Mandibular dimensions of subjects with asymmetric skeletal Class III malocclusion and normal occlusion compared with cone-beam computed tomography

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Introduction: The purpose of this study was to use cone-beam computed tomography to compare mandibular dimensions in subjects with asymmetric skeletal Class III malocclusion and those with normal occlusion.

Methods: Cone-beam computed tomography scans of 38 subjects with normal occlusion and 28 patients with facial asymmetry were evaluated and digitized with Invivo software (Anatomage, San Jose, Calif). Three midsagittal and 13 right and left measurements were taken. The paired t test was used to compare the right and left sides in each group. The Mann-Whitney U test was used to compare the midsagittal variables and the differences between the 2 sides of the group with normal occlusion with those of asymmetry patients.

Results: The posterior part of the mandibular body showed significant differences between the deviated and nondeviated sides in asymmetric Class III patients. The difference of the asymmetry group was significantly greater than that of the normal occlusion group for the mediolateral ramal and the anteroposterior condylar inclinations (P = 0.007 and P = 0.019, respectively).

Conclusions: The asymmetric skeletal Class III group showed significant differences in condylar height, ramus height, and posterior part of the mandibular body compared with the subjects with normal occlusion. These results might be useful for diagnosis and treatment planning of asymmetric Class III patients. (Am J Orthod Dentofacial Orthop 2012;142:179-85)

Lack of harmony between the constituents of the craniofacial complex is considered to be asymmetry.1,2 With the increasing interest in facial appearance, asymmetry poses a great concern to those who want to improve their facial esthetics.

In the evaluation of facial asymmetry, various diagnostic indexes are available for assessing severity and identifying those in need of treatment.3-5 Posteroanterior cephalograms have been widely used to quantify the amount of deviation. However, the reliability of posteroanterior cephalometric measurements is limited because of superimposition of important structures and difficulties in landmark identification.6 Subsequently, various attempts have been made to overcome the limits in 2-dimensional (2D) analysis.3,7-9

Three-dimensional (3D) computed tomography imaging has been proposed to resolve such problems, since it can be effective for diagnosis and treatment planning of patients with maxillofacial deformities. Recently, Gateno et al10 examined the impact of facial asymmetry on the accuracy of both 2D and 3D cephalometric measurements. They concluded that 3D measurements also can be distorted by changes in shape, size, position, and orientation.

Hwang et al11 found that the difference in ramal inclination masked the difference in ramus length in the posteroanterior cephalograms and reported that 3D images might be useful in understanding asymmetrical

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structures. Also, other investigators have used 3D computed tomography scans to compare patients with symmetric and nonsymmetric mandibular prognathism and concluded that both condylar and body units contributed to the asymmetry. However, previous studies on facial morphologic asymmetry have mainly focused on the frontal and lateral planes. Also, no systematic 3D diagnostic method has been available for facial asymmetry, although the accuracy of 3D computed tomography measurements is sufficiently high.

Therefore, the purpose of this study was to compare the dimensions of mandibular morphology between asymmetric skeletal Class III patients and subjects with normal occlusion by using cone-beam computed tomography (CBCT).

**MATERIAL AND METHODS**

The asymmetry group consisted of 28 Class III adults (14 men, 14 women; mean age, 24.85 years) with facial asymmetry who visited the orthodontic department in Seoul Saint Mary's hospital in Korea. The inclusion criteria were Angle Class I molar and canine relationships with ANB angles less than -2° and apparent facial asymmetry with chin deviation of at least 3 mm from the facial midline perpendicular to the interpupillary line at soft-tissue nasion when the patient was seated upright with the Frankfort horizontal plane parallel to the floor. The exclusion criteria included apparent maxillary asymmetry and previous orthodontic or orthognathic treatment.

