Mandibular condyle position: Comparison of articulator mountings and magnetic resonance imaging

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This study evaluated the reliability of jaw positions, the existence of distinct jaw positions, and condyle-disk-fossa relationships in a symptom-free population by using articulator mountings and magnetic resonance imaging (MRI). The subjects examined included 28 men, 22 to 35 years of age, all having Angle Class I molar relationships and no discernible TMJ dysfunction. Records taken included the following: an axiographic face-bow to locate retruded hinge axis position, an interocclusal registration of retruded position (RE), a series of interocclusal registrations for centric occlusion (CO), a leaf gauge-generated centric relation (CR), a series of interocclusal registrations for CR, and MRI. The mandibular position indicator of the SAM articulator (Great Lakes Orthodontics, Ltd., Tonawanda, N.Y.) was used to determine reliability and existence of distinct jaw positions. Magnetic resonance imaging also evaluated jaw positions and anatomic relationships. The results indicate: (1) The articulator analysis of CO and CR is statistically replicable. (2) A distinct jaw position could be demonstrated for CO that was separate from RE and CR. It was not possible to discriminate between RE and CR. (3) Condylar concentricity was observed in half of the sample and remained consistent in RE, CO, and CR. (4) Of the sample 13% demonstrated anteriorly displaced disks that were not influenced by posterior condyle placement. (5) The clinical concept of treating to CR as a preventive measure to improve disk-to-condyle relationships was not supported by this study. (Am J Orthod Dentofac Orthop 1993;104:230-9.)

One of the goals of orthodontic treatment is the establishment of a harmony between occlusal function and the temporomandibular joint (TMJ). However, conflicting claims are being made about occlusion and the role of orthodontics in this relationship. Many investigators think occlusion plays a primary role, and some evidence suggests that orthodontic correction of malocclusion can have a positive influence on TMJ health. Conversely, other studies contend that orthodontic therapy has a potential negative influence by contributing to symptoms of temporomandibular dysfunction (TMD), especially if it creates a discrepancy between centric occlusion (CO) and centric relation (CR). Still other findings indicate that occlusion or orthodontics has no correlation with the incidence of TMD. Since TMD most likely has a multifactorial origin, completely discounting the role of occlusion may be an inappropriate interpretation of published data. Condylar position is a major issue in studies of the TMJ. Occlusal disharmonies from preexisting malocclusions or orthodontic treatment have been reported to create an unphysiologic mandibular position that results in muscle hyperactivity, internal derangements, and pain dysfunction.

Many clinicians consider that an ideal occlusal relationship should be closely correlated to an ideal condyle-disk-fossa relationship, which they refer to as CR. To assess both condylar and occlusal relationships, the use of articulator-mounted models in centric relation is advocated for diagnosis and treatment planning. Theoretically, this technique allows placement of the mandible in a more physiologic position with fewer occlusal-generated condylar deflections from centric relation. The purpose of this study is to determine the reliability of a commonly used CR articulator mounting technique and then to determine the placement of the condyle in relation to the fossa and the disk with magnetic resonance imaging (MRI).
Although the definition of CR and its location remains controversial, the definition of CR has changed from a posterior to an anterior and superior position in the fossa. This position is considered to be the most reliable reference point for accurately recording the relationship of the mandible to the maxilla. As CR was accepted into other areas of dentistry, CR—the reference point became CR—the universal treatment position. However, to be meaningfully defined, CR must show uniqueness of position among other condylar relationships. It must be reproducible, and the imposition of the disk must be determined.

To better understand condyle and fossa positional relationships as reflected on articulators, the visualization of the TMJ is necessary. In contrast to transcranial radiographs and tomography, which are unable to reveal the relationship of the disk to the condyle and fossa, MRI can image the osseous, muscular, and fibrous components of the TMJ without ionizing radiation.

MATERIALS AND METHODS

Subject selection

By using the following criteria, 28 men between the ages of 23 to 34 years were selected to participate in this study: (1) full permanent dentition, except third molars, in an Angle Class I occlusion; and (2) no signs or symptoms of TMD as defined by a normal range of motion, no mandibular deviation on opening or closing, no history of TMD as established by a TMJ health history, and no pain in the prearticular and postarticular and temporal areas on palpation. Clicking in the absence of other symptoms did not exclude a subject from the study since joint sounds are common and may be caused by conditions other than internal derangements.

