Factors related to the prevalence of anterior disc displacement without reduction and bony changes of the temporomandibular joint in patients with facial asymmetry

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A B S T R A C T

Purpose: The aim of the study was to determine the factors related to the prevalence of anterior disc displacement without reduction (ADDwOR) and bony changes of the mandibular condyle (bony changes) in temporomandibular joints (TMJs) of patients with dentofacial deformity exhibiting facial asymmetry.

Patients and methods: A total of 75 female patients (150 joints) with facial asymmetry, who had undergone orthognathic surgery, were examined with magnetic resonance imaging (MRI) of the TMJ and cephalometric analysis. Logistic regression analysis was performed to determine whether there was a statistically significant association between age, cephalometric measurements, and prevalence of ADDwOR and bony changes.

Results: Facial asymmetry, the prevalence of ADDwOR, and bony changes were more frequently found on the left side than that of the right side. Unilateral ADDwOR (n = 28) and unilateral bony changes (n = 14) were only found on the deviated side. The difference between the distance of upper incisal midpoints and lower incisal midpoints from the facial midline (U1–L1 distance) was significantly larger in 36 patients with ADDwOR and 52 patients with bony changes. According to logistic regression analysis, U1–L1 distance might be related to the prevalence of ADDwOR and bony changes in the TMJs with facial asymmetry.

Conclusion: U1–L1 distance related to the prevalence of ADDwOR and bony changes in TMJs of patients with dentofacial deformity exhibiting facial asymmetry.

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1. Introduction

Recently, there has been increasing concern regarding the influence of the temporomandibular joint (TMJ) on dentofacial morphology. An association between TMJ internal derangement shown in disc displacement or bony change of condyle and facial growth abnormality resulting in mandibular asymmetry or retrognathia has been previously suggested [1–3]. Although the etiology of skeletal asymmetry is not well understood, it has been suggested that joint degeneration may lead to shortening of the condyle, with subsequent skeletal asymmetry [1]. Several studies have assessed the association between radiographic depiction of osseous TMJ components and dentofacial morphology in adolescents [4,5], association between clinical signs and symptoms of temporomandibular disease and malocclusion [6–10], morphological features of the condyles as related to malocclusion [11], and association between facial skeletal patterns and magnetic resonance imaging (MRI) of the TMJ [11,12,2]. To evaluate the relationship between TMJ disorders and dentofacial abnormalities, it is necessary to examine the prevalence not only of TMJ symptoms, but also of disc displacement and bony changes in the TMJ. Various imaging techniques can be used to evaluate the TMJ, such as transcranial radiography, tomography, arthrography, computed tomography, and MRI. In particular, MRI shows high diagnostic accuracy in determining the articular disc position related to the condyle and articular eminence [13]. This imaging modality also offers many advantages, such as non-invasiveness, minimal pain, minimal risk, and freedom from exposure to ionizing radiation.

Condylar degenerative changes with TMJ disorders may also lead to deformities resulting in decreased vertical dimension in the proximal mandibular segment [14,15]. The reported prevalence of TMJ symptoms in patients with deformities of the jaw is high, but the relationship between position of the TMJ disc and types of
skeletal abnormalities is not sufficiently known [16,17]. In orthognathic surgery, facial asymmetry is generally treated by sagittal split ramus osteotomy or intraoral vertical ramus osteotomy, which can change the postoperative condylar position. Before planning treatment of patients with facial asymmetry, it is necessary to understand the difference in TMJ morphology between the deviated and non-deviated sides. However, details of the morphology of TMJ and its relationship to the prevalence of facial asymmetry have not been extensively reported.

Therefore, the present study aimed to clarify the morphological factors related to the prevalence of ADDwoR and bony changes in the TMJ of patients with facial asymmetry.

