Comparative Analysis of Condylar Guidance Angle Obtained by Protrusive Interocclusal Records and Radiographic Methods in Edentulous Patients: An In Vivo Study

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Abstract

Purpose To compare between values of condylar inclination obtained by protrusive interocclusal records using extraoral Gothic arch tracing with cone-beam computed tomography (CBCT) scan, and cephalometric and panoramic radiographs in edentulous patients.

Materials and Methods Horizontal condylar guidance angle (HCGA) was measured using the extraoral Gothic arch tracing, CBCT, lateral cephalogram, and orthopantomogram (OPG) in 20 patients aged between 40 and 75 years. HCGAs were determined clinically using protrusive interocclusal records and semi-adjustable articulator after extraoral Gothic arch tracing. Radiographically, Frankfort horizontal plane was marked and a straight line joining the superior-most point and the inferior-most point of posterior slope of the articular eminence (AE) was drawn till the two lines met at an intersection. The angle at this intersection depicted the AE inclination and the angle was measured. Statistical analysis was done using analysis of variance test, multiple comparison was done using Tukey test, and the Pearson correlation coefficient was compiled for different study parameters.

Result A significant difference in condylar guidance was observed among different methods (p-value < 0.05), and significant positive correlations were observed among condylar guidance measured using distinct parameters.

Conclusion It was concluded that horizontal condylar guidance (HCG) values with the radiographic technique were higher than the clinical method. It was observed that mean HCG values were higher by 6.4 degrees in CBCT, 6.7 degrees in OPG, and 9.9 degrees in lateral cephalogram as compared with the clinical value. It was also observed that there was a variation of condylar guidance up to 5 degrees between right and left sides.
Introduction

For better prognosis of prosthodontic rehabilitation, prosthesis must be in consonance with stomatognathic system. In the whole stomatognathic system, the mandible moves independently. All the movements of the jaw are possible primarily because of the two joints working together in synchronisation to achieve maximum functions. The temporo-mandibular joints (TMJs) work together in unison to make movements such as speech, swallowing, and mastication possible. The opening and closing axes of movement of mandible of patient must be same as that of articulator.1

In edentulous patients, the articulator is programmed for the condylar guidance after recording the protrusive record to simulate the mandibular movements for better health and function of the stomatognathic system.2

The angle traversed by the condyle in the articular eminence (AE) is similar to mechanical form located in the posterior region of an articulator that controls its movements.3 The angle formed by the condyle to the horizontal reference plane is referred to as the condylar guidance. This angle differs from patient to patient and also on both sides.4 Failure to record proper condylar guidance leads to occlusal discrepancies that take more time to correct. These lead to patient’s dissatisfaction.5 If the condylar guidance is too steep or flat, it leads to gross inaccuracies in occlusion.6

The patient is trained to give Gothic arch tracing, and centric and protrusive interocclusal records are made commonly. The graphic registering technique is recommended to verify the centric relation and to record the condylar guidance.7 The condylar guidance is adjusted with protrusive record on semi-adjustable articulator that is comparable to inclination of the patient’s TMJ articulation.8 Sources of errors can arise in clinical methods due to unstable record bases, lack of neuromuscular coordination in patient, inappropriate clinical procedures, inaccuracies arising during transfer to records from patient’s mouth to articulator, and improper programming of semi-adjustable articulator.9

To eliminate these errors, radiographic methods that are simpler like panoramic, lateral cephalograms and cone-beam computed tomography (CBCT) can be used where angles can directly be traced.10

Condylar guidance can be recorded more accurately by radiographic methods, as has been proved in literature,11 but which method is best has not been proved. There is difference between orthopantomogram (OPG) and CBCT. OPG provides two-dimensional images with less radiation and more superimposition as compared with CBCT, which provides three-dimensional images with more radiation exposure and less superimposition.12

The present study was conducted to compare the condylar guidance angles measured on HANAU Wide-Vue Articulator using protrusive interocclusal records and extraoral Gothic arch tracing, with the values obtained by tracing the Frankfort horizontal plane and the most superior and inferior points of glenoid fossa and AE in radiographic images.