Records

To standardize technique, all records were taken by the same investigator. In addition to intraoral photographs and diagnostic plaster casts, each subject had another set of casts mounted on a SAM articulator with an axiograph face-bow. The hinge-axis position was established by manipulating the mandible to its most retruded position. The mandibular model was oriented with a fiberglass framework, zinc oxide and eugenol interocclusal record. This procedure was followed by three consecutive interocclusal registrations of CO (habitual bite or maximum intercuspation) and CR (leaf gauge technique of Williamson) with the fiberglass framework system. The leaf gauge is reported to allow the musculature of the subject to seat the condyles more superiorly on the posterior slope of the articulator eminence and to eliminate the operator-induced variability from manipulation. The series of CO and CR records were repeated two more times with a 3- to 7-day interval between each appointment.

The mandibular position indicator (MPI) of the SAM articulator was used to determine the reproducibility of CR. This instrument compares the position of the maxilla with the mandible and records any differences in the horizontal (X), transverse (Y), and vertical (Z) positions of the mandible. Horizontal and vertical dimensions are read in 0.5 mm increments, whereas transverse displacement of the mandible is measured in 0.1 mm increments from a gauge on the MPI. Thus the MPI can measure replicability and positional differences of CR and CO within the described accuracy of this instrument.

Acrylic interocclusal registrations of the most clinically reproducible positions of CO and CR for each patient were constructed. A third acrylic registration was constructed for each patient from the retruded position (RE). These registrations were used to transfer interocclusal relationships in a given jaw position from the articulated casts to the subject for MRI recordings. Since the imaging of the joint must be done in a supine position, the acrylic registration insured proper mandibular positioning.

Magnetic resonance imaging of the right and left temporomandibular joints was performed in CO, CR, and hinge axis positions with a General Electric signa system (GE, Milwaukee, Wis.). The subject’s head was oriented with cross laser reference lines and supported with surface coils and styrofoam packing during the imaging.

To measure the movement between the three jaw positions in the sagittal plane (X and Z positions), a 0.003-inch matte acetate superimposition was created by tracing reproducible structures from the image of the hinge axis that would superimpose on the images of CO and CR. The condyle was also traced from the hinge axis image by using the external or internal margins of cortical bone. To establish reference points for measurements, pin holes were made through the acetate and the image along the condylar head (four holes). The condyle was then transferred to the CO and CR images and was superimposed on the stable structures. The CO and CR images were marked with pin holes through the established holes of the acetate. The acetate was then superimposed on the condyle where the same process was repeated.

Once the reference points were transferred, the acetate could then be realigned on the stable structures of each image by matching the pin holes of the acetate and the image along the glenoid fossa. The condylar position was then marked on the acetate by locating the condylar pin holes with a tracing pen. Three different pen colors were used to allow distinction between the condylar movement of the three jaw positions. By using the hinge axis as a reference point, measurements in the X and Z axes were made. The images were also subjectively evaluated by two independent examiners to analyze the concentricity of the mandibular condyle to the fossa and the disk relationship to the condyle. Finally, data from the MPI articulator analysis were correlated with the data obtained from the MRI.

Statistical analysis

The reliability among measurements taken at time 1 (T₁) was calculated with correlation coefficients. The values for each dependent variable that were recorded at a single sitting were averaged such that each patient had one value for
Table I. MPI means and standard deviations (millimeters) for retruded, centric occlusion, and centric relations (n = 28)

