

A study on the accuracy of horizontal condylar guidance values in edentulous patients using preprosthetic diagnostic radiographs

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Abstract

Context: Determination of horizontal condylar guidance (HCG) by various clinical and radiographic methods was performed by several investigators. If a correlation between HCG values using lateral radiographic tracing and protrusive interocclusal records can be established, the necessity of performing elaborate recording procedures can be eliminated.

Aims: The aim of this study is to evaluate and to compare the correlation between HCG values in edentulous people using the protrusive interocclusal records mounted on a semi-adjustable articulator with the manual tracing of panoramic radiograph and lateral cephalogram.

Materials and Methods: A total of 20 completely edentulous individuals of either sex from 45 to 75 years (mean age 63.15 years) fulfilling the inclusion criteria were included in this *in vivo* study. In all the participants, HCG angles were determined clinically using protrusive interocclusal records and semi-adjustable articulator after intraoral gothic arch tracing. Radiographically, it was obtained by cephalometric tracing of panoramic radiograph and lateral cephalogram.

Results: The present study shows mean HCG \pm standard deviation (SD) of $28.17^\circ \pm 5.99^\circ$ for interocclusal protrusive record while cephalometric tracing method yielded HCG \pm SD of $38.95^\circ \pm 4.77^\circ$ and $35.2^\circ \pm 4.94^\circ$ for lateral cephalogram and orthopantomogram, respectively. A statistically significant positive correlation ($P < 0.0001$) was found among these three methods.

Conclusion: HCG can be successfully determined in edentulous participants by using three aforementioned methods. HCG values from cephalometric tracing of diagnostic radiographs can be used as an adjunct to the clinical method but cannot be used independently for programming a semi-adjustable articulator

Keywords: Cephalometric tracing, horizontal condylar guidance determination, interocclusal protrusive records, panoramic radiograph

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INTRODUCTION

Registration of the accurate condylar path and mandibular movement of the patient on an articulator is the key to success of an appropriate oral rehabilitation. The inclination of the condylar path is thus a fundamental consideration in the prosthetic treatment. If condylar guidance is not recorded properly, this might lead to an increased chairside adjustment time due to arbitrary trimming which can be frustrating for both the patient as well as the dentist.^[1]

Attempt to register the horizontal condylar path started in the early 1900s when Christensen (1902) introduced “protrusive wax check bites.” In the year 1908, Gysi described the graphic method.^[2] Horizontal condylar inclination can be determined by various methods including interocclusal records, pantographic tracings, electronic jaw tracking devices, radiographic methods, etc., but programming semi-adjustable articulator with protrusive interocclusal record is still the most popular method in clinical practice.^[3-6] Intraoral registrations may compromise the accuracy because of dimensional instability of registration materials. Limitations of Gothic arch recording include the effect of tissue resiliency and the requirements of proper ridge anatomy, sufficient interridge distance, stability of denture bases, and good neuromuscular coordination.^[4,7] Even semi-adjustable articulator setting using interocclusal records has a low level of reproducibility and is subject to variables of instrument, operator, and material of interocclusal records.^[8]

The radiographic method of recording the horizontal condylar guidance (HCG) was introduced in the 1970s by authors such as Corbett *et al.*, Ingervall, Christensen, and Slabbert to overcome the disadvantages of clinical methods.^[9-11] The radiographic method is simpler, with the angles being read directly on the radiographs. On lateral cephalogram and panoramic radiograph, various angles of temporomandibular joint (TMJ) are commonly believed to be related to the HCG angle. Frankfurt horizontal plane is taken as a reference plane when HCG is determined.

Jackson (1926), Perry (1985) and Jones *et al.* indicated that cephalometric and panoramic radiography have a special role in diagnosis and treatment planning for removable prosthodontics. These radiographs would be of value in determining retained root fragments, retained tooth, foreign bodies, pathosis, condition of TMG, position of mental foramina, gross changes in alveolar bone height, and alterations of the occlusal vertical dimension.^[12]

If a correlation between HCG values using lateral cephalometry or panoramic radiograph tracing and protrusive interocclusal records can be established in an edentulous population, the necessity of performing elaborate recording procedures can be eliminated. An accurate HCG value can be determined each time from diagnostic radiographs only.

