Mandibular vertical asymmetry in adult orthodontic patients with different vertical growth patterns: 
A cone beam computed tomography study
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ABSTRACT
Objective: To evaluate condylar and ramal vertical asymmetry in adult orthodontic patients with different vertical growth patterns and a clinically normal sagittal skeletal pattern using cone-beam computed tomography (CBCT).

Materials and Methods: The study sample consisted of 101 adult orthodontic patients (48 men and 53 women) divided into three groups according to their vertical growth patterns: high- (33 patients; mean age, 25.06 ± 6.05 years), low- (34 patients; mean age, 24.88 ± 5.22 years), and normal-angle (34 patients; mean age, 24.14 ± 4.26 years) groups. Condylar, ramal, condylar plus ramal height, and index measurements were performed using CBCT images and analyzed using one-way analysis of variance and post hoc Tukey tests.

Results: There was no statistically significant difference in height measurements between right and left sides in each group, except a slight difference of approximately 0.5 mm for condylar height (CH) in the low-angle group (P < .05). No statistically significant gender differences were found for the values (P > .05). In the high-angle group, the ramal height (RH) and condylar plus ramal height (CH + RH) on both sides were found to be less than those of the low- (P < .001) and normal-angle groups (P < .017 and P > .017, respectively), and the asymmetry index values were slightly higher than those of the low- and normal-angle groups (P > .05).

Conclusions: The high-angle group showed statistically significantly smaller values of RH and CH + RH on both sides and statistically insignificantly higher asymmetry index values than the low- and normal-angle groups. (Angle Orthod. 2016;86:271–277.)

KEY WORDS: Condylar asymmetry; Mandibular asymmetry; Cone-beam computed tomography

INTRODUCTION
Vertical malocclusions can result from the interaction of several different etiological factors including growth of the jaws, function of the lips and tongue, and dentoalveolar development with the eruption of the teeth.¹ They might be divided into those that are predominantly skeletal due to the growth patterns of the mandible and maxillae and those that are dentoalveolar in origin.

Three basic types of skeletal vertical growth patterns exist: high- (hyper-), low- (hypo-), and normal-angle (normo-divergent). The high-angle growth pattern is generally associated with increased vertical facial growth, decreased posterior-to-anterior facial-height ratio, increased sella-nasion (SN)–mandibular plane (MP) angle, increased gonial angle, and increased maxillary plane–MP angle.²³ On the other hand, the low-angle growth pattern is characterized by reduced vertical facial growth, increased posterior-to-anterior facial-height ratio, decreased SN-MP, decreased gonial angle, and decreased maxillary plane–MP angle,⁴ while the normal-angle facial growth pattern lies between those types. It has been shown that

posterior rotation of the mandible has a marked effect on mandibular condyle morphology and position.\textsuperscript{5,6}

Habets et al.\textsuperscript{7} described a method for evaluating mandibular vertical asymmetry by calculating the condylar and ramal heights to compare the right and left sides of the mandible. Several authors have used this method to assess mandibular asymmetry in patients with temporomandibular disorders,\textsuperscript{8} unilateral and bilateral posterior crossbites,\textsuperscript{9–11} various sagittal malocclusions,\textsuperscript{12–14} unilateral\textsuperscript{15} and bilateral molar extractions,\textsuperscript{16} and cleft lip and palate.\textsuperscript{17,18}

Although mandibular vertical asymmetry has appeared frequently in the literature, a bibliographic search in Medline using PubMed and the key words “condylar asymmetry,” “mandibular asymmetry,” “vertical growth pattern,” and “CBCT” revealed that no published study has evaluated condylar and ramal vertical asymmetry using cone-beam computed tomography (CBCT) in patients with different vertical growth patterns. Therefore, the aim of the present study was to evaluate mandibular vertical asymmetry in adult patients having various vertical growth patterns (high- and low-angle patterns) and clinically normal sagittal skeletal patterns and to compare the findings with a well-matched control group (normal-angle) using CBCT.

MATERIALS AND METHODS

This study was approved by the local ethical committee of Erciyes University, and all patients signed an informed consent form to allow use of their data for scientific purposes. CBCT scans, taken for diagnostic reasons related to previous dental and orthodontic or orthognathic surgery requirements, were randomly selected from the archives of Erciyes University. The patients were therefore not exposed to any additional radiation for the purpose of the present retrospective study.