Materials and Methods

To conduct the present in vivo study, a total of 20 completely edentulous patients (n = 20) were selected in the Department of Prosthodontics. The procedure was explained to the patients and those who agreed to be part of the study were incorporated with written patient consent.

Patients aged 40 to 70 years, with good mandibular and maxillary ridges, no systemic diseases, normal TMJ, and with good neuromuscular control were selected. Patients with bone loss, mental and psychological challenges, and TMJ pain were not included in the study.

After the patients were selected, horizontal condylar guidance angle (HCGA) was calculated using four methods: extraoral Gothic arch tracing, CBCT, panoramic radiograph, and lateral cephalogram.

Maxillary occlusal rim was mounted with self-centered spring face bow and mandibular occlusal rim was mounted with tentative centric relation on semi-adjustable articulator (HANAU Wide-Vue, California, United States). Extraoral tracers were attached to the respective occlusal rims (∆ Fig. 1). A sharp arrow point Gothic arch tracing was obtained. Centric record was verified and programming of the semi-adjustable articulator was done with the protrusive interocclusal records to obtain the HCGA (∆ Fig. 2).

To record horizontal condylar guidance (HCG) through radiographic methods, CBCT, OPG, and lateral cephalographs were recorded. The scan was done for each patient and radiographic analysis was done for all the three radiographic methods.

CBCT scans were done for each patient with the CBCT unit (Genoray Papaya 3D Plus, Kerala, India) with field of view 16 × 14 at 90 kVp, 5 mA, and 29 seconds of exposure. For lateral cephalogram, exposure parameters were set to the standard of 75 kVp, 20 mA, and exposure time of 1 second on the panoramic machine (ADVAPLEX-DENTOPAN-10 and INX-PAN, Jaipur, India), and for OPG, exposure parameters were set to the standard of 80 kVp, 20 mA, and exposure time of 14 seconds on the panoramic machine (ADVAPLEX-DENTOPAN-10 and INX-PAN, Jaipur, India).

To record HCGA, Frankfort horizontal plane was marked with the help of the two points, viz., the superior-most point on the porion (P) and the inferior-most point of the orbitale (O). After this, the superior-most point and the inferior-most point of posterior slope of the AE were marked. Then a straight line joining these two points was drawn till the two lines met at an intersection. The angle at this intersection depicted the AE inclination, and the angle was measured. This angle was referred to as the HCGA (∆ Figs. 3–5). In total, 140 readings were recorded from 20 patients by calculating HCGA using four methods. Collected data were entered into Microsoft Excel 2016. The statistical analysis was done using SPSS 23.0. Descriptive statistics were compiled. Overall comparison was made using analysis of variance test and multiple comparison was done using Tukey test. The Pearson correlation coefficient was compiled for different study parameters. The level of significance was set at p-value ≤ 0.05.
Results

A significant difference in condylar guidance was observed among different methods (p-value < 0.05). Significant positive correlations were observed among condylar guidance measured using distinct parameters.

The mean HCG by interocclusal method was 27.75 and 27.25 degrees on the right side and left side, respectively, but panoramic radiograph showed 35.05 and 33.35 degrees on the right and left sides, respectively (Tables 1 and 2 and Figs. 6 and 7), with a lesser mean difference of 0.50 degrees with interocclusal record and 0.70 degrees with panoramic radiograph between right and left sides, as shown in the present study. This is also suggested in literature that the right and left eminences have different contours, and slopes. The mean total HCG values obtained from protrusive interocclusal record and lateral cephalogram were 27.50 and 37.40 degrees, respectively (Table 3 and Fig. 8).

The mean HCG values obtained using the CBCT method was 33.95 and 33.85 degrees on the right and left sides, respectively (Tables 4 and 5). The mean total HCGAs
Fig. 4  Lateral cephalogram scan and horizontal condylar guidance angle on lateral cephalogram.