Thus, this study was aimed to evaluate and to compare the correlation between HCG values in edentulous people using manual tracing of orthopantomogram (OPG) and lateral cephalogram with the protrusive interocclusal records mounted on a semi-adjustable articulator. The study was based on a null hypothesis as no correlation exists among condylar guidance angles obtained from cephalometric tracings of radiographs (i.e., OPG and lateral cephalogram) and protrusive interocclusal records.

MATERIALS AND METHODS

Participants for the present study were randomly selected from the patients reporting to the Department of Prosthodontics and Crown and Bridge after obtaining an Ethical Clearance from the Institutional Ethical Committee. A total of 20 completely edentulous participants of either sex (18 males and 2 females) and age group ranging from 45 to 75 years (mean age 63.15 years) fulfilling the inclusion criteria, i.e., having good neuromuscular control, physical and mental health, and well-formed or moderately formed residual alveolar ridge with adequate interridge space were selected. Exclusion criteria included patients with temporomandibular disorders, severe residual ridge resorption, orofacial tumors and gross facial deformity, mucositis, radiation therapy, parafunctional habit, etc.

For the radiographic determination of HCG, one panoramic radiograph and a lateral cephalogram were made for each participant using a digital cephalostat (X-Mind Pano D+, Satelec, Acteon group, Thailand, Bangkok) following manufacturer’s manual. To prevent the superimposition of the image of the condyle over the glenoid fossa in the radiograph, all the radiographs were made in an open mouth position using one standardized bite block. Two bite blocks were prepared from cold cure acrylic resin having a height of 20 mm (for robust or average build participants) and 16 mm (for short-built participants), respectively, as average interarch distance for edentulous participants varied between 16–20 mm as stated by Winkler [Figure 1].^[13,14]

Both the OPGs and lateral cephalograms were manually traced using the guidelines as given by Gilboa *et al.*^[15] The

Frankfurt's horizontal plane (FH plane) was drawn by joining the "orbitale" (lowest point on the infraorbital margin of the orbit) and "porion" (highest point on the margin of the bony auditory meatus).^[16] The most superior point on the glenoid fossa and most inferior point of articular eminence were identified, and the mean curvature line was obtained by joining the two points. A third reference line passing through the same points was extended to intersect the Frankfurt's Horizontal Plane. This angle was measured with a protractor (B. Dayal and Co. Pvt. Ltd, Kolkata, India) and was considered as HCG angle [Figure 1].^[16]

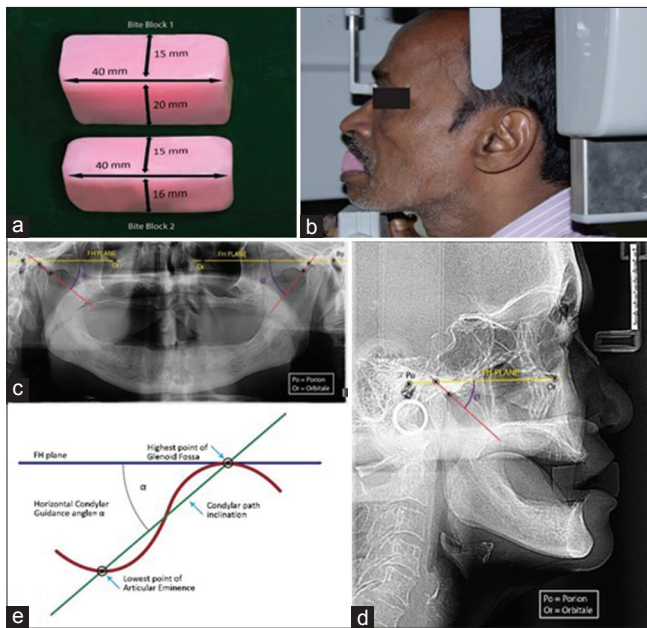


Figure 1: Radiographic tracing method horizontal condylar guidance determination. (a) Bite block 1 (40 mm × 15 mm × 20 mm) and Bite block 2 (40 mm × 15 mm × 16 mm). (b) Patient with bite block. (c) Orthopantomogram. (d) Lateral cephalogram. (e) Line diagram of cephalometric tracing of horizontal condylar guidance angle

