Computed tomography evaluation of the temporomandibular joint in Class II Division 1 and Class III malocclusion patients: Condylar symmetry and condyle-fossa relationship

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Introduction: The purpose of this study was to investigate the condyle-fossa relationship, the concentric position of the condyles, and the dimensional and positional symmetries between the right and left condyles in Class II Division 1 and Class III malocclusion samples. Methods: Thirty subjects from 12 to 38 years of age with Class II Division 1 malocclusion and 16 subjects from 13 to 41 years of age with Class III malocclusion had computed tomography of the temporomandibular joints. The images obtained from the axial slices were evaluated for possible asymmetries in size and position between the condylar processes associated with these malocclusions. The images obtained from the sagittal slices were used to assess the depth of the mandibular fossa, the condyle-fossa relationship, and the concentric position of the condyles associated with these malocclusions. Paired Student t tests were applied, and Pearson product moment correlations were determined after measurements on both sides were obtained. Results: In the Class II Division 1 sample, the distance of condylar process/midsagittal plane (P = 0.019) and posterior joint space (P = 0.049) showed statistically significant differences between the right and left sides. In the Class III sample, there was no statistically significant difference between sides. In the Class II Division 1 sample, the distance of condylar process/midsagittal plane and posterior articular space had statistically significant differences between the right and left sides. Evaluation of the concentric position of the condyles in their mandibular fossae showed nonconcentric positioning for the right and left sides in both the Class II and Class III malocclusion groups. (Am J Orthod Dentofacial Orthop 2009;136:199-206)

It is well known that the shape and function of the temporomandibular joints (TMJs) are intimately related and that the functional loads applied to them exert considerable influence on their morphology.1-3 However, the influence of occlusion on articular morphology is still not completely understood.

Several studies found a significant relationship between some occlusal characteristics and articular morphology.1,2,4,5 Others, however, did not demonstrate these correlations.6-8 Some researches noted the influence of occlusion in the condylar process-mandibular fossa relationship.9-14 The association between specific malocclusions and some characteristics of TMJs reveals a typical characteristic—the concentricity of the condyles in the mandibular fossa.12,15,16 In Class II Division 1 subdivision subjects, although not concentrically positioned, the condyles showed symmetric positioning in relation to one another.17

One factor that has always jeopardized the visualization of the TMJs on conventional radiographic examination is the superimposition of neighboring structures. Computed tomography (CT) imaging allows clear visualization of the areas of interest without superimposition and opens new perspectives for analyzing these joints with the possibility of determining the real dimensions of the structures under study.18,19

The purpose of this study was to investigate, with CT imaging, the condyle-fossa relationship, the concentric position of the condyles, and the dimensional and
positional symmetries between the right and left condyles in Class II Division I and Class III subjects.

MATERIAL AND METHODS

Thirty persons with Class II Division I malocclusion from 12 to 38 years of age and 16 with Class III malocclusion from 13 to 41 years of age underwent CT imaging of the TMJs. These participants met the following requirements: all permanent teeth erupted, except third molars; and no functional mandibular deviations, crossbites, open bites (in Class II), facial asymmetry, or temporomandibular disorders.

The methodology we used was described by Vitral et al16 and Vitral and Telles.17

The CT images were obtained with the patients in maximum dental intercuspation, and their heads were positioned so that the Frankfort and midsagittal planes were perpendicular to the floor. The helicoidal/multi-slice CT was performed with a Somaton Spirit device (Siemens, Xangai, China) at 120 kV and 160 mA. We obtained 1-mm thick slices spaced at 1-mm intervals, using the helicoidal technique. Because this procedure provides images on the axial plane, it was reformatted to produce images sagittally. The selected imaging slices were processed in the same equipment.

The measurements were determined by tracing the selected image structures. As in most CT images, the dimensions did not correspond to the real size of the structures. Therefore, a scale for measurement conversion was determined for each image. The following measurements were assessed on the sagittal plane.