2. Subjects and methods

Subjects in this study comprised 75 women with dentofacial deformity and asymmetry, who underwent orthognathic surgery at Hokkaido University Hospital, Sapporo, Japan. The median age at the time of surgery was 21 years (range 15–48 years). None of the patients had previously been diagnosed with juvenile rheumatoid arthritis. Sagittal skeletal deformities were included in this study. Cases with facial asymmetry showing >2 mm of deviation between the menton and facial midline were included in this study. No men were included in this study to avoid skewing the cephalometric measurements with sex-related differences. The subjects included some women with clinically detectable TMJ signs and symptoms (capsular pain, joint sounds, masticatory muscle tenderness), and some without symptoms. The TMJ of patients with facial asymmetry was examined using MRI to assess the position of the disc and bony changes. The MRI was performed before starting the orthodontic treatment. Position of the disc was examined using sagittal and coronal T1-weighted MR images (T1WI) or proton-density weighted MR images (PDWI) with the mouth closed and open positions. The bilateral surface coil for TMJ was used. The slice/gap thickness of the MRI was 3.0/0.5 mm, and the matrix size was 512 × 192. On the PDWI, repetition time (TR) was 1300 ms and the echo time (TE) was 30 ms. On the T1WI, TR was 700 ms and the TE was 15 ms. We did not process the MR images by software after the MRI had been performed.

Results of MRI were classified as with or without ADDwoR. Subjects were divided into A group (with ADDwoR) and B group (without ADDwoR). ADDwoR was considered present if the disk was displaced anteriorly relative to the posterior slope of the articular eminence and head of the condyle, but without reduction of the disk on mouth-opening. Bony changes were classified as normal (normal cortical bone without erosions and deformity) or abnormal (cortical bone with erosions or deformity). We defined the diagnostic region of interest on MRI as follows: normal cortical without erosions and deformity is that linear low signal area suggesting bone cortex is smooth and definite. Cortical bone with erosion and deformity is that the linear low signal area suggesting bone cortex is flat or concave and irregular.

Subjects were divided into C group (with bony changes) and D group (without bony changes). The subjects were stable in habitual intercuspal position during cephalometric radiographs.

Frontal and lateral cephalometric radiographs were traced and the tracings were digitized using a digitizer interfaced with a desktop computer. Eleven landmarks were digitized on each radiograph, from which twelve cephalometric variables were calculated. Cephalometric landmarks and measurements are illustrated in Figs. 1 and 2. Logistic regression analysis was used to compare the A and B groups or C and D groups with respect to all cephalometric measurements and p-values of less than 0.05 were considered significant.

**Fig. 1.** Lateral cephalometric analysis. Cephalometric landmarks: sella (S); nasion (N); point A (A); point B (B); menton (Me); gonion (Go); articularare (Ar); mandibular plane (MP).
Table 1
Prevalence of ADDwoR and bony changes.

<table>
<thead>
<tr>
<th></th>
<th>ADDwoR n = 75 (%)</th>
<th>Bony changes n = 75 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Right</td>
<td>Left</td>
</tr>
<tr>
<td>Bilateral</td>
<td>6 (50)</td>
<td>35 (50)</td>
</tr>
<tr>
<td>Unilateral</td>
<td>28 (18)</td>
<td>23 (78)</td>
</tr>
<tr>
<td>Deviation side</td>
<td>25 (100)</td>
<td>23 (100)</td>
</tr>
<tr>
<td>Non-deviation side</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Without</td>
<td>41 (41)</td>
<td>24 (59)</td>
</tr>
</tbody>
</table>

ADDwoR, anterior disc displacement without reduction.

3. Results

Table 1 shows the prevalence of ADDwoR and bony changes. Facial asymmetry, the prevalence of ADDwoR, and bony changes were found on the left side more frequently than on the right side. Unilateral ADDwoR (n = 28) and unilateral bony changes (n = 14) were only found on the deviated side. Table 2 shows differences in age and cephalometric measurements among subjects with and without ADDwoR. While univariate logistic regression analysis demonstrated many significant differences among these groups, only the distance of upper incisal midpoints and lower incisal midpoints from the facial midline (U1–L1 distance) was significantly larger in subjects with ADDwoR than in those without ADDwoR when using multivariate logistic regression analysis (p = 0.036; odds ratio, 1.709) (Table 3). Table 4 indicates the differences in age and cephalometric measurements among subjects with and without ADDwoR.

