.

Background

Dentofacial deformity (DFD) and temporomandibular joint disorder (TMD) are critical problems in clinical orthodontics and are known to significantly affect patients’ quality of life [1, 2]. Typically, DFD develops from early adolescence; however, in some cases, it only becomes apparent during and after the maximum pubertal growth period. Similarly, TMD tends to develop during the adolescent growth period or thereafter. Patients with DFD have been found to have a higher prevalence of TMD than the control population [3]. While TMD can develop via several biomedical processes, the maxillomandibular morphological deviation in the sagittal, vertical, and transverse facial planes are considered significant factors in the development of TMD during the late growth period. Skeletal class III (SKIII) malocclusion has been found to be a problem particularly in the Asian population [4], and the maxillomandibular characteristics of SKIII patients and their relationship with articular disc displacement have yet to be clarified.

Articular disc displacement in the temporomandibular joint (TMJ) is a significant indicator of TMD [5, 6]. Previous studies have shown that articular disc displacement is strongly related to the severity of
symptoms in patients with TMD [7–9]. Articular disc displacement can be accurately and reproducibly determined by magnetic resonance imaging (MRI) [10–12]. MRI is performed in both the closed-mouth and opened-mouth positions to evaluate articular disc status [7, 13]. In the closed mouth position, articular disc displacement is diagnosed when the articular disc is not superiorly located at the 12 o’clock position of the mandibular condyle. To evaluate its severity in the opened-mouth position, the extent of reduction of disc displacement into the superior position of the condyle is observed. Disc displacement with or without reduction is potentially related to the severity of TMD, including a limited ability to open the mouth, pain, and/or degenerative changes of the mandibular condyle [14–16].

Sagittally retrognathic and vertically hyperdivergent mandibles are skeletal characteristics that have a significant relationship with the severity of articular disc displacement, although there is no clear evidence of this [17]. Among the various maxillomandibular classifications in the sagittal facial planes, SKIII may be the one least related to articular disc displacement [18]. It is likely that a transversely deviated mandible is associated with articular disc displacement, given that clinical TMD symptoms are commonly seen in patients with skeletal facial asymmetry [19]. Therefore, in the present study, our objectives were to analyze the relationship between the antero-posterior and transverse maxillomandibular characteristics of SKIII patients and the patterns of disc conditions in the TMJ and to determine their relationship with the severity of TMD. Our hypothesis was that more severe articular disc displacement in the TMJ is likely to be associated with a higher deviation of maxillomandibular characteristics in SKIII patients. Basic statistical and multivariate analyses were used to identify the cephalometric parameters directly related to the severity of TMD.

Methods

Patients

Female patients who visited the orthodontic department at our institution for orthodontic treatment between 2009 and 2018 were enrolled in the study. All SKIII patients demonstrated an ANB angle of < 2.3° and Wits appraisal < −4 mm based on the normal values for the female population in Japan [20, 21]. The following exclusion criteria was applied: 1) congenital defects; 2) history of orthodontic treatment; 3) history of trauma and surgery associated with the TMJ; 4) history of tooth extraction, except third molars; 5) no pre-treatment cephalograms or MRI scans of the TMJ available; and 6) poor-quality radiographs and MRI scans. Finally, 57 SKIII samples were included. The average patient age at the first visit was 22.48 ± 7.14 years (range, 14.08–47.42).

MRI scans and analysis

The condition of the patients’ articular discs was evaluated on the sagittal-oblique images of the TMJ acquired in both the closed-mouth and opened-mouth positions by a 1.5-T MRI scanner (Symphony, Siemens, Erlangen, Germany or Gyroscan Intera, Philips, Eindhoven, the Netherlands). Each MRI scan was interpreted by a radiologist who was blinded to the patient’s history. The articular disc conditions in each TMJ were determined as shown in Fig. 1. and described in Table 1.
The samples were divided into the following three groups based on the severity of the disc condition: (1) normal disc position (NDP; n = 24) on both sides of the TMJ; (2) disc displacement with reduction (DDwR; n = 23), composed of either bilateral DDwR or unilateral DDwR and NDP on the other joint; and (3) disc displacement without reduction (DDwoR; n = 10), composed of DDwoR on at least one joint.