1. Depth of the mandibular fossa: measured from the most superior point of the fossa to the plane formed by the most inferior point of the articular tubercle to the most inferior point of the auditory meatus (Fig 1).

2. Anterior joint space: expressed by the shortest distance between the most anterior point of the condyle and the posterior wall of the articular tubercle (Fig 2, a).

3. Superior joint space: measured from the shortest distance between the most superior point of the condyle and the most superior point of the mandibular fossa (Fig 2, b).

4. Posterior joint space: represented by the shortest distance between the most posterior point of the condyle and the posterior wall of the mandibular fossa (Fig 2, c).
The following measurements were assessed on the axial plane.

1. The greatest anteroposterior diameter of the mandibular condylar processes (Fig 3, a).
2. The greatest mediolateral diameter of the mandibular condylar processes (Fig 3, b).
3. The angle between the long axis of the mandibular condylar process and the midsagittal plane (Fig 3, c).
4. The distance between the geometric centers of the condylar processes and the midsagittal plane, measured with a line that passed through the geometric centers of the condylar processes and perpendicular to the midsagittal plane (Fig 3, c).
5. The anteroposterior difference between the geometric center of the right and left condylar processes as reflected on the midsagittal plane (Fig 4, a).

Paired Student t tests were used for each measurement to evaluate the average of differences between the sides for each element of the sample. Pearson product moment correlation coefficients (r) were determined to quantify the correlation between the values of the right and left sides for each measurement.

To assess method error, the intraclass correlation coefficient was used. Two tracings were made for each structure, and every measurement was repeated twice. The correlation coefficient between the measurements of the first and second tracings had a P value of <0.0001.

RESULTS

The descriptive statistics for each measurement from the Class II Division 1 subjects are shown in Table I. The descriptive statistics for the evaluation of the centric position of condyles are shown in Table II.

The mean depths of the mandibular fossae were 7.98 and 8.25 mm for the right and left sides, respectively (P = 0.150; r = .000). The mean anterior joint spaces were 1.28 and 1.11 mm for the right and left sides, respectively (P = 0.051; r = .005). The mean superior joint spaces were 1.62 mm for the right side and 1.66 mm for the left side (P = 0.751; r = .000). The mean posterior joint spaces were 2.38 mm for the right side and 2.16 mm for the left side, respectively (P = 0.049; r = .000).
The mean values for the anteroposterior diameter of the condylar processes were 9.24 mm for the right side and 9.29 mm for the left side ($P = 0.769; r = 0.000$). For the mediolateral diameter of the condylar processes, the values were 21.19 mm for the right side and 20.74 mm for the left side ($P = 0.118; r = 0.000$).

The angles between the plane of the greatest mediolateral diameter of the condylar processes and the midsagittal plane were 67.43° for the right side and 67.80° for the left side ($P = 0.728; r = 0.082$).

The average anteroposterior position of the condylar processes as reflected on the midsagittal plane was 0.69 mm ($P = 0.263$). The mean values for the distance from the geometric center of the condylar processes to the midsagittal plane were 54.39 mm for the right side and 53.77 mm for the left side ($P = 0.019; r = 0.000$).

In the evaluation of the concentric position of the condyles on the right side, the mean values were 1.28 and 2.38 mm for the anterior and posterior joint spaces, respectively ($P = 0.000; r = .311$). On the left side, the mean values were 1.11 and 2.16 mm for the anterior and posterior joint spaces, respectively ($P = 0.000; r = .884$).

The descriptive statistics for each measurement of the Class III subjects are shown in Table III. The descriptive statistics for the evaluation of the concentric position of condyles are shown in Table IV.

The mean depths of the mandibular fossa were 7.95 and 8.04 mm for the right and left sides, respectively ($P = 0.582; r = .000$). The mean anterior joint spaces were 1.25 and 1.23 mm for the right and left sides, respectively ($P = 0.892; r = .076$). The mean superior joint spaces were 1.86 mm for the right side and 1.64 mm for the left side ($P = 0.205; r = .002$). The mean posterior joint spaces were 2.21 mm for the right side and 1.99 mm for the left side, respectively ($P = 0.158; r = .000$).