<table>
<thead>
<tr>
<th>Plane</th>
<th>Statistic</th>
<th>Retruded</th>
<th>Centric occlusion</th>
<th>Centric relation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>( T_1 )</td>
<td>( T_2 )</td>
</tr>
<tr>
<td>Transverse (Y)</td>
<td>( \bar{X} )</td>
<td>0.70</td>
<td>0.02</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>1.39</td>
<td>0.80</td>
<td>0.73</td>
</tr>
<tr>
<td>Left vertical (Z)</td>
<td>( \bar{X} )</td>
<td>-0.02</td>
<td>0.24</td>
<td>0.23</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.37</td>
<td>0.44</td>
<td>0.42</td>
</tr>
<tr>
<td>Left horizontal (X)</td>
<td>( \bar{X} )</td>
<td>-0.07</td>
<td>0.26</td>
<td>0.29</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.40</td>
<td>0.36</td>
<td>0.41</td>
</tr>
<tr>
<td>Right vertical (Z)</td>
<td>( \bar{X} )</td>
<td>0.21</td>
<td>0.42</td>
<td>0.30</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.42</td>
<td>0.44</td>
<td>0.45</td>
</tr>
<tr>
<td>Right horizontal (X)</td>
<td>( \bar{X} )</td>
<td>0.00</td>
<td>0.10</td>
<td>0.14</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.38</td>
<td>0.29</td>
<td>0.32</td>
</tr>
</tbody>
</table>

Transverse plane at \( T_1 \): RE > CO (\( p < 0.05 \)).
Vertical plane at \( T_1 \): Left condyle, CO > CR and CO > RE (\( p < 0.05 \)); right condyle, (\( p < 0.05 \)).
Horizontal plane at \( T_1 \): Left condyle, CO > RE and CO > CR (\( p < 0.05 \)).

Table II. Alpha levels of reliability analysis among the time periods

<table>
<thead>
<tr>
<th>Jaw position</th>
<th>Transverse (Y)</th>
<th>Left vertical (Z)</th>
<th>Left horizontal (X)</th>
<th>Right vertical (Z)</th>
<th>Right horizontal (X)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO</td>
<td>0.87</td>
<td>0.95</td>
<td>0.88</td>
<td>0.94</td>
<td>0.93</td>
</tr>
<tr>
<td>CR</td>
<td>0.93</td>
<td>0.90</td>
<td>0.92</td>
<td>0.92</td>
<td>0.92</td>
</tr>
</tbody>
</table>

*Centric occlusion measurement at all three time periods.
Centric relation measurement at all three time periods.

each dependent variable and the patient was the unit of measurement.

Descriptive statistics were calculated for continuous variables and percentages or frequencies were calculated for categorical variables and ordinal data. Repeated measures analysis of variance with Tukey follow-ups were used to compare RE, CO, and CR at \( T_1 \) for MPI and MRI data for each plane and each side.

The validity of the MPI and the MRI was addressed by comparing data from these techniques with correlational coefficients. The Spearman's correlation coefficient was used to measure the reliability between evaluators of concentricity of the condyles. In the following analysis, only instances in which agreement occurred were used.

With the Friedman test, RE, CO, and CR were compared as to percent of superior condyle positioning, condyle concentricity, and anterior disk placement.

RESULTS

The results of the SAM articulator MPI records are presented in Table I. The means and standard deviations are listed for the three jaw positions, as recorded in the transverse (Y), vertical (Z), and horizontal (X) planes for the left and right TMJs. The Y is established at the left condyle with larger numbers indicating mandibular movement to the left. Table II is a reliability analysis of CO and CR at time 1 (\( T_1 \)), time 2 (\( T_2 \)), and time 3 (\( T_3 \)). Results revealed an alpha level of sufficient consistency between scores to confirm the reliability of \( T_1 \) and to base all other analyses from the \( T_1 \) results. Analysis of RE, CO, and CR at \( T_1 \) for the Y, Z, and X planes (Table I) indicated differences between the following jaw positions: in the Y axis RE > CO, in the Z axis CO > CR and CO > RE for the left condyle and CO > CR for the right condyle, and in the X axis CO > RE and CO > CR for the left condyle.

The means and standard deviations as established from the MRI for the sagittal planes can be seen in Figs. 1 and 2. Retruded position was used as a reference position for CO and CR measurements and therefore was not included in the graph. Significant differences were shown between the following jaw positions: in the Z axis CO > RE and CO > RE for the left condyle and CO > CR for the right condyle, and in the X axis CO > RE and CO > CR for the left condyle.

Validitv as documented by correlation coefficients showed a weak relationship between the MRI and the articulator, with significance only between Z right for CO (r = 0.37) and X right for CO (r = 0.55) at \( p < 0.05 \) (Table III). The MPI data was adjusted to RE for correlation with the MRI data.