The study sample comprised a total of 101 patients (53 women and 48 men) aged 18–34 years (mean age, 24.69 ± 5.18 years) divided into high-, low-, and normal-angle groups based on their vertical growth pattern using the SN-MP angle (high angle, ≥38°; low angle, ≤26°; and control group or normal-angle group, 26°–38°) as the criterion.\textsuperscript{19} The sample included 33 patients in the high- (22 women and 11 men; mean age, 25.06 ± 6.05 years), 34 patients in the low- (16 women and 18 men; mean age, 24.8 ± 5.22 years), and 34 patients in the normal-angle (15 women and 19 men; mean age, 24.14 ± 4.26 years) groups. All patients had skeletal Class I (1° < ANB < 5°)\textsuperscript{20} relationships and the same ethnic origin, and none had a unilateral or bilateral posterior crossbite.

All CBCT data were previously obtained in a standard supine position with the same machine (NewTom 5G, QR Verona, Verona, Italy) using a scanning time of 18 seconds, an exposure time of 3.6 seconds, a collimation height of 13 cm, and a voxel size of 0.3 mm\textsuperscript{3}. The images were transformed to Digital Imaging and Communications in Medicine and then Simplant Pro software, version 13.0 (Materialise, Leuven, Belgium) was used to perform the measurements. The asymmetry measurements were done randomly by an experienced maxillofacial radiologist without knowing the patient’s vertical growth pattern, and an orthodontist performed the cephalometric measurements (ANB and SN-MP).

Condylar height (CH), ramal height (RH), and condylar plus ramal height (CH + RH) measurements (Figure 1) were done as previously elaborated in the literature.\textsuperscript{11,18} The mandibular vertical condylar, ramal, and condylar plus ramal asymmetry indexes (CAI, RAI, and CRAI, respectively) were calculated using the formula described by Habets et al.\textsuperscript{7}

\[
\text{Asymmetry index} = \frac{(\text{Right} - \text{Left})}{(\text{Right} + \text{Left})} \times 100
\]

Statistical Analysis

To determine the random error, 25 CBCT images were randomly selected and all measurements were repeated 3 weeks after the first examination by the same authors without knowing the initial values. Correlation analysis yielded the highest \(r\) value for right (RH; 0.993) and the lowest for left (CH; 0.934) measurements. The error method was calculated using the Houston test, and the results confirmed the reliability of the measurements (the coefficients were above .95).

Since the Shapiro-Wilk test showed that the data were normally distributed (\(P > .05\)), parametric tests were used. A Pearson chi-square test was performed to test gender distribution, and a one-way ANOVA test for comparing age, ANB, SN-MP, CH, RH, CH + RH, CAI, RAI, and CRAI values among the groups. Tukey’s honestly significant difference test was employed for comparing individual differences, taking the Bonferroni correction into account (\(P < .017\)). A paired \(t\) test was used to determine the potential differences between right and left sides for CH, RH, and CH + RH measurements for each group. A Student’s \(t\)-test was used to determine the gender difference according to the asymmetry indexes.

All statistical analyses were performed using the SPSS version 15.0 software package for Windows.
(SPSS, Chicago, Ill); $P < .05$ was considered statistically significant.

RESULTS

Table 1 shows the descriptive data of the patients included in each group. Gender distribution and chronological ages of the patients in all groups were well matched (tested by chi-square and one-way ANOVA, respectively) ($P > .05$ for both tests). Chronological ages of the patients in the high-, low-, and normal-angle groups were 25.06 ± 6.05 years, 24.88 ± 5.22 years, and 24.14 ± 4.26 years, respectively. All patients had a skeletal Class I sagittal relationship (mean ANB, 2.87 ± 1.08°) with no statistically significant differences among the groups ($P > .05$). Statistically significant differences were present among the high-, low-, and normal-angle groups for the SN-MP angle (41.30 ± 3.51°, 22.49 ± 2.39°, and 31.10 ± 1.77°, respectively) at a significance level of $P < .001$.

Table 2 shows the means, standard deviations, and statistical results of the paired t test comparing the CH, RH, and CH + RH measurements of the right and left sides in each group. There was no statistically significant difference between the sides for those measurements in each group ($P > .05$), except for a slight difference of approximately 0.5 mm for CH in the low-angle group ($P < .05$).