The control group included 38 adults (18 men, 20 women; mean age, 22.6 years; SD, 3.2 years) with normal occlusion and esthetically pleasing appearance who volunteered to participate in CBCT evaluations. The inclusion criteria were Angle Class I molar and canine relationships, ANB angle between 0° and 4°, normal overbite and overjet (>0 mm and <4 mm, respectively), minor arch length discrepancy (<3 mm of crowding, <1 mm of spacing), flat or slight curve of Spee (<2 mm), and full permanent dentition with normal tooth size and shape, except for the third molars. The exclusion criteria included deviations in the dental midline, crossbite, history of previous orthodontic or orthognathic treatment, restorations extending to contact areas, cusp tips, incisal edges, and missing teeth. CBCT scans were taken with the Alphard VEGA (Asahi Roentgen, Kyoto, Japan). The following settings were used: field of view, 200 x 179 mm; 80 kV; 5.00 mA; exposure time, 17 seconds; voxel size, 0.39 mm; and slice thickness, 1.00 mm. The volume render tab in Invivo (version 5.01; Anatomage, San Jose, Calif) was used to view, digitize, and measure the CBCT scans. First, reorientation of each scan was performed. Nasion was selected as the origin of the x, y, and z coordinates. The horizontal plane was defined through the right and left orbitale and the left porion, and the midsagittal plane was defined by passing through nasion, and the anterior and posterior nasal spines (Fig). Then, menton, gonion, condylion, sigmoid notch, and mesiobuccal cusp of the maxillary first molars were digitized. Also, a new reference point was constructed at the most convex point on the curvature of the mandibular body between menton and gonion, midway between the inner and outer borders of the mandibular body on each side (Fig). Table I gives the definitions of the cephalometric variables measured in this study. The side toward which the chin was shifted was called the deviated side, and the other side was called the nondeviated side.

All digitizations were performed by 1 investigator (M.B.), who had much experience in 3D technology. To test intraexaminer reliability, 10 randomly selected CBCT scans were digitized 2 weeks later by the same operator. The results of the intraclass correlation coefficient test showed high reliability between the 2 assessments (>0.8).

**Statistical analysis**

Statistical analysis was performed with software (version 16.0.2.1; SPSS, Chicago, Ill). The right and left sides of the groups were compared by using paired t tests. Because the values of the midsagittal measurements in the normal occlusion group did not have a normal distribution when assessed with the Shapiro-Wilk test, the Mann-Whitney U test was used to compare the normal occlusion and the asymmetrical skeletal Class III groups. For the measurement of the pairs, the differences in each parameter between the right and left sides of the normal occlusion subjects were compared with those of the deviated and nondeviated sides of the asymmetry patients with the Mann-Whitney U test.

**RESULTS**

Table II shows the differences between the asymmetric skeletal Class III and the normal occlusion groups for the linear variables. The posterior part of mandibular body was significantly larger on the nondeviated side than on the deviated side in the asymmetry group. The difference between the 2 sides of the asymmetry group was significantly greater than that of the normal occlusion group for condylar height, ramus height, and posterior part of the mandibular body (P <0.001, P <0.001, and P = 0.006, respectively).

Table III presents the comparisons of the angular variables. In the asymmetric Class III group, there was a significant difference only in the mediolateral ramal
inclusion, with the deviated side showing a significantly greater value \((P<0.001)\). In the comparison of the 2 groups, there were significant differences in mediolateral ramal inclination and anteroposterior condylar inclination \((P = 0.007\) and \(P = 0.019\), respectively). Both variables showed greater differences between the 2 sides of the asymmetry group compared with the normal occlusion group.

In Table IV, in the evaluation of the midsagittal variables between the asymmetric Class III and the normal occlusion groups, menton to midsagittal and menton deviation angle were significantly larger in the asymmetric Class III group \((P<0.001)\). However, menton angle showed no differences \((P = 0.89)\).

### DISCUSSION

As the demand for facial esthetics increases, more patients become self-aware of facial asymmetry, which calls for greater attention to the mandibular asymmetry in diagnosis.\(^{15}\) Therefore, the aim of our study was to evaluate the mandibular dimensions by using 3D analysis, since no landmarks or measurements have been established for the analysis of facial asymmetry.

