Is There “A Best” Centric Relation Record? Centric Relation Records, Condyle Positions, and Their Practical Significance

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Purpose: To investigate if and how the positions of condyles in centric relation (CR) varied from each other using different CR records. Materials and Methods: Condylar positions in CR were repeatedly recorded by four licensed clinicians in 81 stomatognathically healthy, fully dentate subjects with six different types of CR records. The maxillary casts were mounted in articulators after individual facebow transfer, and the mandibular casts were mounted with a central bearing point (CBP) registration on the tip of the Gothic arch. Mean values from three registrations of the centric condylar positions with each of the six methods were calculated, and comparative calculations were made. Results: The median spatial distances of the condylar positions between the CBP and all other CR records was 0.73 ± 0.24 mm (0 to 3.19 mm). The median spatial values between the condylar positions of the different CR records ranged from 0.48 to 0.79 mm. Statistically, the positions of almost all types of registration were slightly different from each other. Conclusion: Different CR records reproduce slightly different positions of the mandible, which is especially true for CBP registration, whereas reproducibilities and SDs between registrations are similar. Unrefined wax-wafer registrations using bimanual manipulation have proven particularly successful with regard to precision and time requirements, as has CBP registration with regard to condylar position. Int J Prosthodont 2023;36:262–272. doi: 10.11607/ijp.7786

Centric relation (CR) records are used in fully dentate patients to record the CR of the mandible intraorally and to mount casts in an articulator. CR plays an essential and practical role for functional and occlusal analysis, fabrication of occlusal splints, and extensive prosthetic restoration of the stomatognathic system (ie, reconstruction of the mandibular posture in patients with a reduced number of supporting areas).

Indications for this dentally manipulated reference position of the mandible have been disputed for decades—there are different views on the aims and methodology of its definition, which are subject to constant change.1–11 The basic problems for practical implementation are, among others, that the desired “cranio-ventral, not laterally
displaced position of both condyles with physiological
condyle-discus relation and physiological stress on the
involved tissue structures\(^9\) cannot be made visible on the
patient, as the mandibular posture is not limited to hard
tissue, and only indirect control is possible.

Condylar positions obtained by using different CR
records are part of comprehensive study on mandible
postures and registrations, and the reproducibility of CR
and maximal intercuspal position (MIP), as well as the
distances between them, have previously been calculated
and published by the same author group.\(^{12-14}\)

The working hypotheses for this evaluation were that
different methods of recording CR would have an influ-
ence on the spatial condylar positions and that there
would be differences between these positions.

MATERIALS AND METHODS

Selection of the test group, production of the casts, the
exact course of the study, fabrication of the registrations
(Figs 1 and 2), and the electronic measuring device (Fig
3) have been previously described.\(^{12-14}\)

In the second session of the examination, the subjects
were seated in a dental treatment chair with the Camp-
er’s plane inclined about 30 degrees dorsally to the floor
and with the head leaning. After functional examination
of the stomatognathic system by extraoral palpation of
the masticatory muscles and wide jaw opening (painless
result required), the first interocclusal contact between
the maxillary and mandibular teeth arising in centric
occlusion was marked intraorally (Lauritzen grip.)\(^{15,16}\)
Individual centric hinge axes were determined with a mechanical SAM axiograph and always started registration of the CR with the intraoral central bearing point (CBP) method in order to mount the casts uniformly on the articulators. This was followed by recording of the neuromuscular position using tapping points and adduction (not the subject of this publication). All subsequent determinations of CR were prescribed for each practitioner in an alternating order determined at the beginning. The entire sample was shared by four licensed practitioners in a similar distribution (W.L.: n = 19; W.N.: n = 18; P.S.: n = 19; K.H.U.: n = 25). Six different registrations of the CR were performed in each subject three times each (n = 18 CR records per subject; approximately 3 hours of time per examination in the second session). Incisal rising of the jaws was measured by the CR records on the anterior teeth with a simple ruler.

