Re-evaluation of the Condylar Path as the Reference for Occlusion

Sumiya Hobo, Hisao Takayama

The condylar path is "the path traveled by the mandibular condyle in the temporomandibular joint during various mandibular movements." It is an accepted belief that good occlusion can be created in a restoration when the condylar path is reproduced precisely on an articulator. For this purpose gnathologists have used the pantograph and the fully adjustable articulator. There are, however, contrary opinions on such use of the condylar path.

Craddock reports that there is no correlation between the sagittal condylar paths, as measured by check bite, and the configuration of the condylar tubercle obtained by radiographs. Based on the literature review, Christensen and Slabbert assert that the posterior bony surface of the articular tubercle is never parallel with the more or less curvilinear or zigzag paths scribed as the sagittal condylar movements; further, they state that the sagittal condylar guidance angle is not a single and well-defined angle; rather a number of highly variable angles might exist.

Experienced clinicians often find the movement of the articulator is not coincident with the facets on the cast when an articulator is adjusted using condylar path measurements. Donegan and Christensen report there are differences between the measured value of the condylar path obtained by the check bite method (31 degrees) and by adjusting the articulator to match occlusal facets on the cast (24 degrees). The existence of a facet indicates the maxillary and mandibular teeth slide along an abraded surface. This phenomenon threw into question the value of measured condylar path.

If a measured sagittal condylar path is 40 degrees, the wax-up done on an articulator with this condylar path setting would produce a cusp angle of 40 degrees. Because the average sagittal cusp angle of natural teeth is about 25 degrees, a cusp angle of 40 degrees is too sharp and may result in a cuspal interference. Thus it is questionable whether precise reproduction of the condylar path on an articulator helps to produce good occlusion. The measurement and reproduction of the condylar path as the reference for occlusion, therefore, should be re-evaluated.

Deviation of the Condylar Path

McCollum recorded the condylar path of the patient using a pantograph and found it did not change either when the mandible was guided by cusps of the natural teeth or when clutches with various bearing pins were used. From this finding, he concluded the condylar path is a fixed factor that defies change; anterior guidance, on the other hand, can be changed freely by a dentist. This has been a basic gnathologic principle for years.

Beard and Clayton reported that when the condylar path is traced repeatedly on a pantograph, the tracing line deviates and the deviations among temporomandibular disorder (TMD) patients are larger than those in healthy individuals. Clark and Lynn used the Sophon Visiform (U.S. Shiazai, Los Angeles, Calif) as a measuring device for mandibular movement. They compared the incisal point path between "normal" patients and TMD patients. The results showed the TMD patients had larger discrepancies in the incisal path. From this, it was theorized that TMD patients show discrepancies in their condylar path tracings instead of smooth tracings.
Table 1  Maximum amounts of buffer spacing (mm)

<table>
<thead>
<tr>
<th></th>
<th>Protrusive</th>
<th>Nonworking side</th>
<th>Working side</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.8</td>
<td>0.8</td>
<td>0.3</td>
</tr>
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</table>

inferiorly and 0.1 mm long anteroposteriorly (Fig 1). From these data, the deviation of the working-side condylar path was assumed to be 0.3 mm maximum.

Hobo\(^{11}\) thought the condylar path deviations were “buffer spacing” which exists in the glenoid fossa (Table 1). Because the temporomandibular joint (TMJ) is subject to heavy mechanical stress, the buffer spacing allows condylar mobility and helps prevent transmission of direct stress to the articular eminence across the articular disk. If the buffer spacing does not exist and the condyle transmits heavy stresses, the disk would not be able withstand direct forces. Damage such as anterior disk displacement or a disk perforation would result.

Hansson et al\(^ {12}\) histologically examined the thickness of the soft tissue layers and the articular disk in the TMJ. They reported the soft tissue layers are thickest on the condyle superiorly, about 0.4 to 0.5 mm, and in the temporal component of the posteroinferior slope of the articular tubercle, about 0.5 mm; in the articular disk they are thickest posteri

These findings prove that the condylar path is not a fixed line, that it deviates.

### Eccentric and Returning Condylar Path

We measured mandibular movement using an electronic measuring system that allowed back-and-forth movement of the condylar paths. Differences were found between the eccentric and returning condylar paths.\(^ {13}\) When 17 healthy subjects,
Table 2 Width (mm) between the eccentric and returning condylar paths

<table>
<thead>
<tr>
<th>Path Type</th>
<th>Mean ± SD</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protrusive movement</td>
<td>0.44 ± 0.26</td>
<td>0.96</td>
</tr>
<tr>
<td>Lateral movement</td>
<td>0.79 ± 0.37</td>
<td>1.53</td>
</tr>
</tbody>
</table>

20 to 24 years of age, were examined further, this difference was consistent within each subject, with the returning condylar path always passing above the eccentric condylar path. Rarely did both paths superimpose. No single case was discovered in which the eccentric condylar path existed above the returning condylar path (Fig 2a).