Table 1  Comparison of condylar guidance on right side using different methods (using ANOVA)

<table>
<thead>
<tr>
<th>Method</th>
<th>Mean</th>
<th>SD</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Median</th>
<th>F</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral cephalogram</td>
<td>37.40</td>
<td>4.63</td>
<td>30.00</td>
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<td>37.00</td>
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<td>45.00</td>
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<td>25.00</td>
<td>45.00</td>
<td>32.00</td>
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<td>Clinical</td>
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<td>20.00</td>
<td>45.00</td>
<td>25.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: ANOVA, analysis of variance; CBCT, cone-beam computed tomography; OPG, orthopantomogram; SD, standard deviation.

Fig. 5  Orthopantomogram (OPG) scan and horizontal condylar guidance angle on OPG.

Comparative Analysis of CGA Obtained by Protrusive Interocclusal Records and Radiographic Methods  Verma et al.

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obtained from protrusive interocclusal record and CBCT were 27.50 and 33.90 degrees, respectively (►Table 3), and the mean total HCG difference between CBCT method and protrusive interocclusal records was 6.4 degrees (►Table 6). It was drawn that HCG values with the radiographic technique were higher than the clinical method.

**Discussion**

“The inclination of the condylar guidance or condylar inclination is a definite, anatomical conception”—Hanau (page 13).13 The condyle path inclination must be determined in relation to the cranial plane or a line of reference. The condylar angle is relative and it is easy to use the Frankfort horizontal reference plane with face bow, so the protrusive record method is the most practical method to record the condylar path angle. The recording of condylar path in each individual is necessary because of reported variations in the condylar paths of different subjects and frequently on opposite sides of the same person.14

As suggested by Isberg and Westesson,15 condylar path is related to steepness of AE. There is active role of soft tissues during various condylar movements. In the present study, centric and protrusive interocclusal records were made with impression plaster, which is most dimensionally stable and accurate material as recommended by Rothstein.16

To calculate HCGA, precise expertise and experience of the operator is required as it takes multiple clinical steps. Thus, many clinicians avoid these procedures and take average value (i.e., 33 degrees) as it varies from 22 to 65 degrees.17

The HANAU Wide-Vue Articulator was programmed by the protrusive interocclusal record.18 Self-centered spring bow was used to record Frankfort’s horizontal plane. This plane was also traced on a panoramic and cephalometric radiograph by joining the porion and the orbitale. Three-dimensional computed tomography (CT) images outlined the AE and glenoid fossae in 20 subjects.

The average HCG by protrusive method in the present study ranged from 17 to 43 degrees, whereas panoramic radiographs, lateral cephalogram, and CBCT ranged from 26 to 41 degrees, 30 to 45 degrees, and 25 to 43 degrees, respectively (►Table 6). Same observations were given by Zamacona et al where HCG ranged from 5 to 55 degrees.19
The mean total HCG difference between two methods was 6.7 degrees, which is comparable to Gilboa et al\(^6\) (7 degrees), Tannamala et al (4 degrees) and Kumari et al (13 degrees). These differences may be due to overlapping of the outlines of mandibular notch, coronoid process, and zygomatic arch in an OPG.\(^2,20\)

The mean total HCG values were found to be higher (9.90) in radiographic method than clinical method as also studied by Paul et al\(^10\) as they found approximately 11 degrees but differed from the findings of Galagali et al\(^8\) where they found that panoramic radiographs showed a higher HCG value than that of lateral cephalogram. The authors used two lateral

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**Table 4** Multiple comparison of clinical condylar guidance on right side with other methods (using Tukey test)

<table>
<thead>
<tr>
<th>(I) Group</th>
<th>(J) Group</th>
<th>Mean difference (I–J)</th>
<th>Standard error</th>
<th>p-Value</th>
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</thead>
<tbody>
<tr>
<td>Clinical</td>
<td>Lateral cephalogram</td>
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<td>0.000</td>
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<td>CBCT</td>
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<td>0.007</td>
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</table>