The first step was to perform mandibular guidance (force: about 25 N) with support of the horizontal mandibular branches by means of the Lauritzen grip to adapt the different record wafers to the occlusal relief of the teeth. Care was taken to keep the leading forearm as close as possible to the median plane of the subjects. In the second step, tin foil, acrylic, and unrefined and refined wax wafers were refined with the practitioner standing behind the subjects using the Dawson grip (bimanual manipulation), having the subjects open their jaws very slightly and close them, quickly and repeatedly, under guidance so that the records could not change their position. These records were only ever accepted as finished when the subjects could no longer feel any differences between the right and left or dorsal and anterior sectors during a careful tactile closing movement and touch under bimanual manipulation and when they had even and simultaneous contact.

Only in the case of the CBP and the frontal jig were the materials allowed to cure with active jaw closure of the subjects and without further intervening of dental manipulation. All too deep occlusal impressions were cut back with a scalpel, and it was ensured that all records were swing-free and fit accurately on each cast (otherwise, the records were repeated). The following CR records were used (Fig 1):

1. CBP with half-sided plaster keys.
2. Neuromuscular records with CBP plates (in the context of discussion of the condylar position of the check-bite registrations in this publication, recording of the neuromuscular mandibular posture will not be discussed further).
3. Tin foil records (expectation of low shrinkage and good fit).
4. Acrylic wafer records (expectation of good suitability for dispatch).
5. Frontal jig with half-sided thermoplastic registrations (expectation of minimal bite raising and maintaining good vertical dimension).
6. Unrefined wax wafer records.
7. Refined wax wafer records (well adaptable to dentition, minimal fabrication time).

Evaluation
An average value was formed for each individual record from two readings per dial gauge after each assembly of the record-cast complex. This mean value defined the initial position of the condylar balls of the maxillary part of the measuring articulator for comparison of the records. The absolute values of the differences of measurement 1 minus measurement 2, measurement 2 minus measurement 3, and measurement 1 minus measurement 3 were then calculated. Each individual result is identical to the deviations of two CR records from each other. The reproducibility of a procedure then resulted from averaging these deviations over all subjects. The total spatial displacement (d) of the condylar spheres was calculated according to the following formula:

\[ d = \sqrt{2 \times (\text{sagittal})^2 + (\text{vertical})^2 + (\text{transversal})^2} \]

Evaluation of the measured values was done using SPSS software (IBM). Results that were greater than the mean of the sample plus four times the SD were excluded from the calculations of the final results. For statistically significant differences, the 5% significance level had to be reached (P < .05). Friedman test, Wilcoxon U test, and Kruskal-Wallis H test were used for comparisons between procedures, practitioners, and subject gender, depending on the indication.

RESULTS
Sample characteristics of the 81 fully dentate subjects have already been described. Only the registration-related rising of the jaws in the area of the incisors was on average 5 ± 1 mm (2 to 8 mm, Table 1). The time required for each registration (between 1 and 15 minutes) depended on the procedures, materials used, and subjects (Table 2).

On 64 casts mounted according to the CBP method, the first interocclusal contact between the maxillary and mandibular teeth after lowering the articulators’ incisal pin could be compared to the intraoral findings in centric occlusion:

- n = 16: intraoral and articulator contacts matched.
- n = 23: intraoral and articulator contacts matched, but there were additional contacts in the articulator.
- n = 25: intraoral and articulator contacts were different.
The reproducibilities of the CR records in the individual spatial directions are shown in Table 3. The spatial reproducibility was 0.43 ± 0.18 mm (0 to 2.13 mm) for the CBP registrations and 0.39 ± 0.11 mm (0 to 2.16 mm) for the other records. The median values were 0.34 mm for the CBP registrations and 0.31 mm for the other records combined (Table 4 and Fig 4).12

No statistically significant differences could be calculated between the patient genders, previously performed orthodontic treatments, Angle class, number of fillings, procedure, or material, which is also evident from the similar SD values. At the 0.5% level (P < .05), only the reproducibilities between the CBP and other records differed in the transversal direction. Consistently different record reproducibilities depending on the practitioner

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**Table 1** Increase in Vertical Relations (mm) in the Incisal Area