### Cephalometric images and analysis

The postero-anterior (P-A) and lateral cephalometric images were traced on a Cintiq digitizer interface version 21UX (Wacom, Saitama, Japan) using CorelDraw Essentials software version X6 (Corel, Ottawa, Canada). The anatomical landmarks and reference planes used in this study are indicated in Fig. 2. On a P-A cephalogram, the line between both sides of the lateral orbitale was defined as the horizontal reference plane, and the line perpendicular to the horizontal reference plane passing through the tip of the crista galli was defined as the mid-facial plane. All 25 cephalometric variables were measured using Winceph software, version 9.0 (Rise, Sendai, Japan), as described in Tables 2 and 3 for the respective P-A and lateral cephalometric measurements. The bilateral variables on the P-A cephalograms were calculated into an asymmetry index using the following formula [22–24]:

\[
\frac{\text{Difference between right and left side values}}{\text{Average of right and left side values}} \times 100
\]

All tracings, landmark identifications, and measurements were performed by the same observer.

### Statistical analysis

All cephalometric images were traced and measured twice after a 7-day interval. The intraclass correlation coefficients for tracing, landmark identification, and measurement were all > 0.95, indicating excellent intraobserver reliability.

The differences in maxillomandibular characteristics among the three groups of disc conditions (NDP, DDwR, DDwoR) were analyzed using the Kruskal–Wallis and Dunn–Bonferroni tests at a significance level of 0.05.

Twenty-five maxillomandibular variables measured on the P-A and lateral cephalograms were used to extract the principal components of the maxillomandibular characteristics for principal component analysis (PCA). The distribution of articular disc conditions in the SKIII samples was plotted for the first three principal components.

### Results

Of the maxillomandibular characteristics analyzed on the P-A cephalograms (Table 4), four variables related to mandibular characteristics were found to differ significantly among the study groups. No maxillary parameters were found. As shown in Fig. 3, those in the DDwoR group were more likely to be characterized by a significantly larger menton deviation, FMdP cant, Cd-Ag asymmetry index, and Cd-Me asymmetry index than those in the bilateral NDP group (P < 0.01). Furthermore, those in the DDwoR group
had a significantly larger menton deviation, Cd-Ag asymmetry index, and Cd-Me asymmetry index than those in the DDwR group (P < 0.05).

Among the maxillomandibular characteristics analyzed on the lateral cephalograms, no differences were found among the groups (Table 5). That is, there was no statistically significant difference in the angular or linear measurements for the anteroposterior jaw position and relationship, including facial convexity, SNA, SNB, ANB, and Wit's appraisal, among the groups. Furthermore, there were no between-group differences in the lateral cephalometric parameters indicating mandibular size or in the parameters relating to vertical facial balance, such as the Frankfort-mandibular plane angle, palatal plane angle, N-ANS, and N-Me.

The rotated component matrix on the PCA is presented in Table 6. The 25 cephalometric variables could be classified into eight principal components with an eigenvalue higher than 1.00. The first principal component mainly represented the asymmetry of the mandible (the menton deviation, FMdP cant, and mandibular asymmetry indices). The second principal component included the variables related to the anteroposterior maxillomandibular relationship (ANB angle, facial convexity, and Wits appraisal). The third and fourth principal components were related to the vertical mandibular orientation (mandibular plane angle, gonial angle, and ramal inclination) and mandibular size (total mandibular length, ramus height, lower face height, and mandibular body length), respectively. The other remaining principal components mostly represented the variables related to characteristics of the maxilla.

A scatterplot of the samples with NDP, DDwR, and DDwoR on each pair of the first three principal components is shown in Fig. 4. A scatterplot of the articular disc conditions on each pair of all eight principal components is provided in the Supplementary Figure. These figures indicate that only the first principal component appears to be able to distinguish temporomandibular disc conditions in female SKIII patients.

**Discussion**

Maxillofacial morphology, especially the characteristics of the mandible, is one of the etiologies related to TMD. A significant relationship has been found between retrognathic, hyperdivergent, and asymmetric mandibles and the severity of articular disc displacement [4, 17]. Among the anteroposterior jaw relationships (SKI, SKII, and SKIII), the relationship between SKIII and articular disc displacement is the smallest [18]. However, in our study, some maxillomandibular characteristics of SKIII were found to be significantly related to articular disc conditions. From the P-A cephalometric analysis, SKIII samples with DDwoR were found to have greater mandibular asymmetry than those with DDwR and NDP. This finding suggests that asymmetric mandibular characteristics represent one of the etiologies related to the severity of articular disc conditions in SKIII female patients.