*Abbreviations: CBCT, cone-beam computed tomography; OPG, orthopantomogram.*

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**Table 5** Multiple comparison of clinical condylar guidance on left side with other methods (using Tukey test)

<table>
<thead>
<tr>
<th>(I) Group</th>
<th>(J) Group</th>
<th>Mean difference (I–J)</th>
<th>Standard error</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Clinical</td>
<td>CBCT</td>
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<td>1.85729</td>
<td>0.004</td>
</tr>
</tbody>
</table>

*Abbreviations: CBCT, cone-beam computed tomography; OPG, orthopantomogram.*

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**Table 6** Multiple comparison of clinical total condylar guidance with other methods (using Tukey test)

<table>
<thead>
<tr>
<th>(I) Group</th>
<th>(J) Group</th>
<th>Mean difference (I–J)</th>
<th>Standard error</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical</td>
<td>Lateral cephalogram</td>
<td>9.90000</td>
<td>1.79813</td>
<td>0.000</td>
</tr>
<tr>
<td>Clinical</td>
<td>OPG</td>
<td>6.70000</td>
<td>1.79813</td>
<td>0.002</td>
</tr>
<tr>
<td>Clinical</td>
<td>CBCT</td>
<td>6.40000</td>
<td>1.79813</td>
<td>0.004</td>
</tr>
</tbody>
</table>

*Abbreviations: CBCT, cone-beam computed tomography; OPG, orthopantomogram.*
cephalograms of either side in dentulous population, while the present study attempted the tracings on lateral cephalograms that showed overlapping of the right and left sides as the sensor was present only in the right side.

The HCG values obtained from CBCT scan were higher than clinical methods. Brewka21 did not agree to it. Christensen and Slabbert22 stated that condylar guidance angle obtained clinically did not match with radiographic method as condylar angle varies with the degree of protrusion. Shreshta et al11 compared condylar guidance obtained by CT and clinical methods; sagittal condylar guidance angles obtained by CT were approximately 10 degrees more than clinical methods. The present study found that the condylar guidance values by the three radiographic methods were greater than the protrusive interocclusal method.

There are certain drawbacks of radiographic method such as distortion, head and reference plane orientation, and outline of zygomatic arch. This may be different from the guiding inclination with approximately 4 to 6 mm of protrusion, which is clinically significant.23 Despite these magnification errors, the radiograph is useful for comparison between right and left side TMJs with relatively same magnification errors. Both OPG and CBCT are reproducible radiographs unlike the other TMJ-specific radiographs that are subject to projection errors.24

Moreover, Davis and Mackay25 had discussed the digital imaging with high-quality images, low radiation exposure, direct analysis, and as accurate as manual technique. CBCT reveals accurate morphology of the AE.

The difference in values of both methods could be justified due to active role played by the ligaments and muscles. The present study was conducted to compare the accuracy of radiographic method with conventional protrusive record method to record HCG inclination.8

Finally, the result of this study may have varied because of the demerits of semi-adjustable articulators as it takes only self-centered face bow and could not simulate all the mandibular movements as arbitrary hinge axis was used. This might be the reason for the variance between the CBCT and the rest of the methods.11 The CBCT availability for all the clinicians is not possible, especially for those working in rural areas. Future studies should investigate the possible effects that TMJ disorders might have on clinical methods. In spite of these factors, this study represents an important step forward in the direction of improving accuracy of condylar guidance angle determination in prosthodontic rehabilitation. However, further studies with larger sample sizes are required to confirm the result of the present study.

Conclusion

Within the limitations of the study, as small sample size and class I edentulous patients were included, it was concluded that with the radiographic technique the HCG values were higher than the clinical method; mean HCG values were higher by 6.4 degrees in CBCT, 6.7 degrees in OPG, and 9.9 degrees in lateral cephalogram as compared with the clinical value, and in all 20 subjects (100% sample size) there was a variation of condylar guidance up to 5 degrees between right and left sides.

Conflict of Interest
None declared.

References