<table>
<thead>
<tr>
<th>Material</th>
<th>Mean ± SD</th>
<th>Median</th>
<th>Maximum</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBP (n = 80)</td>
<td>4 ± 1</td>
<td>4</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Tin foil (n = 80)</td>
<td>4 ± 1</td>
<td>4</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Acrylic wafers (n = 80)</td>
<td>5 ± 1</td>
<td>6</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Anterior jig (n = 81)</td>
<td>3 ± 1</td>
<td>3</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Unrefined wax wafer (n = 79)</td>
<td>5 ± 1</td>
<td>5</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Refined wax wafer (n = 81)</td>
<td>6 ± 1</td>
<td>6</td>
<td>9</td>
<td>5</td>
</tr>
</tbody>
</table>

**Table 2** Duration of Individual Registration Across All Practitioners

<table>
<thead>
<tr>
<th>Material</th>
<th>Mean ± SD</th>
<th>Median</th>
<th>Maximum</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBP (n = 80)</td>
<td>8 ± 3</td>
<td>8</td>
<td>15</td>
<td>2</td>
</tr>
<tr>
<td>Tin foil (n = 79)</td>
<td>6 ± 2</td>
<td>6</td>
<td>15</td>
<td>3</td>
</tr>
<tr>
<td>Acrylic wafers (n = 79)</td>
<td>6 ± 2</td>
<td>5</td>
<td>14</td>
<td>3</td>
</tr>
<tr>
<td>Anterior jig (n = 81)</td>
<td>6 ± 2</td>
<td>6</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Unrefined wax wafer (n = 78)</td>
<td>2 ± 1</td>
<td>2</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Refined wax wafer (n = 78)</td>
<td>5 ± 2</td>
<td>6</td>
<td>8</td>
<td>3</td>
</tr>
</tbody>
</table>

**Table 3** Reproducibilities (mm) of CR Records in the Individual Spatial Directions

<table>
<thead>
<tr>
<th>Spatial directions</th>
<th>CBP (n = 78)</th>
<th>Tin foil (n = 78)</th>
<th>Acrylic wafers (n = 79)</th>
<th>Anterior jig (n = 81)</th>
<th>Unrefined wax wafer (n = 77)</th>
<th>Refined wax wafer (n = 77)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sagittal</td>
<td>0.20 ± 0.17</td>
<td>0.21 ± 0.20</td>
<td>0.25 ± 0.22</td>
<td>0.24 ± 0.19</td>
<td>0.16 ± 0.16</td>
<td>0.20 ± 0.19</td>
</tr>
<tr>
<td>Vertical</td>
<td>0.23 ± 0.20</td>
<td>0.27 ± 0.25</td>
<td>0.30 ± 0.24</td>
<td>0.30 ± 0.28</td>
<td>0.20 ± 0.20</td>
<td>0.21 ± 0.20</td>
</tr>
<tr>
<td>Transversal</td>
<td>0.18 ± 0.18</td>
<td>0.11 ± 0.10</td>
<td>0.13 ± 0.12</td>
<td>0.13 ± 0.12</td>
<td>0.11 ± 0.12</td>
<td>0.11 ± 0.09</td>
</tr>
<tr>
<td>Left</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sagittal</td>
<td>0.22 ± 0.23</td>
<td>0.23 ± 0.20</td>
<td>0.22 ± 0.22</td>
<td>0.24 ± 0.22</td>
<td>0.18 ± 0.15</td>
<td>0.17 ± 0.14</td>
</tr>
<tr>
<td>Vertical</td>
<td>0.27 ± 0.27</td>
<td>0.27 ± 0.24</td>
<td>0.30 ± 0.29</td>
<td>0.26 ± 0.22</td>
<td>0.22 ± 0.20</td>
<td>0.21 ± 0.20</td>
</tr>
<tr>
<td>Transversal</td>
<td>0.19 ± 0.18</td>
<td>0.11 ± 0.10</td>
<td>0.13 ± 0.13</td>
<td>0.12 ± 0.11</td>
<td>0.11 ± 0.08</td>
<td>0.11 ± 0.10</td>
</tr>
</tbody>
</table>

Data are reported as mean ± SD across all practitioners.