The descriptive mandibular asymmetry indices for both women and men were calculated separately in each group to investigate the relation between genders. No statistically significant gender differences were found for the values and thus the data were pooled for further statistical analysis (Table 3).
Table 2. Comparison of Height Measurements Between Sides Among Vertical Groups

<table>
<thead>
<tr>
<th>Variable</th>
<th>High Angle</th>
<th>Low Angle</th>
<th>Normal Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Right Side</td>
<td>Left Side</td>
<td>Right Side</td>
</tr>
<tr>
<td>CH</td>
<td>4.26 ± 0.09</td>
<td>4.18 ± 0.89</td>
<td>4.31 ± 0.95</td>
</tr>
<tr>
<td>RH</td>
<td>46.33 ± 0.33</td>
<td>46.50 ± 0.08</td>
<td>50.63 ± 3.11</td>
</tr>
<tr>
<td>CH + RH</td>
<td>50.58 ± 4.44</td>
<td>50.67 ± 4.32</td>
<td>54.93 ± 3.63</td>
</tr>
</tbody>
</table>

* CH indicates condylar height; RH, ramal height; CR + RH, condylar-plus-ramal height.  
* P indicates results of paired-samples t test.

In the high-angle group, RH and CH + RH on both sides were statistically significantly less than those of the low-angle group (P < .001). The high-angle group had statistically significantly lower RH values on both sides compared with the normal-angle group (P < .01). On the other hand, the CAI, RAI, and CRAI values in the high (11.54% ± 6.95%, 3.53% ± 2.78%, and 3.29% ± 2.82%, respectively) and low (10.09% ± 7.96%, 2.63% ± 1.81%, and 2.59% ± 1.87%, respectively)-angle groups were found to be slightly higher compared with the normal-angle group (8.57% ± 7.32%, 2.28% ± 2.04%, and 2.27% ± 1.68%, respectively). However, these differences were statistically insignificant (P > .05; Table 4).

## DISCUSSION

Mandibular asymmetry can be assessed by various tools including clinical assessment; photographs; radiographs such as panoramic, frontal, and lateral cephalograms; computed tomography (CT); and CBCT.21,22 Most previous studies9,12–17,23 investigating the relationship between condylar asymmetry and various malocclusions were carried out using panoramic films. Although this technology has an acceptable cost-benefit ratio because of its minimal radiation exposure, it suffers from limitations similar to those derived from the conventional cephalometric analyses including magnification, distortion, and superimposition of anatomical structures.24 Contemporary three-dimensional technology makes it feasible to achieve true (1:1 in size) images devoid of magnification.10 Although radiation exposure could be an issue, CT is the gold standard for determining condylar asymmetries.25 In the present study, CBCT images were used to assess condylar and ramal vertical asymmetry in adult patients having various vertical growth patterns since CBCT provides a relatively low radiation dose with low costs compared with CT. In addition, Simplant Pro software version 13.0 was used to perform the measurements. The threshold value could be set from the scan, the required structure could be separated from its surrounding structures, and the software allows us to visualize an area that was superimposed by other structures and to evaluate its actual dimensions.10 The Houston and correlation analyses confirmed the high reliability of the variable values as previously reported for the CBCT images of the two- and three-dimensional measurements.10,11,18,26–31

Comparing right and left sides for the CH, RH, and CH + RH values in the high-, low-, and normal-angle groups showed only a slight difference of approximately 0.5 mm for CH in the low-angle group (P < .05), indicating an almost symmetrical posterior vertical height of the mandible in all studied groups. Similarly, no statistically significant differences were reported for right and left sides in patients with or without any malocclusion.9,11,32 However, some authors23,33 using panoramic

Table 3. Comparison of Mandibular Asymmetry Indexes Between Genders

<table>
<thead>
<tr>
<th>Group</th>
<th>Variable (%)</th>
<th>Mean (SD)</th>
<th>Mean (SD)</th>
<th>P*</th>
</tr>
</thead>
<tbody>
<tr>
<td>High angle</td>
<td>CAI</td>
<td>11.29 (8.08)</td>
<td>11.67 (6.51)</td>
<td>.884</td>
</tr>
<tr>
<td>(W/M:22/11)</td>
<td>RAI</td>
<td>4.81 (3.22)</td>
<td>2.99 (2.36)</td>
<td>.060</td>
</tr>
<tr>
<td></td>
<td>CRAI</td>
<td>4.65 (3.27)</td>
<td>2.71 (2.37)</td>
<td>.051</td>
</tr>
<tr>
<td>Low angle</td>
<td>CAI</td>
<td>11.16 (8.50)</td>
<td>8.90 (7.39)</td>
<td>.417</td>
</tr>
<tr>
<td>(W/M:16/18)</td>
<td>RAI</td>
<td>2.87 (1.94)</td>
<td>2.36 (1.68)</td>
<td>.425</td>
</tr>
<tr>
<td></td>
<td>CRAI</td>
<td>2.96 (1.95)</td>
<td>2.18 (1.75)</td>
<td>.228</td>
</tr>
<tr>
<td>Normal angle</td>
<td>CAI</td>
<td>10.29 (7.44)</td>
<td>6.39 (6.80)</td>
<td>.125</td>
</tr>
<tr>
<td>(W/M:15/19)</td>
<td>RAI</td>
<td>2.62 (2.44)</td>
<td>1.84 (1.35)</td>
<td>.275</td>
</tr>
<tr>
<td></td>
<td>CRAI</td>
<td>2.71 (1.91)</td>
<td>1.72 (1.17)</td>
<td>.088</td>
</tr>
</tbody>
</table>