Table 2
Statistical comparison of age and cephalometric variables of subjects with ADDwoR (group A), those without ADDwoR (group B) – univariate analysis.

<table>
<thead>
<tr>
<th></th>
<th>Group A n = 34</th>
<th>Group B n = 41</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median (range)</td>
<td>Median (range)</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>21 (15–39)</td>
<td>21 (15–48)</td>
<td>.8465</td>
</tr>
<tr>
<td>Overjet (mm)</td>
<td>1.0 (–4.0–9.0)</td>
<td>–1.0 (–5.0–6.5)</td>
<td>.0077</td>
</tr>
<tr>
<td>Overbite (mm)</td>
<td>0.5 (–4.5–4.2)</td>
<td>0.9 (–4.5–5.5)</td>
<td>.3207</td>
</tr>
<tr>
<td>DFM at L1 (mm)</td>
<td>4.5 (–4.5–4.2)</td>
<td>3.0 (1.5–8.0)</td>
<td>.0449</td>
</tr>
<tr>
<td>DFM at Me (mm)</td>
<td>7.5 (2.0–20.0)</td>
<td>4.0 (2.0–12.5)</td>
<td>.0437</td>
</tr>
<tr>
<td>U1–L1 distance (mm)</td>
<td>4.8 (0.5–11.3)</td>
<td>3.3 (1.5–8.0)</td>
<td>.0105</td>
</tr>
<tr>
<td>OP angle (°)</td>
<td>1.8 (0–6.0)</td>
<td>1.0 (0–6.0)</td>
<td>.0067</td>
</tr>
<tr>
<td>SNA angle (°)</td>
<td>82.2 (73.9–87.0)</td>
<td>81.9 (75.9–92.5)</td>
<td>.5224</td>
</tr>
<tr>
<td>SNB angle (°)</td>
<td>80.2 (71.2–90.0)</td>
<td>82.4 (76.9–93.8)</td>
<td>.0167</td>
</tr>
<tr>
<td>ANB angle (°)</td>
<td>1.5 (–6.0–7.5)</td>
<td>–1.2 (–6.2–7.9)</td>
<td>.0026</td>
</tr>
<tr>
<td>GZN angle (°)</td>
<td>87.4 (79.9–102.2)</td>
<td>85.4 (84.5–96.6)</td>
<td>.0005</td>
</tr>
<tr>
<td>SN-MP angle (°)</td>
<td>40.1 (29.0–48.6)</td>
<td>37.4 (25.0–51.5)</td>
<td>.0286</td>
</tr>
<tr>
<td>Gonial angle (°)</td>
<td>133.6 (111.9–147.6)</td>
<td>132.9 (117.9–140.4)</td>
<td>.8974</td>
</tr>
</tbody>
</table>

ADDwoR, anterior disc displacement without reduction; DFM, deviation from the facial midline; L1, lower incisor edge; Me, menton; U1, midpoint of the upper incisor edge; OP, occlusal plane; S, sella; N, nasion; A, point A; B, point B; GZN, SN plane to ramus plane; MP, mandibular plane.

* p < 0.05 (logistic regression analysis).
Table 3
Factors related to prevalence of anterior disc displacement without reduction of temporomandibular joints in dentofacial deformity with facial asymmetry – multivariate analysis.

<table>
<thead>
<tr>
<th></th>
<th>Odds ratio</th>
<th>95% Confidence interval</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>U1–L1 distance*</td>
<td>1.709</td>
<td>0.515–0.978</td>
<td>0.036</td>
</tr>
</tbody>
</table>

U1, midpoint of the upper incisor edge; L1, lower incisor edge.

* p < 0.05 (logistic regression analysis).

Table 4
Statistical comparison of age and cephalometric variables of subjects with bony changes (group C) and those without bony changes (group D) – univariate analysis.