**Table 4** Spatial Reproducibility (Total Spatial Displacements; mm) of the Centric Condylar Position Records Across All Clinicians

<table>
<thead>
<tr>
<th>Material</th>
<th>Mean ± SD</th>
<th>Median</th>
<th>Maximum</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBP (n = 78)</td>
<td>0.43 ± 0.18</td>
<td>0.34</td>
<td>2.13</td>
<td>0.02</td>
</tr>
<tr>
<td>Tin foil (n = 78)</td>
<td>0.40 ± 0.10</td>
<td>0.32</td>
<td>1.69</td>
<td>0.01</td>
</tr>
<tr>
<td>Acrylic wafers (n = 79)</td>
<td>0.44 ± 0.13</td>
<td>0.34</td>
<td>2.16</td>
<td>0.02</td>
</tr>
<tr>
<td>Anterior jig (n = 79)</td>
<td>0.43 ± 0.12</td>
<td>0.34</td>
<td>1.77</td>
<td>0.02</td>
</tr>
<tr>
<td>Unrefined wax wafer (n = 77)</td>
<td>0.33 ± 0.08</td>
<td>0.27</td>
<td>1.37</td>
<td>0.02</td>
</tr>
<tr>
<td>Refined wax wafer (n = 77)</td>
<td>0.34 ± 0.10</td>
<td>0.28</td>
<td>1.47</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Data are for the left and right sides combined.
Fig 4  Reproducibilities of the different types of CR records. Redrawn from Utz et al.12

Table 5 provides information on the relative positional differences in the individual spatial directions between the condylar positions achieved by the different registrations (CBP registrations as reference). These differences were significant in the sagittal and vertical directions at the 0.1% level compared to the CBP registrations (P < .01). Only the mandibular positions determined using the tin foil and acrylic wafer records were not statistically significantly different.

Table 6 shows the spatial position differences (total distance) between the condylar positions achieved by the different records (CBP registrations as reference). The median spatial values between the different condylar positions resulting from the different records were between 0.48 and 0.79 mm. The records with the frontal jigs were furthest from the CBP registrations on both sides. On average, the centric condylar positions of all other records deviated by 0.73 ± 0.24 mm (0.05 to 3.19 mm) from their positions with the CBP registrations.

In the graphical representations (Figs 5 to 7), the CBP registrations were placed in the center of the coordinate axes, and deviations of the unrefined wax wafer were arbitrarily used for comparison. Looking at the sagittal and horizontal planes, the centric condylar positions of the unrefined wax records were, on average, further dorsal and further caudal of the CBP registrations on both sides. The graphical representations for the other five records of centric condylar positions were similar in principle to the unrefined wax records graph.

were also unable to be determined. If statistical differences occurred in individual cases, they concerned different spatial directions that did not reveal any systematic tendencies.

The results of this study include all parameters associated with the registration process: impression-taking, cast and record fabrication, material properties of the records, record-cast mounting, biologic parameters, and practitioners. The results of this study are very reliable, as the resulting measurements for the interindividual comparisons of the positions are based on the mean values of three independent records, each of which was measured twice by reassembling the cast-registration complex. Four licensed dentists were involved in the procedures, and the sample was sufficiently large per practitioner. Therefore, the results do not only reflect the results of individuals.

However, the chosen experimental design does not allow for a direct comparison between the different practitioners because different subjects were examined in each case. The results published so far differ with regard to the influence of the practitioner.26–28 If the differences between practitioners are within the range of the measured values for repeatability of the records, an influence of the examiner can certainly be excluded. In any case, an influence of practitioner could be proven in earlier studies.27–29

A check with split-cast mounting and subsequent exclusion of “nonidentical” records before the measurements, in accordance with the recommended clinical procedure, would likely have reduced the extremely high values of reproducibility. However, because of the additional effort involved, it was decided not to perform this in the present study—with an exact procedure, occlusal discrepancies from approximately 0.1 mm onwards can become visible on a split-cast; however, the sensitivity of a split-cast check also depends significantly on the spatial placement of the casts in the articulator, in that the further anteriorly and caudally they are placed, the less sensitive the split-cast system becomes.30 This consideration led to use of median values for comparison.