Several studies have used posteroanterior cephalograms to demonstrate asymmetry even in normal, pleasing faces and have shown that soft tissues tend to minimize the underlying asymmetry.\(^{16,17}\) On the other hand, Peck et al\(^{18}\) reported that the differences between the right and left measurements were insignificant. Nevertheless, the reliability of cephalometric measurements is limited because of the difficulty in identification of some landmarks because of superimposition.\(^{6}\) Recently, Yanez-Vico et al\(^{19}\) evaluated 3D computed tomography images and found a slight asymmetry in their control group, but without statistical assessment. In our study, there was no significant difference between the 2 sides in the normal occlusion group.

### Table I. Definitions of the measured variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>Gonial angle</td>
<td>Angle between the menton-gonion and condylion-gonion vectors of both sides</td>
</tr>
<tr>
<td>Ramus height</td>
<td>Distance between condylion and gonion of both sides</td>
</tr>
<tr>
<td>Condylar height</td>
<td>Vertical distance from condylion to the mandibular body curve sigmoid plane</td>
</tr>
<tr>
<td>Mandibular body length</td>
<td>Distance between gonion of both sides and menton</td>
</tr>
<tr>
<td>Condyle to midsagittal plane</td>
<td>Perpendicular distance from right and left condylion to the midsagittal plane projected on the coronal plane</td>
</tr>
<tr>
<td>Gonion to midsagittal plane</td>
<td>Perpendicular distance from right and left gonion to the midsagittal plane projected on the coronal plane</td>
</tr>
<tr>
<td>Menton deviation angle</td>
<td>Angle between the midline and the menton-anterior nasal spine vector</td>
</tr>
<tr>
<td>Menton to midsagittal plane</td>
<td>Perpendicular distance from menton to the midsagittal plane projected on the coronal plane</td>
</tr>
<tr>
<td>Menton angle</td>
<td>Angle between the right and left gonion-menton vectors</td>
</tr>
<tr>
<td>Maxillary height</td>
<td>Perpendicular distance from each side mesiobuccal cusp of the first molar to the Frankfort horizontal plane projected on the coronal plane</td>
</tr>
<tr>
<td>Anterior part of mandibular body</td>
<td>Distance between menton and the mandibular body curve on each side</td>
</tr>
<tr>
<td>Posterior part of mandibular body</td>
<td>Distance between the mandibular body curve and gonion on each side</td>
</tr>
<tr>
<td>Mediolateral ramal inclination</td>
<td>Inner angle between the right and left condylion-gonion and the Frankfort plane projected on the frontal plane</td>
</tr>
<tr>
<td>Anteroposterior ramal inclination</td>
<td>Inner angle between the right and left condylion-gonion and the Frankfort plane projected on the midsagittal plane</td>
</tr>
<tr>
<td>Anteroposterior condylar inclination</td>
<td>Angle between the vector passing through the condyle parallel to the condyle neck and the Frankfort plane projected on the midsagittal plane</td>
</tr>
<tr>
<td>Mandibular body curve angle</td>
<td>Angle between the anterior and posterior mandibular body lines</td>
</tr>
</tbody>
</table>