The superior-most condylar position can be evalu-
Retruded Position Used as a Reference Point
Vertical Plane (Z)

![Graph showing jaw positions in the Z axis]

Jaw Position

Fig. 1. MRI comparison of jaw relationships in vertical plane.

Retruded Position Used as a Reference Point
Horizontal Plane (X)

![Graph showing jaw positions in the X axis]

Jaw Position

Fig. 2. MRI comparison of jaw relationships in horizontal plane.

ated by comparing condylar movement in the Z axis. To confirm the Z axis spatial relationship (Fig. 1), the distance from the most concave portion of the fossa to the most convex surface of the condyle was measured. Any of the three jaw positions can share the superior position if no measurable differences can be found between their vertical positioning. The percentages of superior condylar positions for right and left TMJs is
Retruded Centric Occlusion Jaw Position

Right Side N = 28, Left Side N = 26

Fig. 3. Superior condylar position.

Table III. Validity coefficient between MRI and articulator

<table>
<thead>
<tr>
<th></th>
<th>Left vertical (Z)</th>
<th>Left horizontal (X)</th>
<th>Right vertical (Z)</th>
<th>Right horizontal (X)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO</td>
<td>0.13</td>
<td>-0.18</td>
<td>0.37*</td>
<td>0.55*</td>
</tr>
<tr>
<td>CR</td>
<td>0.15</td>
<td>0.04</td>
<td>0.25</td>
<td>0.28</td>
</tr>
</tbody>
</table>

*p < 0.05.

Table IV. Reliability coefficients between two examiners for concentricity and disk placement

<table>
<thead>
<tr>
<th></th>
<th>Left</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RE</td>
<td>CO</td>
</tr>
<tr>
<td>Concentricity</td>
<td>0.93</td>
<td>0.92</td>
</tr>
<tr>
<td>Disk placement</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

*All values were significant (P < 0.001).

presented in Fig. 3. The Friedman test shows there is no significant difference between the three jaw positions with this evaluation.

Two independent clinicians completed a subjective evaluation of concentricity and disk placement. The reliability analysis between the two examiners showed a very high degree of correlation (Table IV). Figs. 4 and 5 show the distribution of condylar position (anterior, positive; posterior, negative) in relation to the three jaw positions. Fig. 6 shows the percent of anterior disk placement as it relates to the three jaw positions. A normal disk-to-condyle relationship is shown in Fig. 7, and an anteriorly displaced disk is shown in Fig. 8. No significant difference existed between the three jaw positions for concentricity or anterior disk placement.

**DISCUSSION**

**Reliability of jaw positions**

The two important jaw relationships examined for reliability were CO and CR. Retruded (RE) was included in the study as a reference for CR because of the implication found in the old and the new definitions
of CR that these positions should be different from each other. The results showed CO and CR to be reliable among tests.

**Positional relationships among RE, CO, and CR**

Positional relationships were analyzed by transverse (Y), vertical (Z), and horizontal (X) planes with the MPI. The sagittal (X and Z) plane was further analyzed by MRI. This procedure allowed a correlation of data between MPI and MRI in the sagittal plane.

The transverse (Y) plane recorded positive numbers for means showing jaw positions slightly to the left of the MPI center (Table I). This deviation from zero is not considered significant since manufacturers state that measurements of 0.4 mm or less are not accurate. A greater variation existed in the transverse plane than
was found in the sagittal planes. Such variation could be explained by the osseous asymmetry between right and left halves of the face and the cranium. This variation then cannot be directly compared with the variation found in the sagittal plane. The MPI data established that a significant difference existed between the jaw positions of RE and CO.

The MPI and MRI data were used to evaluate dis-
distinct jaw positions in the sagittal plane. The baseline or 0 value for the MPI means and standard deviations was established from the axiographic location of the hinge axis position. Therefore it would be expected that interocclusal registrations of RE should be close to the 0 value and that CO and CR would be further from the baseline if their positions were significantly different. The variability, as reflected by the standard deviations, shows approximately ±0.5 mm or less from the mean for MPI and also MRI values (Table I, Figs. 1 and 2). This range is satisfactory since measurements less than 0.5 mm were not discernible. These data suggests the existence of distinct jaw positions between CO and either RE or CR.