The measured increase of the vertical arch relation due to the interocclusal records was on average 5 ± 1 mm in the incisal area. This was likely caused by the way the records were made, but especially by the participants being fully dentate and not allowed to have any antagonistic contacts during determination of the CR.31–34 Not surprisingly, the frontal jig produced the least vertical elevation: The thermoplastic frontal jig can be used like a leaf gauge,35,36 and with a little patience, a low, consistent contact can be achieved in the incisal area. This was likely caused by the way the records were made, but especially by the participants being fully dentate and not allowed to have any antagonistic contacts during determination of the CR.31–34 Not surprisingly, the frontal jig produced the least vertical elevation: The thermoplastic frontal jig can be used like a leaf gauge,35,36 and with a little patience, a low, controlled increase of the vertical relation can be achieved.

If the vertical relation in the articulator needs to be lowered by, for example, 4 mm after the mean-value mounting of casts with CR records, occlusal errors of approximately 0.6 mm or more can occur.37,38 However, since the interocclusal records in the present study all
had an increase in vertical relation, they varied by only 3 mm on average (see Table 2). As individual hinge axis points were used, this error is certainly negligible.

A fixed order of performing CR records could theoretically have had an effect on the reproducibility of the results, as it can be assumed that the subjects became more “practiced” with each subsequent registration. This problem was circumvented by always changing the order of the registrations in advance (with the exception of the CBP registrations).

Variations of the Centric Condylar Positions and Interpretations

The median reproducibility values of individual records between 0.27 and 0.34 mm (see Tables 3 and 4) and the consequences have been discussed previously.12 The reproducibilities of the different methods did not differ from each other in the present study, a finding that was highlighted by the similar SD values.11

The median distances of the centric condylar positions of the different methods from the CBP registration were larger values, between 0.52 and 0.81 mm (see Tables 5 and 6), but the ranges overlapped. Therefore, the null hypothesis that different CR registration procedures have an influence on the spatial condylar position was accepted. This has two major clinical consequences:

First, for clinical control of the first interocclusal contacts in CR, the Lauritzen grip is usually used. However, since the definitive registration may be carried out with other methods, this results in slightly different mandibular postures in the articulator. Therefore, contrary to popular belief, the corresponding contacts on the casts are not always and under every condition the same intraorally and in the articulator, a finding that was also found in the present study when mounting with the CBP method.39 If the same procedure is used for testing and registration, a match is more likely to be found. Of course, in addition to the type of mandibular guidance.

### Table 5

Positional Differences (mm) in CBP Registration Relative to the Other Tested Methods in the Individual Spatial Directions.

<table>
<thead>
<tr>
<th>Spatial direction</th>
<th>Tin foil (n = 75)</th>
<th>Acrylic wafers (n = 77)</th>
<th>Anterior jig (n = 76)</th>
<th>Unrefined wax wafer (n = 75)</th>
<th>Refined wax wafer (n = 75)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Right</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sagittal</td>
<td>0.35 ± 0.34,</td>
<td>0.29 ± 0.33,</td>
<td>0.56 ± 0.33*,</td>
<td>0.41 ± 0.39,</td>
<td>0.47 ± 0.31,</td>
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<td></td>
<td>dorsal</td>
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<td>dorsal</td>
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<td>dorsal</td>
</tr>
<tr>
<td>Vertical</td>
<td>0.27 ± 0.39,</td>
<td>0.23 ± 0.40,</td>
<td>0.63 ± 0.51*,</td>
<td>0.20 ± 0.48,</td>
<td>0.37 ± 0.42,</td>
</tr>
<tr>
<td></td>
<td>caudal</td>
<td>caudal</td>
<td>caudal</td>
<td>caudal</td>
<td>caudal</td>
</tr>
<tr>
<td>Transversal</td>
<td>0.02 ± 0.24,</td>
<td>0.01 ± 0.24,</td>
<td>0.02 ± 0.25,</td>
<td>0.02 ± 0.24,</td>
<td>0.01 ± 0.25,</td>
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<td></td>
<td>lateral</td>
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<td>lateral</td>
<td>lateral</td>
<td>lateral</td>
</tr>
<tr>
<td><strong>Left</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sagittal</td>
<td>0.34 ± 0.39,</td>
<td>0.31 ± 0.37,</td>
<td>0.54 ± 0.38*,</td>
<td>0.44 ± 0.39,</td>
<td>0.47 ± 0.36,</td>
</tr>
<tr>
<td></td>
<td>dorsal</td>
<td>dorsal</td>
<td>dorsal</td>
<td>dorsal</td>
<td>dorsal</td>
</tr>
<tr>
<td>Vertical</td>
<td>0.27 ± 0.38,</td>
<td>0.27 ± 0.47,</td>
<td>0.64 ± 0.48*,</td>
<td>0.25 ± 0.44,</td>
<td>0.38 ± 0.42,</td>
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<td></td>
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<td>caudal</td>
<td>caudal</td>
</tr>
<tr>
<td>Transversal</td>
<td>0.01 ± 0.23,</td>
<td>0.03 ± 0.24,</td>
<td>0.04 ± 0.24,</td>
<td>0.01 ± 0.23,</td>
<td>0.03 ± 0.23,</td>
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<td>lateral</td>
<td>lateral</td>
</tr>
</tbody>
</table>