The graphic data outputs of both condylar paths were examined. The width between the eccentric and returning condylar paths, measured at 2 mm from the maximum intercuspation, averaged 0.44 mm during protrusive movement and 0.79 mm during lateral movement (Table 2).

The eccentric and returning paths are not straight. An arc, drawn with a radius of 2 mm with the center of the condyle at maximum intercuspation, made two intersections on the path, one an eccentric path and the other a returning path. The angle formed by each line drawn from the center of the condyle to each intersection point and the horizontal reference plane was regarded as the sagittal inclination of the eccentric and returning condylar paths (Fig 2b). As a result, the difference between the sagittal inclinations of eccentric and returning condylar paths averaged 13 degrees during protrusive movement and 23 degrees upon nonworking-side lateral movement (Table 3).

The condylar path measured by use of a pantograph is an eccentric condylar path: the returning condylar path cannot be measured in daily practice. Utilizing the above data, we can approximate the returning condylar path of an individual patient by subtracting 13 degrees from the eccentric protru-
sive condylar path and 23 degrees from the lateral movement. These condylar paths are well matched to the cusp angle of molars.

The eccentric and returning condylar paths differ from the deviation of condylar paths when measured repeatedly, because these paths are created by the physiologic difference in muscles utilized. The muscles functioning during returning movement are the muscles that function during mastication. The eccentric movement is only its preparation. Therefore, the muscular force during returning movement should be stronger than the one during eccentric movement. The mobility of the soft connective tissue between the condyle and glenoid fossa may explain the variability of the condylar path. This is further evidence of the variability of the condylar path.

### Table 3 Comparison between sagittal condylar path inclinations of eccentric and returning paths (mm)

<table>
<thead>
<tr>
<th></th>
<th>Eccentric path</th>
<th>Returning path</th>
<th>Difference (mean)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Protrusive movement</td>
<td>40.1</td>
<td>13.8</td>
<td>27.4</td>
</tr>
<tr>
<td>Lateral movement</td>
<td>40.5</td>
<td>11.8</td>
<td>17.5</td>
</tr>
</tbody>
</table>

**Artificial Control of the Condylar Path**

Hobo\(^{14,15}\) found the average working-side condylar path (Bennett movement) moves straight outward on the terminal hinge axis and does not deviate within the sagittal plane. This suggests it is a natural occurrence for the working-side condyle to move to this direction as a healthy TMJ (Fig 3). Under the assumption that the working-side condyle translates straight outward along the terminal hinge axis, the imaginary lateral incisal path for each patient was computed mathematically using the mathematical model of mandibular movement and named as the neutral line.\(^16\)

It was clearly observed that when a patient’s lateral incisal path (canine guidance) deviated from the neutral line, the working-side condylar path deviated sagittally. In other words, when the lateral incisal path is positioned above the neutral line, the work-
Fig 3 Bird's-eye view of the motion of intercondylar axis. During lateral movements, the mandible rotates around a center of rotation and advances straight outward along the terminal hinge axis, together with the body of the mandible as a whole. (From Hobo S: An electronic mandibular movement measuring system: its principle and clinical applications. In: Restoration of the Partially Dentate Mouth. Bates et al (eds). Chicago: Quintessence 1984; 55-78. Used with permission.)

In this way, the sagittal deviation of the working-side condylar path shows a strong correlation with the deviation from the neutral line of the lateral incisal path. The correlation coefficient between the two deviations was 0.99 in the superoinferior direction and 0.97 in an anteroposterior direction (P = .001). This suggests the possibility that the working-side condylar path may deviate sagittally, as influenced by anterior guidance.

To verify this clinically, it was necessary to determine whether the working-side condylar path can be controlled by changing the anterior guidance. The subjects of this experiment were patients whose working-side condylar paths deviated more than 1 mm within the sagittal plane. The condylar paths of an arcon-type semiadjustable articulator on which the working-side condyle moves on the terminal hinge axis were adjusted using a patient's measured condylar path. The neutral line was converted mathematically to a computed value for the anterior guide table of an articulator.

Study casts mounted on the articulator were used to fabricate a resin guide table (Figs 5a to 5c). The
Fig 4 When the lateral incisal path is positioned above the neutral line, the working-side condylar path deviates superiorly. When the lateral incisal path is positioned under the neutral line, the working-side path deviates inferiorly. Solid line (condylar path) = measured working-side condylar path; solid line (incisal line) = measured lateral incisal path; dotted line (condylar path) = imaginary working-side condylar path which is supposed to deviate straight outward along the terminal hinge axis; dotted line (incisal path) = imaginary lateral incisal path – the neutral line computed for each patient under the assumption that the working-side condyle translates straight outward along the terminal hinge axis. (From Hobo et al: Osseointegration and Oral Rehabilitation. Tokyo: Quintessence 1990. Used with permission.)

Fig 5a Maxillary resin guide table used for the artificial control test of the working-side condylar path.