The mean values for the anteroposterior diameter of the condylar processes were 9.71 mm for the right side and 9.35 mm for the left side ($P = 0.282; r = .004$). For the mediolateral diameter of the condylar processes, the values were 21.83 mm for the right side and 21.85 mm for the left side ($P = 0.966; r = .000$).

The measurement for the angle between the plane of the largest mediolateral diameter of the condylar processes and the midsagittal plane were 72.88° for the right side and 71.25° for the left side ($P = 0.336; r = .195$).

The average anteroposterior position of the condylar processes as reflected on the midsagittal plane was 0.77 mm ($P = 0.263$). The mean values for the distance from the geometric center of the condylar processes to the midsagittal plane were 52.31 mm for the right side and 53.65 mm for the left side ($P = 0.077; r = .000$).

In the evaluation of the concentric position of the condyles on the right side, the mean values were 1.25 and 2.21 mm for the anterior and posterior joint spaces, respectively ($P = 0.006; r = .387$). On the left side, the mean values were 1.23 and 1.99 mm for the anterior and posterior joint spaces, respectively ($P = 0.001; r = .079$).
DISCUSSION

Understanding TMJ morphology and its spatial disposition in different malocclusions, and the influence of orthodontic treatment on its structures during the stages of human development, are still challenging for orthodontists. The articular tissues have considerable potential for adaptation to changing functional demands; this should be kept in mind when planning orthodontic treatment.

CT imaging has been shown to be the ideal tool for TMJ assessment. Three-dimensional information from a series of thin slices of the internal structure to be evaluated eliminates superimposition, offers higher sensitivity during differentiation of tissues when compared with conventional radiography, and allows manipulating and adjusting the image after scanning; these are some advantages of CT.

Anterior open-bite subjects were not included in the Class II Division 1 sample because they might have significantly smaller vertical height of the articular fossa. This restriction was not applied to deep overbite patients, since the possibility of subjects with this malocclusion having posterior displacement of the mandible during closure has not been confirmed.

Posterior crossbite patients were not included in the Class II sample because this malocclusion might be associated with mandibular functional deviations. Severe condylar asymmetries observed in CT scans are most frequently caused by these deviations. In such cases, the image does not correspond to the real mandibular position; instead, it reflects an adaptive occlusal deviation.

Anterior and posterior crossbites are characteristic of Class III malocclusions, they were included in this group, but only if there were no functional deviations.

The axial slice is the most appropriate one to assess the symmetry between the condyles in the anteroposterior and mediolateral aspects, because it shows both condyles in the same image and allows the determination of reference planes such as the median sagittal plane. This also permits measuring the real dimensions of the condyles and their angulations. The sagittal slice is the most appropriate for assessing the condyle-fossa relationship. It allows analysis of condylar concentricity.