<table>
<thead>
<tr>
<th></th>
<th>Group C (n = 52)</th>
<th>Group D (n = 23)</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>21 (15–48)</td>
<td>20 (15–46)</td>
<td>.4990</td>
</tr>
<tr>
<td>Over jet (mm)</td>
<td>0.3 (–5.0–9.0)</td>
<td>–0.5 (–6.0–2.0)</td>
<td>.0158*</td>
</tr>
<tr>
<td>Over bite (mm)</td>
<td>0.9 (–4.5–4.2)</td>
<td>0.5 (–2.5–5.5)</td>
<td>.3443</td>
</tr>
<tr>
<td>DFM at L1 (mm)</td>
<td>4.0 (0.5–143)</td>
<td>3.0 (1.5–8.0)</td>
<td>.2920</td>
</tr>
<tr>
<td>DFM at Me (mm)</td>
<td>6.0 (2.0–20.0)</td>
<td>4.0 (2.0–11.0)</td>
<td>.1531</td>
</tr>
<tr>
<td>U1–L1 distance (mm)</td>
<td>4.5 (0.5–11.3)</td>
<td>3.3 (1.0–8.0)</td>
<td>.0127*</td>
</tr>
<tr>
<td>OP angle (°)</td>
<td>1.5 (0–6.0)</td>
<td>1.0 (0–3.5)</td>
<td>.0040*</td>
</tr>
<tr>
<td>SNA angle (°)</td>
<td>82.2 (73.9–92.5)</td>
<td>81.5 (75.3–89.1)</td>
<td>.6433</td>
</tr>
<tr>
<td>SNB angle (°)</td>
<td>81.0 (71.2–93.8)</td>
<td>82.4 (74.1–92.1)</td>
<td>.2025</td>
</tr>
<tr>
<td>ANB angle (°)</td>
<td>0.4 (–6.0–7.9)</td>
<td>–1.0 (–6.2–3.5)</td>
<td>.0129*</td>
</tr>
<tr>
<td>GZN angle (°)</td>
<td>87.0 (75.5–102.2)</td>
<td>85.4 (78.5–91.7)</td>
<td>.0689</td>
</tr>
<tr>
<td>SN-MP angle (°)</td>
<td>39.4 (27.3–48.6)</td>
<td>38.8 (25.0–51.5)</td>
<td>.6276</td>
</tr>
<tr>
<td>Gonial angle (°)</td>
<td>134.4 (123.1–139.8)</td>
<td>134.4 (123.1–139.8)</td>
<td>.2507</td>
</tr>
</tbody>
</table>

DFM, deviation from the facial midline; L1, lower incisor edge; Me, menton; U1, midpoint of the upper incisor edge; OP, occlusal plane; S, sella; N, nasion; A, point A; B, point B; GZN, MP, mandibular plane.

* p < 0.05 (logistic regression analysis).

Table 5
Factors related to prevalence of bony changes of temporomandibular joints in dentofacial deformity with facial asymmetry – multivariate analysis.

<table>
<thead>
<tr>
<th></th>
<th>Odds ratio</th>
<th>95% Confidence interval</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>U1–L1 distance*</td>
<td>1.562</td>
<td>0.371–0.851</td>
<td>.007</td>
</tr>
</tbody>
</table>

U1, midpoint of the upper incisor edge; L1, lower incisor edge.

* p < 0.05 (logistic regression analysis).

Without bony changes. While univariate logistic regression analysis demonstrated many significant differences among groups, only the U1–L1 distance was significantly larger in subjects with bony changes than in those without bony changes when using multiple logistic regression analysis (p = 0.007; odds ratio, 1.562) (Table 5).

4. Discussion

We found that the distance of upper incisal midpoint and lower incisal midpoint from the facial midline was related to the prevalence of ADDwoR and bony changes in the TMJ of patients with facial asymmetry. The findings of this study showed that inter-maxillary right–left deviation affected the prevalence of ADDwoR and bony changes in the TMJ more than mandibular deviation or maxillary midline discrepancy. In other words, horizontal occlusal instability strongly affected the prevalence of internal derangement of TMJ. A causal relationship has been reported between internal derangement of the TMJ and an abnormal facial skeleton, which is characterized primarily by a retrognathic mandible, mandibular asymmetry, and occlusal instability [18].

