Comparison between the inclination of the sagittal condylar path obtained by the protrusive check bite method and that obtained using a six-degrees of freedom mandibular movement analyzing system.

II. Patients missing many teeth

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Conventionally, the protrusive check bite method has often been used clinically to measure inclination of the sagittal condylar path on an articulator. This method, however, involves several problems such as instability in determining the inclination. We assessed the ability of a digital six-degrees of freedom mandibular movement analyzing system to measure sagittal condylar path inclination, and compared the results with data generated using two other methods, the protrusive check bite method and the Gnatho-Hexagraph method. We found that the Gnatho-Hexagaph provided a useful means of measuring sagittal condylar path inclination in patients with a large number of missing teeth. We also found that use of the Gnatho-Hexagraph facilitated measurement of the sagittal condylar path inclination simply on the basis of the mouth-opening movement, without requiring measurements during anterior movement. This method is not affected by various problems known to be associated with the conventional protrusive check bite method. (J Osaka Dent Univ 2009; 43: 129–134)

Key words: Inclination of sagittal condylar path; Check bite; Gnatho-Hexagraph

INTRODUCTION

The protrusive check bite method is usually employed during clinical practice to determine inclination of the sagittal condylar path on an adjustable articulator. When used for individuals with dentures, however, this method has been reported to have several problems, such as inconsistent recordings caused by variations in compressibility at different locations in the supporting mucosa, and differences in adaptability of the alveolar ridge mucosa to forces on the denture.1,2 With these problems in mind, we studied the effectiveness of the digital six-degrees of freedom mandibular movement analyzing system (Gnatho-Hexagraph, Ono Sokki Co., Ltd., Kanagawa) that measures inclination of the sagittal condylar path, and compares the obtained data with that generated by the conventional protrusive check bite method in normal dentulous subjects. The comparison revealed that the Gnatho-Hexagraph is effective for measuring inclination of the sagittal condylar path of normal edentulous individuals if the kinematic axis point is utilized during measurements.3

However, it was still not known whether the sagittal condylar path inclination measured with the six-degrees of freedom mandibular movement analyzing system would be clinically useful in edentulous patients or in those with many missing teeth, in view of the influence of compressibility of the alveolar ridge mucosa and other factors. Therefore, we evaluated the clinical applicability of the Gnatho-Hexagraph as a means of determining the sagittal condylar path inclination during prosthetic treatment of edentulous patients and those with many missing teeth. We obtained data on inclination of the sagittal condylar path with the conventional protrusive check bite method and compared it with that ob-
tained using the Gnatho-Hexagraph in patients with many missing teeth and in patients with only the mandibular anterior teeth.

MATERIALS AND METHODS

Subjects
The study involved four patients who were edentulous except for the mandibular anterior teeth, and who were free of subjective and objective abnormalities in jaw function. They were selected from the outpatients visiting the Department of Geriatric Dentistry, Osaka Dental University Hospital, and had an average age of 79 ± 8 years.

Sagittal condylar path inclination measurements with the protrusive check bite method
An impression was taken with an individual tray in combination with hydrophilic vinyl silicone impression material (Examixfine, GC, Tokyo, Japan). Ultra-hard plaster was then used to make models of the upper and lower dentition. A V-shaped groove was formed on the basal plane to enable split casting. The articulator used was the condylar articulator Hanau H2-0 (Teledyne Hanau, New York, USA). After the occlusal registration plate was prepared and the occlusal relation obtained by conventional methods, the maxillary model was transferred onto the articulator with a special face bow. A gothic arch tracer for intraoral use (Sun Dental, Osaka, Japan) was then fixed on the maxillary and mandibular occlusal registration plates on the articulator. Before conducting the experiment, each subject practiced gothic arch tracing to verify the absence of any deviation in the horizontal jaw position.

When the protrusive check bite method was used, a plaster impression was taken with the mandible 5 mm forward of the apex of the gothic arch along the anterior movement path for each subject.4 The inclination of the sagittal condylar path was measured by split casting. In view of possible errors in measurement, the sagittal condylar path adjustment scale of the articulator was read 5 times for each occlusal registration to determine the inclination of the sagittal condylar path.