### Table I. Statistical analysis of Class II Division 1

<table>
<thead>
<tr>
<th></th>
<th>Mean, right side</th>
<th>Mean, left side</th>
<th>SD, right side</th>
<th>SD, left side</th>
<th>Right side-left side</th>
<th>P value, paired Student t test</th>
<th>Pearson product correlation (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth of mandibular fossa (mm)</td>
<td>7.98</td>
<td>8.25</td>
<td>1.46</td>
<td>1.61</td>
<td>-0.27</td>
<td>0.150</td>
<td>.000</td>
</tr>
<tr>
<td>Anterior joint space (mm)</td>
<td>1.28</td>
<td>1.11</td>
<td>0.43</td>
<td>0.47</td>
<td>0.17</td>
<td>0.051</td>
<td>.000</td>
</tr>
<tr>
<td>Superior joint space (mm)</td>
<td>1.62</td>
<td>1.66</td>
<td>0.63</td>
<td>0.69</td>
<td>-0.03</td>
<td>0.751</td>
<td>.005</td>
</tr>
<tr>
<td>Posterior joint space (mm)</td>
<td>2.38</td>
<td>2.16</td>
<td>0.76</td>
<td>0.70</td>
<td>0.21</td>
<td>0.049</td>
<td>.000</td>
</tr>
<tr>
<td>Anteroposterior diameter of condylar process (mm)</td>
<td>9.24</td>
<td>9.29</td>
<td>1.54</td>
<td>1.45</td>
<td>-0.05</td>
<td>0.769</td>
<td>.000</td>
</tr>
<tr>
<td>Mediolateral diameter of condylar process (mm)</td>
<td>21.19</td>
<td>20.74</td>
<td>2.65</td>
<td>2.36</td>
<td>0.45</td>
<td>0.118</td>
<td>.000</td>
</tr>
<tr>
<td>Angle condylar process/midsagittal plane (°)</td>
<td>67.43</td>
<td>67.80</td>
<td>8.80</td>
<td>10.49</td>
<td>-0.37</td>
<td>0.728</td>
<td>.082</td>
</tr>
<tr>
<td>Anteroposterior difference of condylar process (mm)</td>
<td>0.00</td>
<td>0.69</td>
<td>0.00</td>
<td>3.30</td>
<td>-0.69</td>
<td>0.263</td>
<td>—</td>
</tr>
<tr>
<td>Distance, condylar process/midsagittal plane (mm)</td>
<td>54.39</td>
<td>53.77</td>
<td>3.87</td>
<td>3.75</td>
<td>0.62</td>
<td>0.019</td>
<td>.000</td>
</tr>
</tbody>
</table>

### Table II. Statistical analysis: concentric position of condyles, Class II Division 1

<table>
<thead>
<tr>
<th></th>
<th>Anterior joint space</th>
<th>Posterior joint space</th>
<th>Anterior joint space-posterior joint space</th>
<th>P (paired Student t test)</th>
<th>r (Pearson product moment correlation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentric position of condyles, right side (mm)</td>
<td>1.28 (0.43)</td>
<td>2.38 (0.76)</td>
<td>-1.10</td>
<td>0.000</td>
<td>.311</td>
</tr>
<tr>
<td>Concentric position of condyles, left side (mm)</td>
<td>1.11 (0.47)</td>
<td>2.16 (0.70)</td>
<td>-1.05</td>
<td>0.000</td>
<td>.884</td>
</tr>
</tbody>
</table>

Data are expressed as mean (standard deviation).
by comparing the anterior and posterior articular spaces. The depth of the mandibular fossa can also be determined with this technique.

We found no statistically significant differences between the right and left sides for the anteroposterior and mediolateral dimensions of the condyles in the Class II Division 1 subjects. The lack of asymmetry in these measurements is similar to those reported elsewhere, in which the same methodology was applied for different types of malocclusions.17,25

In the assessment of the distance of condylar process/midsagittal plane, the \( P \) value was 0.019. Although there was a small difference between the averages (0.62 mm) regarding the values found and the correlation was significant between both sides, lower values on the left side were predominantly found. No occlusal characteristics in the sample could account for this asymmetry. Condyle position asymmetries are most frequently associated with functional deviations, and, in this case, such asymmetry is seen in the 3 planes of space. This finding differs from the characteristics of Class II Division 1 subdivision,17 Class I,25 and our Class III sample.

In the study of the angulation of the condylar processes in relation to the median sagittal plane, it was verified that, although there was no significant difference between the values for the right and left sides (\( P = 0.728 \)), the correlation between them was low (\( r = 0.195 \)). Using the same methodology in a Class I malocclusion sample, Rodrigues et al25 found the same characteristic—an angulation with no significant difference between the right and left sides—but with a low correlation between them.