In this study, sagittal skeletal deformities such as mandibular prognathism or mandibular retrognathia were included. However, the ANB angle was significantly related to the prevalence of ADDwoR and bony changes in univariate analysis, distance of upper incisal midpoint and lower incisal midpoint from the facial midline was only significantly related to the prevalence of ADDwoR and bony changes in multivariate analysis. These results indicate right–left deviation contribute more to the prevalence of ADDwoR and bony changes than sagittal jaw relationships in facial asymmetry.

Temporomandibular disorder (TMD) is associated with disturbed facial skeletal growth such as mandibular deviation in rabbits or humans [11,19]. Some authors have reported internal derangement of TMJ as a primary cause of growth disturbance, including mandibular asymmetry [11,20]. In vivo experiments of disc displacement in rabbits have also verified that permanent articular disc displacement is one causal factor in the development of mandibular midline asymmetry [21]. Occlusal instability, midline discrepancy, right–left differences in molar relationship, and inclination of the frontal occlusal plane have been considered to be important occlusal characteristics in patients with TMJ disorders [22,23]. These reports support our findings. However, previous studies had not determined the factors related to the prevalence of anterior disc displacement without reduction and bony changes in the TMJ of patients with facial asymmetry.

The results of this study confirm that facial asymmetry, the prevalence of ADDwoR, and bony changes were found more frequently on the left side than on the right side. In a recent study, the chewing side, bite force symmetry, and occlusal contact area of subjects with different facial vertical patterns were evaluated. Mesofacial, brachyfacial, and dolichofacial individuals presented asymmetry in occlusal contact area, showing larger values on the left side. Asymmetry of bite force was found only in dolicho facial subjects, with a higher bite force exerted on the left side [24]. Moreover, the role of TCOFI insertion mutations in Taiwanese patients with craniofacial anomalies was studied; the mutant treacle probably exhibited defects in nuclear trafficking and appeared to affect the development of the left side of the face (6/6 cases) more than the right side of the face (0/6) [25]. Although these results may be related to our findings, the reason why facial asymmetry and
internal derangement are observed more frequently on the left side than on the right side could not be elucidated.

Unilateral ADDwoR and unilateral bony changes were only found on the deviated side in this study. In a previous study, anterior disc displacement was observed mostly on the deviated side in patients with mandibular deviation [26]. This is in agreement with our findings. These findings indicate that a different etiology exists between bilateral internal derangement and unilateral internal derangement. The TMJ is a unique joint which functions with both sides operating in tandem as different forces act on each side.

It has been reported that surgical correction of mandibular prognathism could improve the stress balance on TMJ in the frontal aspect in subjects with mandibular prognathism with and without asymmetry after orthognathic surgery using the rigid bodies spring model. Although the underlying mechanisms remain uncertain, one possibility is that excessive mandibular stress on the condylar heads in patients with facial asymmetry overlords the TMJ [15]. Measurement of differences in intra-articular pressure of TMJ or masticatory function between patients with facial asymmetry and control subjects without dentofacial abnormalities during mandibular function should help to clarify the mechanisms involved.

Because of the high predilection for TMD in women compared with men, and identification of estrogen receptors in TMJ tissues in some species, it has been suggested that there is a role for estrogen in the pathogenesis of TMD. Estrogen decreased cartilage thickness by inhibition of chondrocyte proliferation and increased chondrocyte maturation [27]. Estrogen has the potential to cause temporomandibular joint disease with induction of the proinflammatory cytokines, interleukin (IL)-1 beta, IL-6, and IL-8 [28]. For this reason, no men were included in this study to avoid skewing the cephalometric measurements with sex-related differences.

In conclusion, we must pay attention to ADDwoR and bony changes in the TMJ of patients with facial asymmetry in intermaxillary large right–left deviation. Our findings indicate that internal derangement of TMJ is closely related to etiology of facial asymmetry. If clinically possible, we recommend obtaining TMJ radiographs or MRI in children when symptoms of TMD or facial dysmorphogenesis are evident and continue to observe these patients in order to determine the etiology of facial asymmetry.

References