In the vertical (Z) plane CR is often described as the most superior position. Evaluation of the MPI data revealed that significant differences between jaw positions only existed between CO as compared with RE and CR for the left condyle, and CO as compared with CR for the right condyle (Table I). In all relationships, CO was positioned inferiorly to RE and CR. Evaluation of MRI data confirmed that CO was inferior in position when compared with RE and CR, but significance was only found between RE and CO for the left condyle (Fig. 1). The MRI data also illustrated the relationship of the condylar position in RE when referenced to the glenoid fossa (Fig. 3). Collectively considered, the data support the existence of a distinct jaw position for CO inferior to RE and CR.

In the horizontal (X) plane, the definitions and articles previously mentioned would support a CR position anterior to RE. Evaluation of the MPI data revealed CO to be positioned anteriorly to RE and CR on both the left and right sides. However, statistical significance was only found on the left side between CO and RE and between CO and CR (Table I). The MRI data also revealed that CO was positioned anteriorly to RE and CR but statistical significance was only found on the right side between CO and CR (Fig. 2). A collective evaluation of the data would suggest that CO was positioned anteriorly to RE and CR, but the MPI data failed to correlate statistically with the MRI data. These differences might be explained by the lack of a sharp demarcation of cortical bone on the MRI image that reduced the accuracy of the measurements. In addition, small measurements and large variations...
potentially create small changes in interpretation of MPI or MRI data that could greatly change statistical significance.

Combining vertical and horizontal axes of the sagittal plane allows further correlation of the data. The data of the present study provide evidence that CO is a distinct jaw position, separate from RE and CR. This finding is substantiated by a condylar position inferior and anterior to RE and CR. The data do not support distinct condylar positions for RE and CR and do not suggest that CO and CR are coincident. The latter is in contrast to what was previously described as the ideal relationship for a healthy TMJ.\(^{29,32,35}\) Possible reasons for these observations might be that a separation of RE and CR fails to exist, and CO and CR are not found coincident within the normal population. Conversely, RE and CR could be distinct jaw positions, but the leaf gauge does not establish CR, thus preventing coincidence with CO in the normal population.

**Condyle to fossa relationship**

The issue of diagnosis and treatment to different condylar relationships often focuses on the issue of concentricity. The present study shows that most persons within this population are concentric (Figs. 4 and 5). The distribution pattern of all three jaw positions supports the concept that a concentrically placed condyle represents the most common position in defining what is normal. It is important to note, that although this entire sample was selected from a normal population, approximately half of the condyles were not defined as being concentric. Further evaluation of the data revealed that approximately half of the patients did not change their condylar position in reference to the fossa for RE, CO, or CR. In other words, if the patient was concentric, anteriorly or posteriorly placed, they maintained that same classification for all three jaw relationships. Therefore diagnosis of the health of the TMJ on the basis of concentricity is not supported by the present data. Furthermore, changing the concentric, anterior, or posterior through manipulation status may not be possible in many cases.

**Disk-to-condyle relationship**

One of the most common problems affecting the TMJ is internal derangement, which includes the abnormal relationship of the articular disk relative to the mandibular condyle, the fossa, and the articular eminence. Of the 54 joints examined with MRI, 7 (13%) were diagnosed as having anterior disk placement. Although this result is less than the 32% reported by Kircos,\(^{17}\) it does confirm the presence of anterior disk placement in a symptom-free population.

In half of the anteriorly displaced disks observed in the present study, the condyle was posteriorly positioned. In the other half, the condyle was concentric or anteriorly positioned. This is in contrast to a previous report that indicated an anteriorly displaced disk was associated with a posterior condylar position (Figs. 7 and 8).\(^{48}\)

Two of the seven subjects with anteriorly displaced disks had joint sounds, and five subjects with normal disk relationships had joint sounds. This finding supports previous reports that, in the absence of other symptoms, joint sounds cannot be considered sufficient evidence of dysfunction.\(^5\)

**CONCLUSIONS**

1. The articulator analysis of CO and CR is statistically replicable.
2. Condylar concentricity was observed in half of the sample and remained consistent in RE, CO, and CR.
3. Of the sample 13% demonstrated anteriorly displaced disks that were not influenced by posterior condylar placement.
4. The clinical concept of treating to CR as a preventive measure to improve disk-to-condyle relationships was not supported by this study.

**REFERENCES**


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