Fig 5b Mandibular resin guide pin (tip of a diameter = 2 mm) used for the artificial control test of the working-side condylar path.

Fig 5c The guide table and the guide pin are placed intraorally.
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Fig 6 Results of the artificial control test of the working-side condylar path obtained by measuring the lateral movement of the subject using electronic measuring system. Dotted line = measured data obtained when the maxillary and mandibular teeth slide in contact. Solid line = measured data obtained by placing resin guide table and guide pin in the subject's mouth and allowing the guide table and tip of the guide pin to slide in contact. (R) right lateral movement; (L) left lateral movement.

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Table 4  Influence of the condylar path on the amount of disocclusion (mm/degree)

<table>
<thead>
<tr>
<th></th>
<th>Sagittal protrusive inclination</th>
<th>Sagittal lateral inclination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protrusive movement</td>
<td>0.020</td>
<td>-</td>
</tr>
<tr>
<td>On nonworking side</td>
<td>-</td>
<td>0.015</td>
</tr>
<tr>
<td>On working side</td>
<td>-</td>
<td>-0.002</td>
</tr>
</tbody>
</table>

Table 5  Influence of the incisal path on the amount of disocclusion (mm/degree)

<table>
<thead>
<tr>
<th></th>
<th>Sagittal protrusive inclination</th>
<th>Anterior lateral inclination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protrusive movement</td>
<td>0.038</td>
<td>-</td>
</tr>
<tr>
<td>On nonworking side</td>
<td>-</td>
<td>0.042</td>
</tr>
<tr>
<td>On working side</td>
<td>-</td>
<td>0.038</td>
</tr>
</tbody>
</table>

the measured value of a patient's condylar path as a reference for occlusion has posed a crucial question.

Influence of the Condylar Path on Occlusion

The influence of the condylar path on the amount of disocclusion at the second molars was computed using the mathematical model of mandibular movement. The method used for this evaluation was as follows. The amount of disocclusion at the second molars during protrusive movement when the condyle moved 3 mm from centric relation was 1.0 mm. When the sagittal protrusive condylar path inclination decreased, it displaced the position of the cusp of the mandibular second molar in a superior direction by 0.020 mm per degree (Table 4). In the same manner, the rate of influence of the sagittal lateral condylar path inclination was computed. They were 0.015 mm on the nonworking side and -0.002 mm on the working side per degree.

To compare the influence of the condylar path on anterior guidance, the influence of the incisal path on the amount of disocclusion at the mandibular second molar was also computed. When the sagittal incisal path inclination decreases by one degree, the amount of disocclusion will decrease by 0.038 mm during protrusive movement. When the anterior lateral incisal path inclination decreases, the amount of disocclusion will decrease by 0.042 mm on the nonworking side and 0.038 mm on the working side during lateral movement (Table 5).

The above result was compared with that of the condylar path. The ratio of the influences of condylar and incisal paths was 1:2 during protrusive movement and 1:3 on the nonworking side and 1:4 on the working side during lateral movement (Figs 7a and 7b).

These results show that the influence of anterior guidance on disocclusion is much greater than the influence of the condylar path. The concept that anterior guidance is less important than the condylar path must be reversed.
Conclusion

The quality of measuring systems for mandibular movement has been drastically improved since the days of McCollum. For example, a mechanical pantograph cannot measure Bennett movement graphically and digitally, as is possible today. The accuracy of the mechanical pantograph was about 1.0 mm but electronic systems are capable of measuring to about 0.1 mm. Scientific data obtained through these systems are changing old concepts. Therefore, gnathology must progress accordingly.

Because the emphasis in gnathologic treatment has shifted from balanced occlusion to mutually protected occlusion, anterior guidance has gained importance. In order to reproduce mutually protected occlusion, it is necessary to give equal consideration to the three apices of the mandibular triangle. Reliance solely on the condylar path must change. Because the condylar path deviates greatly and the influence of the condylar path on occlusion is much smaller than that of anterior guidance, use of the condylar path as the reference for occlusion is questionable. However, this does not mean pantographic measurement of the condylar path is obsolete. The pantograph is an effective tool in the diagnosis and assessment of TMD and is considered essential for educational purposes.

During mandibular movement each apex of the mandibular triangle has two degrees of freedom for movement, for a total of six degrees of freedom. In order to obtain precise measurement, process the output data, and analyze the results, a computerization of the pantograph is indispensable. Since the mechanical pantograph lacks one apex, the anterior position, it is capable of measurement in only four degrees of freedom. The mechanical pantograph, therefore, is inadequate.

The next-generation pantographic system must be a total system capable of measuring eccentric movements.
and masticatory movements with six degrees of freedom under tooth-contact condition, measuring opening and closing movements in reference to a horizontal plane, centric relation, and vertical dimension, and at the same time, measuring muscle activity. The addition of computer graphics would be especially helpful in patient education.

References

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17. Hobo S, Takayama H: Analysis of cuspid guidance effect on the working side condyle path (In progress).

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