Sagittal condylar path inclination measurement with the six-degrees of freedom mandibular movement analyzing system
The Gnatho-Hexagraph JM-1000 (Ono Sokki, Kanagawa, Japan) was used for measurement of the sagittal condylar path inclination with a six-degrees of freedom mandibular movement analyzing system. The head frame for the Gnatho-Hexagraph was placed on each subject. A mandibular face bow was applied via an adhesive-attached clutch to the mandibular anterior teeth. During measurements, the maxillary and mandibular occlusal registration plates with fixed gothic arch tracer were retained in the oral cavity of each subject. The following mandibular motions were performed under continuous occlusal force.

1) The mandible was moved from the intercuspal position along the habitual mouth opening-closing path to maximum opening and then returned to the intercuspal position. This is the "mouth-opening movement".

2) The mandible was moved from the intercuspal to maximum anterior protrusion by sliding in contact along the tracing plate of the gothic arch tracer, and then returned to the intercuspal position. This is "anterior movement".

After they had adequately practiced the exercise, measurements were conducted five times in each subject. The condylar point used for measurement was the clinical condylar point determined by the examiner through palpation of the skin over the subject’s condyle. The points analyzed to determine the sagittal condylar path inclination were the starting point of condylar movement and the point with a Euclidean distance (U) of 5 mm over the condylar point motion pattern (U; U^2 = x^2 + y^2 + z^2; x; anterior component, y; horizontal component, z; vertical component).3

Statistical analysis
The Frankfurt horizontal plane served as the reference plane for analysis. In the statistical analysis of parameters, the t-test was employed for comparing the sagittal condylar path inclination, measured by the Gnatho-Hexagraph, between mouth-opening
and anterior movements. Multiple comparison (Tukey-Kramer test) was employed for comparison between the sagittal condylar path inclination measured with the protrusive check bite method and that measured with the Gnatho-Hexagraph.

RESULTS

Sagittal condylar path inclination measured with the protrusive check bite method

The mean inclination of the sagittal condylar path measured in all subjects by the protrusive check bite method, using the condylar articulator Hanau H 2-0, was 34.4±7.3 degrees relative to the Frankfurt horizontal plane (Table 1).

Sagittal condylar path inclination measured by the Gnatho-Hexagraph during mouth-opening and anterior movements

Figure 1 shows the data for the sagittal condylar path measured by the Gnatho-Hexagraph along a 5 mm excursion of the condylar point during mouth-opening movement and the data during anterior movement. The mean sagittal condylar path inclination in all subjects was 35.9±11.1 degrees during mouth-opening and 33.3±6.1 degrees during anterior movement. There was no significant difference between the sagittal condylar path obtained during mouth-opening and that obtained during anterior movements (p>0.05, t-test; Table 2-1).

Comparison between the sagittal condylar path inclination measured by the protrusive check bite method and that measured by the Gnatho-Hexagraph

Table 1 and Figure 1 compare the sagittal condylar path inclination measured using the protrusive check bite method with that measured using the Gnatho-Hexagraph along a 5 mm excursion of the condylar point during mouth-opening and anterior movement. Multiple comparisons using the Tukey-Kramer test at a significance level of 5% revealed no significant difference between the sagittal condylar path inclination measured by the protrusive check bite method and that measured by the Gnatho-Hexagraph during mouth-opening or anterior movement (Table 2-2).

Table 2-1 t-test results for comparison of the sagittal condylar path inclination during mouth-opening and anterior movements measured by the Gnatho-Hexagraph

<table>
<thead>
<tr>
<th>Mean Difference</th>
<th>d.f.</th>
<th>t-value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.552</td>
<td>39</td>
<td>0.929</td>
<td>0.3584</td>
</tr>
</tbody>
</table>

Table 2-2 Tukey-Kramer test results for comparison of the sagittal condylar path inclination during mouth-opening and anterior movements measured by the Gnatho-Hexagraph

<table>
<thead>
<tr>
<th>Source</th>
<th>d.f.</th>
<th>Sum of squares</th>
<th>Unbiased variance</th>
<th>F value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groupe</td>
<td>2</td>
<td>66.507</td>
<td>33.253</td>
<td>0.482</td>
<td>0.6201</td>
</tr>
<tr>
<td>Error</td>
<td>58</td>
<td>4003.334</td>
<td>69.023</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>60</td>
<td>4069.841</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 1 Inclination of the sagittal condylar path obtained by the protrusive check bite method and by the Gnatho-Hexagraph.
DISCUSSION