In the present study, we also used PCA to determine whether any of the principal components of the maxillomandibular characteristics can be used as indicators of the articular disc conditions in SKIII patients. It was found that the first principal component related to mandibular asymmetry distinguished
those in the SKIII group with DDwoR from those in the other groups. This finding was in good agreement with the results of the basic statistical analysis. Our results indicate that SKIII patients are likely to have a more severe articular disc condition when they demonstrate mandibular asymmetry. Furthermore, the cephalometric characteristics of those in the DDwR group were similar to those in the NDP group. This finding was somewhat unexpected because those in the DDwR group did not show heavy asymmetry of the mandible and suggests mandibular asymmetry may be caused by severe TMD. One possibility is that TMD results in asymmetry of the mandible and that asymmetric growth is not the primary cause of facial asymmetry during growth. Moreover, among our three study groups, the group with DDwoR was found to have the largest average values for ANB, facial convexity, Wits appraisal, Frankfort-mandibular plane angle, gonial angle, and ramal inclination, even though the differences were not determined to be significant. It should also be acknowledged that despite having recruited patients with a severe SKIII pattern as study participants, the amount of sagittal discrepancy in the jaw may not have been large enough for a significant difference to be observed among the groups.

Conclusions

The relationship between the antero-posterior and transverse maxillomandibular characteristics of SKIII patients and TMJ disc condition patterns was investigated to determine their relationship with the severity of TMD. The results of a basic statistical analysis and a multivariate analysis allowed identification of the cephalometric parameters directly related to the severity of TMD. Our results indicate a strong relationship between the internal derangement of the TMJ and skeletal facial asymmetry in SKIII patients. It was also found that DDwoR, specifically, is related to maxillomandibular asymmetry. Further studies of SKIII samples during the growth period will be carried out to clarify the causes and effects of facial asymmetry and TMD. It is also necessary to determine the impact of orthodontic-orthognathic treatment on TMD at the end of treatment.

Declarations

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Ethical Approval

This study is applicable for human studies. The Ethics Committee of our institute approved the study with the Protocol No 2020-242.

Competing interests

The authors declare that they have no competing interests.

Authors’ contributions

S.S. and K.H. collected the data; All cephalometric images were traced by S.S. and approved by K.H; All MRI of TMJ were analyzed by K.O; S.S. and K.H. interpreted the data; K.S. supervised statistical analysis;
S.S. analyzed the data and drafted the manuscript; I.T. revised the manuscript; I.T. and K.Y. supervised the direction of the study; All authors have read and approved the manuscript.

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**Availability of data and materials**

The datasets used and/or analysed during the current study are available from the corresponding author upon reasonable request.

**References**


Tables

Tables 1 to 6 are available in the Supplementary Files section.

Figures
Figure 1

Analysis of MRI scans. Representative appearance of the articular disc condition is shown. The left column is the MRI scan in sagittal-oblique sections in the closed-mouth position; the right column is the MRI scan in sagittal-oblique sections in the opened-mouth position. (A, B) Normal disc position (NDP). (C, D) Disc displacement with reduction (DDwR). (E, F) Disc displacement without reduction (DDwoR).
Reference points and planes are shown for P-A (A, B) and lateral (C, D) cephalometric analyses. (A) Ag, antegonial notch; ANS, anterior nasal spine; Cd, condylion; CG, crista galli; Lo, lateral orbitale; Me, menton; Mo, buccal tip of upper first molar; Mx, deepest point on the curve of the molar process of maxilla. (B) Reference planes and variable planes in P-A cephalograms are shown. FMdP, frontal mandibular plane; FMxP, frontal maxillary plane; FOP, frontal occlusal plane. (C) A, point A; ANS, anterior nasal spine; Ar,
articulare; B, point B; Cd, condylion; Gn, gnathion; Go, gonion; I1, point between the tips of the upper and lower incisors; Me, menton; M6, point between cuspal tips of the upper and lower first molars; N, nasion; Or, orbitale; PNS, posterior nasal spine; Po, porion; Pog, pogonion; Ptm, pterygomaxillary fissure; S, sella. (D) Reference planes and variable planes in lateral cephalograms are shown.

Figure 3.
Box and whisker plots indicate maxillomandibular characteristics, which differ significantly among the groups according to articular disc conditions. (A) Menton deviation, (B) FMdP cant, (C) Cd-Ag asymmetry index, and (D) Cd-Me asymmetry index. NDP, normal disc position; DDwR, disc displacement with reduction; DDwoR, disc displacement without reduction.

Figure 4
Scatter plots for the skeletal class III samples with different disc conditions (bilateral-NDP, DDwR, and DDwoR) on the first three principal components. (A) PC1 and PC2. (B) PC2 and PC3 (C) PC1 and PC3. (D) Three-dimensional scatter plots of samples with different disc conditions among the first three principal components.

A1. Scatter plots for the skeletal class III samples with different disc conditions (bilateral-NDP, DDwR, and DDwoR) on each pair of all eight principal components.

**Supplementary Files**

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- Clin.OrallInvestig.tables.xlsx
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