The sagittal and vertical distances printed in bold are on average closest to the condylar positions of the CBP registrations. The records with a frontal jig resulted in a position that was on average the furthest dorsal and caudal compared to all other records (marked with *).

### Table 6

Spatial Position Differences of CR Registrations Relative to the CBP Methods Tested

<table>
<thead>
<tr>
<th></th>
<th>Tin foil (n = 75)</th>
<th>Acrylic wafers (n = 77)</th>
<th>Anterior jig (n = 76)</th>
<th>Unrefined wax wafer (n = 75)</th>
<th>Refined wax wafer (n = 75)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Right</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>0.61</td>
<td>0.60</td>
<td>0.92</td>
<td>0.68</td>
<td>0.73</td>
</tr>
<tr>
<td>SD</td>
<td>0.24</td>
<td>0.24</td>
<td>0.25</td>
<td>0.24</td>
<td>0.25</td>
</tr>
<tr>
<td>Median</td>
<td>0.48</td>
<td>0.56</td>
<td>0.83</td>
<td>0.59</td>
<td>0.69</td>
</tr>
<tr>
<td>Maximum</td>
<td>2.71</td>
<td>1.57</td>
<td>3.19</td>
<td>2.68</td>
<td>2.93</td>
</tr>
<tr>
<td><strong>Left</strong></td>
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<tr>
<td>Mean</td>
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<td>0.64</td>
<td>0.94</td>
<td>0.72</td>
<td>0.79</td>
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<tr>
<td>SD</td>
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<tr>
<td>Median</td>
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<td>0.55</td>
<td>0.79</td>
<td>0.70</td>
<td>0.76</td>
</tr>
<tr>
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<td>2.44</td>
<td>2.74</td>
<td>3.17</td>
<td>1.77</td>
<td>1.45</td>
</tr>
</tbody>
</table>
| **Right + left** | Mean             | 0.52                   | 0.56                 | 0.81                        | 0.65                      | 0.73

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and procedure, this also depends on the force used in guidance and the proximity of the individual interocclusal contacts of a jaw in CR.

Second, the slightly different CR records depending on the procedure mean that the choice of the type of record or measuring method also implies a choice in condylar position. Physiology and adaptation, reproducibility, control, time, and practicability are important factors in the dentist’s decision for or against a method.

The unrefined and refined wax wafers with the Dawson grip (bimanual manipulation) proved to be very good in terms of the time required and, to the authors’ surprise, also in terms of reproducibility (Table 2). This is advantageous because this material can be adapted to different dentitions more easily than other methods and because it is easier and quicker to produce several records, which is a clinical prerequisite for sorting out faulty registrations using the split-cast method. However, the wax must become as hard as possible after cooling; otherwise, it can “compress” during mounting of the casts.

On the other hand, all registrations with wafers, despite bimanual guidance and shaping, did not lead to the “upper and anterior” condylar position aspired to in theory today. Here, CBP registrations would be preferable as the only method, as they placed the condyle in a more anterior and cranial position than all other records by an average of approximately 0.5 mm, exactly what is theoretically aimed for. This is despite the fact that the mandible was guided during Gothic arch recording by means of the Lauritzen grip and coded over the tip of the Gothic arch (see Fig 2). This is not handled in the same way in different studies, which may explain the differing results.