Experimental method
The check bite method\(^6\) is often used clinically as a relatively simple means of measuring sagittal condylar path inclination. However, this method has problems such as errors in measurement associated with manipulation and excessive play in the articulator's joint mechanism.\(^{1,2,6,7}\) These factors can markedly affect measurement of the sagittal condylar path inclination with this method. To minimize errors in measurement, the present study involved 5 sessions of measurements on the articulator conducted by the same examiner\(^5\) using the same check bite for each subject. When an optical, non-contact type, three-dimensional, six-degrees of freedom mandibular movement analyzing system is used for measurement of sagittal condylar path inclination, it is possible to avoid errors associated with such factors as occlusal recording materials, the examiner's skill level, and mechanical errors associated with the articulator.\(^8\)

In edentulous patients and those with few remaining teeth, the alveolar ridge mucosa may be compressed by occlusal forces during the use of dentures. It has been reported that although the sagittal condylar path inclination is closely associated with the anatomical morphology of the temporomandibular joint, in patients who use dentures, the inclination can be more effectively measured with the check bite method, which takes mucosal compression into account.\(^7,10\) We selected patients for this study who had only mandibular anterior teeth because this makes fixation of the face bow for the Gnatho-Hexagraph very convenient. We measured the sagittal condylar path inclination, taking into account the compression of alveolar ridge mucosa using the conventional check bite method, and compared the results with the sagittal condylar path inclination measured using the Gnatho-Hexagraph. This was done to evaluate the usefulness of the Gnatho-Hexagraph as a means of measuring sagittal condylar path inclination in edentulous patients and in those with few remaining teeth.

The authors previously analyzed the sagittal condylar path inclination in normal dentulous individuals, with the clinical condylar and kinematic axis points serving as reference.\(^3\) Although we attempted to estimate the kinematic axis point in advance, this was impossible because multiple attempts resulted in considerable variations caused by factors such as mobility of the bite plate. For this reason, the kinematic axis point was not adopted as the representative condylar point in this study. We only employed the clinical condylar point for measurement of the sagittal condylar path inclination.

Results

Sagittal condylar path inclination measured by the protrusive check bite method
The sagittal condylar path inclination measured by the protrusive check bite method was $34.4 \pm 7.3$ degrees relative to the Frankfurt horizontal plane. Gysi\(^9\) reported that the average sagittal condylar path inclination of dentulous subjects, measured relative to the occlusal plane, was 33 degrees. Lunden et al.\(^12\) reported the same parameter in dentulous individuals to be about 40 degrees relative to the Frankfurt horizontal plane. Miyachi et al.,\(^13\) who used the condylar articulator Hanau H 2, reported that the average sagittal condylar path inclination relative to the Frankfurt horizontal plane was 30.0 degrees in fully edentulous patients and 29.3% in patients with no maxillary teeth. Our results are essentially the same as those reported by these investigators. We previously found that the sagittal condylar path inclination relative to the Frankfurt horizontal plane in dentulous individuals averaged $50.9 \pm 13.1$ degrees.\(^7\) The sagittal condylar path inclination measured with the protrusive check bite method in the present study was smaller than the inclination that we previously reported. This discrepancy may be attributable to the fact that the subjects in the present study were older (79±8 years). Age-related flattening of the condyle and the condylar path results in a decrease in the sagittal condylar path inclination.\(^14\)
Comparison of sagittal condylar path inclination measured by the Gnatho-Hexagraph during mouth-opening and during anterior movements

When the sagittal condylar path inclination is measured in edentulous patients and in those with many missing teeth, the protrusive check bite is usually taken at a point 5 mm anterior to the intercuspal position. Therefore, we measured the sagittal condylar path inclination with the Gnatho-Hexagraph at a point 5 mm anterior to the condylar point.

In our previous study involving analysis of the sagittal condylar path inclination measured with the Gnatho-Hexagraph in dentulous individuals, the inclination during mouth-opening movement did not differ significantly from that during anterior movement when the kinematic axis point served as the representative condylar point. However, in the same study, there was a significant difference between the sagittal condylar path inclination during mouth-opening and that during anterior movements when the clinical condylar point served as a representative of the condylar point.