The results showed no significant difference between the right and left sides for anterior (\( P = 0.051 \)) and superior (\( P = 0.051 \)) articular spaces. However, there was a statistically significant difference (\( P = 0.049 \)) between both sides for posterior articular space. Since sagittal evaluation showed no significant differences regarding condylar dimension and positioning, the asymmetry in the posterior articular space can be explained by the different dimensions of the mandibular fossae.

Although no significant difference was found between the right and left sides for anterior joint space,
the mean value obtained for the right side (1.28 mm) was greater than that for the left side (1.11 mm). Cohlmia et al.14 reported that the left condyle was more anteriorly positioned than the right in a sample of patients with malocclusion after comparing the anterior articular spaces of the right and left TMJs. According to these authors, this asymmetry could be related to normal cranial base asymmetries and side preferences during mastication. However, a simple comparison between the right and left articular spaces with sagittal examination does not provide sufficient information to conclude that 1 condyle is in a more anterior or posterior position than the other. This association should be assessed with axial images, because, when no positional or dimensional condylar asymmetry is found in this slice, the differences in articular spaces are associated with the dimension or the asymmetric positioning of the mandibular fossae.

The evaluation of condylar concentricity showed that both sides were characterized by nonconcentric positioning of the condyles; they were more anteriorly positioned in the mandibular fossa.

Our findings for the Class III subjects did not show statistically significant differences between the right and left condylar processes. The same characteristic found in samples of different malocclusions for the angulation of the condylar processes in relation to the median sagittal plane was also found in subjects with Class III malocclusion: no significant difference between the right and left sides, but low correlation between them.17,25

The results showed no significant difference between the right and left sides for anterior \( (P = 0.892) \), superior \( (P = 0.205) \), and posterior \( (P = 0.158) \) joint spaces. The correlation for anterior joint space was low, although the difference was not significant between sides.

Katsavrias and Halazonetis,3 studying structure characteristics of the TMJs in subjects with Class II and Class III malocclusions, concluded that the Class III group had an intermediate anteroposterior condylar position between that of Class I Division 1 and Class II Division 2 patients, but the condyle was closer to the fossa in the vertical direction. This characteristic was not observed in our study. The mean superior joint spaces in the Class II sample were 1.62 mm (right side) and 1.66 mm (left side). In the Class III sample, they were 1.86 mm (right side) and 1.64 mm (left side). The superior joint space on the right side was greater in the Class III sample.

The evaluation of condylar concentricity showed that both sides were characterized by nonconcentric positioning of the condyles. The values for the assessment of the concentric position of the condyles show that, in the Class II Division 1 sample, the lack of centralization is more relevant than in the Class III sample. In the Class II Division 1 group, the difference between the averages (anteroposterior joint space) was –1.10 mm for the right side and –1.05 mm for the left side.

In the Class III sample, these values were –0.95 mm for the right side and –0.76 mm for the left side. Rodrigues et al.25 in a Class I sample, found values of –0.58 mm for the right side and –0.43 mm for the left side, demonstrating that the condyles are more concentrically positioned than in Class II Division 1 and Class III samples. Vitral et al.16 observed, in a Class II Division 1 subdivision sample, values of –0.54 mm for the right side and –0.61 mm for the left side, showing greater concentricity than that of Class II Division 1.

In general, in the assessment of symmetries between the condyles, the results seem to confirm that occlusal features might be associated with TMJ structure remodeling to create symmetrical relationships, because dimensional and positional symmetries between the condyles are characteristics of different malocclusions.17,24-26 According to several studies, the lack of condyle centralization, with anterior joint spaces smaller than posterior joint spaces, is a common finding among the various malocclusions.3,12,15,16,25

CONCLUSIONS

In the Class II Division 1 malocclusion sample, the distance of condylar process/midsagittal plane and posterior articular space showed a statistically significant difference between the right and left sides. In the Class III sample, there was no statistically significant difference between the 2 sides.

Evaluation of the concentric position of the condyles in their respective mandibular fossae showed nonconcentric positioning for the right and left sides in both the Class II and Class III malocclusion groups.

REFERENCES

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