Keying on the tip of the Gothic arch does not mean that this results in a “forced” mandibular posture; therefore, it is also not recommended to encode “behind” the arrow angle tip, as this is preset in some electronic procedures (in the intraoral pressure-dependent registration [IPR] or digital intraoral registration [DIR] systems) because then the condylar “play” toward the dorsal becomes too large. Incidentally, the clinical consequence is also that the practitioner can more frequently move the mandible into a slightly more dorsal position during the intraoral check of a restoration registered on the tip of the Gothic arch with the CBP method and finished in this way. In
extreme cases—at least with complete dentures—this can give the impression that the relation is fixed too far anteriorly. The minimum necessary increase in the vertical relation for registration does not differ in CBP registration from other methods, nor does its basic reproducibility.

However, in the present authors’ view, CBP registrations also have disadvantages compared to other methods presented here, for instance:

- Split-cast control (several drawings, but usually only one interocclusal record, and therefore no split-cast control).
- Adaptation of CBP plates to the different intraoral dental situations. It is important that the registration plates load each arch either only on the mucosa or only over the teeth in CR so that determination of the relation is stable. This problem has led the present authors’ clinic to use the system largely exclusively for complete dentures or similar situations (eg, several double crowns next to each other) and only rarely for purely fixed restorations.

Originally, it was assumed that the frontal jig method could have a similar effect as the CBP registrations, as the frontal jig is actually the same as a central-bearing pin in fully dentate persons and lies only slightly further anterior. This should automatically move the condyles into an upper position. However, the procedure obviously places the condyles in the most dorsal and caudal position on average compared to all other records, despite the existing muscle traction during curing. From this finding, it can be concluded that bimanual manipulation, but without a frontal jig, may indeed have some effect on a favorable condylar position.47

Comparison to the Literature
The present authors are not aware of any study that has validly measured and compared the condylar distances between multiple CR records. In any case, results in the literature concerning CR positions are contradictory. As far as accuracy and interpretability are concerned, radiologic and magnetic resonance imaging procedures for determining CR should be used with caution because of the three-dimensionality and the lack of reference points.48-54 All existing comparative results show that the condylar positions within a method and also between methods can vary.41,45-47,55-75

It is certainly indisputable that the type of manual guidance can influence the position of the mandible42,47,40 and that the materials of the records do not play the essential role they were previously thought to play.11

Adaptability of CR
The discussions as to whether it is “correct” and “physiologic” to build dentures in a mandibular posture guided by the practitioner and to “force” the patient into such a “nonphysiologic” posture seem as topical today as they were in the times of the first gnathologists.10,15,76-80 From the present authors’ point of view, practice is the decisive factor: depending on the number, position, and condition of the remaining teeth, and even the health of the stomatognathic system, it is no longer possible to adopt or maintain MIP (a prime case being the edentulous patient). In these cases, the mandible can only be assigned by determining CR or the neuromuscular position; there are no other comprehensible possibilities. Thus, the fundamental question arises as to whether CR is at all suitable as a restorative starting position. The following considerations may provide an answer:

- About 10% of people have centric occlusion; ie, CR and MIP coincide, and they function in CR. It is therefore a physiologic position that occurs in humans.14,71,81
- The spatial reproducibility of CR (0.3 to 0.4 mm) is lower than MIP (0.1 to 0.2 mm).12,13,82 Since restorations are built up in centric occlusion and one does not want to correct much occlusally during placement, registrations must be as precise as possible. From clinical experience and studies on stereognosis in complete dentures, it can be concluded that occlusal precision will facilitate adaptation.83 As stated by Celenza, “the precision of the position may be more important than the position itself.”84 The accuracy of CR is clinically sufficient if the disadvantages are considered; however, for this reason alone, the transfer of MIP for dentures will be preferred if this mandibular posture is actually indicated.
- The spatial distances of the CR from the MIP in the condylar area are on average approximately 0.86 ± 0.52 mm.14 These distances are slightly larger than the distances measured between the individual CR records (on average 0.73 ± 0.24 mm). This possibly describes an “adaptive condylar range” and is one reason why the different registration procedures can all be used in practice.11
- The positional differences of the condyles in both CR and MIP are surprisingly large and very individual. This means that the temporomandibular joints should not be thought of purely mechanically like an articulator; this is shown, among other things, when terminal fixed partial dentures are prepared and there is no interocclusal space left despite occlusal reduction.14
- As the gold standard in CR, occlusal splints are not only tolerated but can also eliminate pain85-88 or be used to test out a new mandibular posture. This is another indication of the physiology of a CR set under moderate guidance.
Dental practice has shown over decades that restorations in CR are well tolerated in patients with a full dentition and in edentulous patients, regardless of the registration procedures used. This shows, as do the occlusal splints, that the stomatognathic system is obviously adaptive.