We measured the sagittal condylar path inclination with the clinical condylar point serving as the representative condylar point. The average of this parameter in all subjects was slightly greater during mouth-opening than during anterior movements, although this difference was not significant. This difference may be explained as follows. During mouth-opening movement in normal dentulous individuals, the condyle rotates around the hinge axis and then moves in the antero-inferior direction while tracing a slightly more marked S-shaped curve as compared to the curve depicted during anterior movement. For this reason, when a condylar point slightly off-center of condylar rotation is selected as the representative condylar point for measurements, the trace of the condyle during mouth-opening movement markedly differs from that during anterior movement, resulting in a different sagittal condylar path inclination. However, in elderly patients who have many missing teeth, the influence of the deviation of the representative condylar point from the center of condylar rotation is smaller, possibly resulting in the lack of a marked difference in the condylar path between mouth-opening and anterior movements.

Comparison between the sagittal condylar path inclination measured with the protrusive check bite method and that measured with the Gnatho-Hexagraph

In the present study involving patients with many missing teeth, a bite plate with a fixed gothic arch tracer was placed in the oral cavity of each subject, and the sagittal condylar path inclination was measured during the test movement while occlusal force was applied to the alveolar ridge mucosa. During anterior movement, occlusal force remains applied to the maxillary and mandibular occlusal registration plates throughout the contact sliding process, from the intercuspal position to the most anterior occlusal position, along the tracing plate of the gothic arch tracer and during the subsequent return to the intercuspal position. The sagittal condylar path inclination measured during anterior movement includes the inclination attributable to compression of the alveolar ridge mucosa. However, during mouth-opening movement, although occlusal force is present in the intercuspal position, the occlusal registration plate is freed from occlusal force when the mouth-opening movement begins. The alveolar ridge mucosa remains uncompressed until the intercuspal position is restored. For this reason, the sagittal condylar path inclination at a point after a 5 mm excursion does not include inclination arising from compression of the alveolar ridge mucosa.

In the present study, the sagittal condylar path inclination measured by the protrusive check bite method, which included compression of alveolar ridge mucosa, did not differ significantly from that measured with the Gnatho-Hexagraph during anterior movement, which included compression of the alveolar ridge mucosa. Furthermore, the former did not differ significantly from the sagittal condylar path inclination measured by the Gnatho-Hexagraph during mouth-opening movement, which did not include any inclination arising from compression of alveolar ridge mucosa.
These results indicate that in patients with few remaining teeth, the sagittal condylar path inclination measured by the Gnatho-Hexagraph is comparable to that measured with the protrusive check bite method, even when the inclination is measured during mouth-opening movement. Assuming that the conventional protrusive check bite method is clinically useful as a means of measuring the sagittal condylar path inclination, we may say that the Gnatho-Hexagraph is also useful as a means of measuring the sagittal condylar path inclination in patients with few remaining teeth. This is because this method allows the effective recording of the jaw position and facilitates measurement of sagittal condylar path inclination simply based on mouth-opening movement, even in elderly denture users in whom anterior movement of the mandible is difficult. Also, the Gnatho-Hexagraph is not affected by the various problems known to be associated with the conventional protrusive check bite method.

CONCLUSION

Data obtained by the protrusive check bite method was compared with that generated by the Gnatho-Hexagraph in four patients who were edentulous except for the mandibular anterior teeth, and who were free of subjective and objective abnormalities in jaw function. We found that the mean inclination of the sagittal condylar path measured with the protrusive check bite method was 34.4°±7.3 degrees relative to the Frankfurt horizontal plane. The sagittal condylar path inclination measured by the Gnatho-Hexagraph during mouth-opening did not differ significantly from that obtained during anterior movement. Also, the sagittal condylar path inclination measured by the protrusive check bite method did not differ significantly from that measured by the Gnatho-Hexagraph during mouth-opening or anterior movement.

These results indicate that the Gnatho-Hexagraph provides a valid means of measuring sagittal condylar path inclination in patients with few remaining teeth. The results additionally suggest that use of the Gnatho-Hexagraph allows straightforward measurement of sagittal condylar path inclination simply on the basis of the mouth-opening movement, without requiring measurement during anterior movement. For this reason it is not affected by the various problems known to be associated with the conventional protrusive check bite method.

REFERENCES

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