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**Fig.** Landmarks and linear and angular variables used in this study: A, frontal view of the skull; B, three quarters view of the skull; C, frontal view of the mandible; D, lateral view of the mandible; E, submandibular view of the mandible. 1, Nasion; 2, orbitale; 3, anterior nasal spine; 4, menton; 5, gonion; 6, condylion; 7, maxillary first molar; 8, sigmoid notch; 9, mandibular body curve; 10, gonial angle; 11, ramus height; 12, condylar height; 13, mandibular body length; 14, condyle to midsagittal plane; 15, gonion to midsagittal plane; 16, menton deviation angle; 17, menton to midsagittal plane; 18, menton angle; 19, maxillary height; 20, anterior part of the mandibular body; 21, posterior part of the mandibular body; 22, mediolateral ramal inclination; 23, anteroposterior ramal inclination; 24, anteroposterior condylar inclination; 25, mandibular body curve angle.
Hwang et al11 analyzed the frontal and lateral ramal inclinations as the cause of asymmetry using 3D images. They found that the difference in ramal inclination masked the difference in ramus length in the posteroanterior cephalometric measurements. You et al12 compared patients with symmetric and nonsymmetric mandibular prognathism and concluded that both condylar and body units contributed to the asymmetry. In agreement, our study showed that the difference between the 2 sides of the asymmetry group was significantly greater than that of the normal occlusion group for the condylar and ramus heights, the posterior part of mandibular body, and the mediolateral ramal and anteroposterior condylar inclinations. However, the lack of significant differences between the deviated and nondeviated sides of the asymmetry group might be due to the sample size.

Traditionally, mandibular body length is measured by a straight line in a conventional analysis, although it is really a curve. In our study, to measure this curved length of the mandibular body accurately and conveniently, a new landmark—mandibular body curve—was constructed as the most convex point on the curve between menton and gonion. This length was measured separately in the anterior and posterior parts. Asymmetric skeletal Class III patients tended to have longer posterior parts of the mandibular body than did those with normal occlusion.

Table II. Comparisons of the linear measurements between the asymmetric skeletal Class III and the normal occlusion groups and between both sides in each group

<table>
<thead>
<tr>
<th>Variable (mm)</th>
<th>Asymmetric skeletal Class III (n = 28)</th>
<th>Normal occlusion (n = 38)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Deviated side</td>
<td>Nondeviated side</td>
</tr>
<tr>
<td>Ramus height</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td></td>
<td>53.23 (5.52)</td>
<td>54.77 (6.80)</td>
</tr>
<tr>
<td>Mandibular body length</td>
<td>88.87 (6.67)</td>
<td>89.87 (5.81)</td>
</tr>
<tr>
<td>Anterior part of mandibular body</td>
<td>14.35 (1.96)</td>
<td>13.99 (2.49)</td>
</tr>
<tr>
<td>Posterior part of mandibular body</td>
<td>79.06 (7.39)</td>
<td>80.56 (6.61)</td>
</tr>
<tr>
<td>Condylion to midsagittal</td>
<td>51.64 (3.02)</td>
<td>51.46 (3.69)</td>
</tr>
<tr>
<td>Gonion to midsagittal</td>
<td>48.47 (4.64)</td>
<td>47.97 (4.75)</td>
</tr>
<tr>
<td>Maxillary height</td>
<td>47.63 (3.55)</td>
<td>48.30 (3.75)</td>
</tr>
<tr>
<td>Condylar height</td>
<td>19.06 (3.30)</td>
<td>20.06 (3.08)</td>
</tr>
<tr>
<td>Condylar head width</td>
<td>16.56 (2.52)</td>
<td>16.94 (2.79)</td>
</tr>
</tbody>
</table>

*Paired t tests between the 2 sides in each group; †Mann-Whitney U test between the absolute differences between the sides of both groups.

Table III. Comparison of the angular measurements between the asymmetric skeletal Class III and the normal occlusion groups and between both sides in each group

<table>
<thead>
<tr>
<th>Variable (°)</th>
<th>Asymmetric skeletal Class III (n = 28)</th>
<th>Normal occlusion (n = 38)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Deviated side</td>
<td>Nondeviated side</td>
</tr>
<tr>
<td>Gonial angle</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td></td>
<td>121.08 (6.39)</td>
<td>120.62 (5.91)</td>
</tr>
<tr>
<td>Mediolateral ramal inclination</td>
<td>86.59 (3.98)</td>
<td>83.52 (4.05)</td>
</tr>
<tr>
<td>Anteroposterior ramal inclination</td>
<td>84.46 (4.30)</td>
<td>83.44 (4.24)</td>
</tr>
<tr>
<td>Mandibular body curve angle</td>
<td>132.02 (4.05)</td>
<td>132.20 (4.67)</td>
</tr>
<tr>
<td>Anteroposterior condylar inclination</td>
<td>65.37 (5.91)</td>
<td>62.84 (5.95)</td>
</tr>
</tbody>
</table>

*Paired t tests between the 2 sides in each group; †Mann-Whitney U test between the absolute differences between the sides of both groups.
However, this tendency could not be found when this length was measured directly. Therefore, this might indicate that the posterior part of the mandibular length has an important role in 3D asymmetry evaluation.