Dentists and dental experts depend on an acceptably reproducible horizontal arch relation in order to be able to repeatedly check the occlusion in reconstructions of mandibular posture.

However, when using CR in patients, some important precautions must be taken according to the authors’ experience:

- Some practice is needed in guiding to this mandibular position.
- The most important part of making CR records—the determination of the occlusion—needs precise action.
- A small but ensured interocclusal space during registration (ie, no interocclusal contacts) is required.
- Three CR records are necessary for later checking of the matching with a split cast.
- If the vertical relation is increased, the use of a facebow may be quality assurance.
- In addition, a physiologically moderate guidance of the mandible cannot be avoided, because otherwise there is a risk of faulty registration. As soon as the arch is opened, the condyles will in many cases perform a protrusive movement at the same time. Of course, this also depends on the extent of the vertical anterior overbite.

Incidentally, after a restoration in CR, a re-emerging distance between CR and MIP occurs more frequently over the course of the following years, based on the authors’ own observations. Celenza also described corresponding experiences in 1979. This, in turn, is an indication that a small distance between CR and MIP, up to approximately 0.5 mm, must be considered physiologic.

CONCLUSIONS

For recording the centric condylar position, unrefined and refined wax wafers have proven themselves in terms of reproducibility, time, and handling in fully dentate individuals. With all methods, however, useful and similar results with a spatial repeatability of approximately 0.3 mm in the condylar area can be achieved.

Although the relative condylar positions differed between the individual methods by approximately 0.5 to 0.8 mm, these values overlapped with each other. Compared to all other records, the records with the frontal jig positioned the condyles furthest dorsally and caudally and are therefore less recommended. Only with the help of the CBP method can a condylar position be achieved that has, on average, a spatial distance approximately 0.7 mm further anterior and cranial to values with the usual interocclusal records. The CBP method is particularly suitable for the fabrication of complete dentures for several other reasons.

There is no single method or exclusive record for selecting a CR record in patients with a full dentition. For individual cases, the present authors always register a position from a whole range of possible postures and determine a point from this in the articulator as the starting point. Thus, a certain adaptation from the patient to the mandibular posture set in this way must always be expected.

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REFERENCES
Impact of Maxillofacial Growth on Implants Placed in Adults: A Narrative Review

To determine the effect of lifetime maxillofacial changes on dental implants placed in adults, analyze the clinical implications of these changes, identify prognostic factors, and offer possible solutions. The relationship between implant placement and maxillofacial changes, occurring during not only the active growth period but also the entire span of adulthood, has not been extensively examined. Vertical differences between implants and adjacent teeth due to the anklyotic behavior of the former might be observed at any age and endanger restoration biologically, functionally, and esthetically. Regarding interproximal contacts, firm contact loss may occur within a few months after restoration, resulting in food impaction. Many prognostic factors have been reported, but most do not exhibit a statistically significant association with implant infraocclusion and interproximal contact loss. Incorporation of alternative solutions, accurate treatment planning, strict recall protocols, and retrievability of implant-supported restorations can facilitate efficient management of complications. Maxillomandibular changes throughout adulthood may lead to complications such as implant infraocclusion and interproximal contact loss. Rehabilitation of edentulism should be characterized by well-designed and flexible treatment plans to resolve long-term complications efficiently. Further long-term clinical studies are needed to identify other risk factors. Treatment plans for implant therapy should be reconsidered for adults. Careful patient monitoring and early intervention are essential for securing treatment outcomes.