* CAI indicates condylar asymmetry index; RAI, ramal asymmetry index; CRAI, condylar-plus-ramal asymmetry index; W/M, women/men; SD, standard deviation.  
* P indicates results of Student t test comparing genders.
films reported significant side differences for patients with unilateral crossbite, while recent studies using CBCT images have indicated the similarity of right and left sides in patients with unilateral crossbite. The use of panoramic films in those studies might have caused this difference because of their low reproducibility compared with that of the CBCTs.

In contrast to the finding of Saglam, we observed that the asymmetry indices were not affected by gender (tested by means of the Student t test); thus the data were pooled for further statistical comparison. In agreement with our finding, several authors also reported no statistically significant differences for asymmetry indexes between genders.

In the present study, CAI values in the high- (11.54% ± 6.95%) and low-angle (10.09% ± 7.96%) groups were found to be slightly higher than those of the normal-angle group (8.57% ± 7.32%; P > .05). These values are higher compared with the 3% threshold value of Habets et al., showing that all patients included in the present study had asymmetric mandibles according to the CAI values. The CAI values found in the normal-angle group were less than the findings of Celikoglu et al. (12.11% ± 9.63%) and Halicioglu et al. (10.58% ± 9.48%) using CBCT images for the control groups having normal occlusion. According to Habets et al., a 3% index ratio could result from a 1-cm change in head position while the panoramic film is being taken; therefore, asymmetry index values greater than 3% should be considered as mandibular asymmetry. Our study examined this hypothesis because the patient’s head position is not an assessment criterion when using CBCT, and the findings showed that the investigators interested in condylar asymmetry should revise the 3% CAI threshold value of Habets et al., as reported previously. In addition, previous studies using panoramic films also reported that CAI values in normal occlusion groups were over 7%, within the limitations of those films.

Regarding the RAI and CRAI values, no statistically significant differences were present among the vertical groups, except a slight increase in the high-angle group (3.53% ± 2.78% and 3.29% ± 2.82%, respectively).
compared with the low- (2.63% ± 1.81% and 2.59% ± 1.87%, respectively) and normal-angle (2.28% ± 2.04% and 2.27% ± 1.68%, respectively) groups. On the other hand, the RH and CH + RH values of both right and left sides were highest in the low-angle group, and lowest in the high-angle group (P < .001). In agreement with our finding, a significant difference was noted among the vertical growth patterns for ramus height, as the highest value in the low-angle group and the lowest value in the low-angle group.²⁴,³⁶

It is difficult to compare our findings with those of previous studies evaluating condylar asymmetry, as there have been no studies investigating mandibular vertical asymmetry in different vertical growth patterns. Thus, further studies are needed to prove or compare our findings. We did not include any patients with unilateral or bilateral crossbite or sagittal malocclusion to eliminate those aberrations’ effect on mandibular asymmetry, since previous studies have shown that mandibular asymmetry values differ in patients with unilateral or bilateral posterior crossbite⁹,²³,³³ or Class II or III malocclusions¹⁴,²² compared with normal occlusion groups.

CONCLUSIONS

• There was no statistically significant difference in height measurements between right and left sides in each group, except a slight difference of approximately 0.5 mm for CH in the low-angle group (P < .05).
• No statistically significant gender differences were found for the asymmetry index values (P > .05).
• In the high-angle group, RH and CH + RH on both sides were found to be less than those of the low- (P < .001) and normal-angle groups (P < .017 and P > .017, respectively), and asymmetry index values were statistically insignificantly higher than those of the low- and normal-angle groups (P > .05). Clinicians and surgeons should be aware of these differences for high-angle patients needing orthognathic surgery.

REFERENCES