There has been rapid technological advancement in 3D radiographic images. It is crucial to properly reorient the reconstructed image of the head to a correct and reproducible position. Gatenio et al\textsuperscript{10} reported that reliability of the direct 3D measurements could be questionable if there is significant asymmetry, depending on head position. Also, several studies that used various software programs reported high accuracy of the linear and angular measurements in 3D volume rendering CBCT images compared with the physical measurements.\textsuperscript{20-22}

Kook and Kim\textsuperscript{23} proposed a clinical method to easily reorient the head using frontal facial and intraoral photographs. Unfortunately, this approach lacks the adjustment of the coordination system. Since nasion and anterior nasal spine tend to fall on or close to the midsagittal plane in 90\% of the population,\textsuperscript{24} therefore, in our study, the midsagittal plane was determined by nasion, anterior nasal spine, and posterior nasal spine. Nasion was selected as the baseline of the 3D coordinate system because it is relatively less affected by facial asymmetry.

In a previous study, the reproducibility of the gonial area was reported to be the lowest in 3D cephalometric analysis.\textsuperscript{25} To improve this low reproducibility, Fuyama et al\textsuperscript{26} offered more precise definitions of each sagittal, axial, and coronal section of the image. Also, in our study, gonion was defined as the point of the mandible midway between the lowermost point on the posterior border of the ramus and the most posterior point on the lower border of the mandible.

Hwang et al\textsuperscript{11} suggested that measurements of the frontal and lateral ramal inclinations were required to precisely analyze asymmetry. In our study, the term mediolateral ramal inclination was used in place of frontal ramal inclination to prevent misunderstanding that frontal might be confused as the anteroposterior inclination of the ramus. Also, anteroposterior ramal inclination was replaced with lateral ramal inclination (Fig. C and D).

In our study, no comparison of the mandibular variables was conducted between the Class III and the normal occlusion subjects other than the 3 midsagittal variables: menton angle, menton deviation angle, and menton to midline. Nonetheless, we compared the differences between the deviated and nondeviated sides of the asymmetry group, and the differences between the right and left sides of the normal occlusion subjects. This comparison of differences was aimed to evaluate the amount of asymmetry in both groups of subjects.

Maeda et al\textsuperscript{27} reported that deviation of menton was observed in patients with asymmetry with the highest incidence. Based on the posteroanterior cephalometric measurements, 80\% of the asymmetry was solely detected in the mandible, and both the maxilla and the mandible were involved in remaining 20\% of the cases.\textsuperscript{28} Another report described similar results, with 64\% in the mandible and 36\% in the maxilla and the mandible.\textsuperscript{29} In our study, the inclusion criterion was at least 3 mm of menton deviation from the facial midline, and maxillary asymmetry was excluded. These strict criteria might have affected the small sample size, but the sex and age distributions of both groups were almost identical. Further study with a larger sample might be beneficial for more detailed evaluation of mandibular morphology.

**CONCLUSIONS**

We compared mandibular morphology between asymmetric Class III patients and normal occlusion subjects using CBCT. Our findings are summarized as follows.

1. The deviated side of the asymmetry group had a significantly larger mediolateral ramal inclination than the nondeviated side.
2. The deviated and nondeviated sides of the asymmetry skeletal Class III group showed significant differences in condylar and ramus heights, posterior part of the mandibular body, and mediolateral ramal and anteroposterior condylar inclinations compared with those of the subjects with normal occlusion.

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**REFERENCES**