For the clinical HCG registration, maxillary and mandibular primary impressions were made with impression compound (DPI Pinnacle functional impression compound, Mumbai) for each of the 20 participants and casts were poured with Type II dental stone (BN plast, BN Chemicals, West Bengal). Custom trays were fabricated by cold-cure acrylic resin (DPI RR cold cure, Mumbai) and the final impressions made with zinc oxide-eugenol impression paste (DPI impression paste, Mumbai) after proper border molding with green stick compound (DPI Pinnacle tracing sticks, Mumbai). Master casts were poured with Type III dental stone (BN stone, BN Chemicals, West Bengal). Occlusal rims of proper dimension were fabricated on trial denture base (DPI RR cold cure, Mumbai) of 2-mm thickness.^[17] Facebow (Hanau™ Spring Bow, Whip Mix Corporation, USA) records were made to mount the maxillary cast on the Hanau™ Wide-Vue Articulator (Whip Mix Corporation, USA). The Hanau™ Wide-Vue articulator had a condylar track of numerical scale with increments of 5°. To obtain the readings with accuracy up to 1°, a protractor modified to have angulations from -20° to +60° along with a movable pointer was fixed on to the condylar shaft [Figure 2]. If the pointer was at 0.5 or more decimals on the protractor, the higher value was considered for the reading.^[13] After taking tentative vertical jaw relation, an intraoral gothic arch tracing was done to make centric and 6-mm protrusive plaster interocclusal records [Figure 2]. The protrusive check bite was used to register the right and left HCG values on the Hanau™ Wide-Vue articulator [Figure 2].

The data recordings comprised three sets of values for all participants ($n = 20$), i.e., the right and left HCG angle obtained by protrusive interocclusal records, by cephalometric tracing of panoramic radiographs and the right HCG angle obtained by lateral cephalogram tracings.

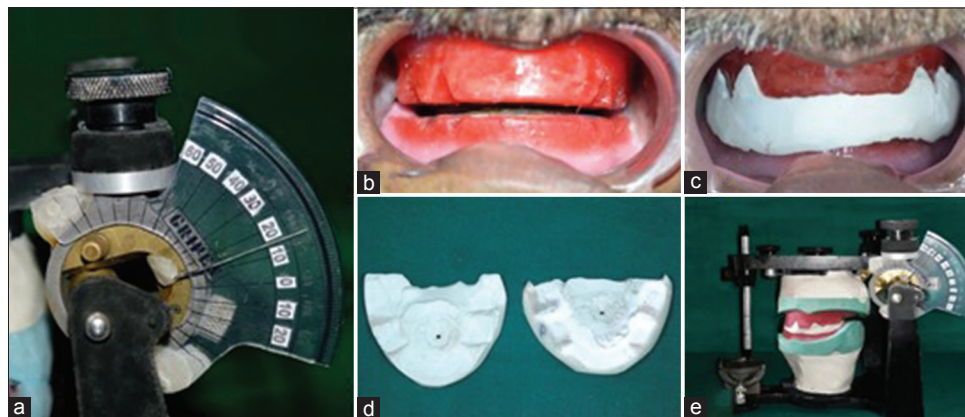


Figure 2: Clinical method horizontal condylar guidance determination. (a) Modification of calibration in condylar part of Hanau™ Wide-Vue articulator. (b) Intraoral gothic arch tracing. (c) Making of protrusive record. (d) Centric and protrusive records. (e) Programming semi-adjustable articulator and registration of horizontal condylar guidance values

Since the sensor of the digital cephalostat (X-Mind Pano D+, Satelec, Acteon Group, Thailand, Bangkok) was placed on the right side of the subject and the source of the X-ray was on the left side, the values of the right side of lateral cephalogram were considered for tabulation of correlation between the three methods.

RESULTS

For statistical analysis, data were entered into a Microsoft Excel spreadsheet and then analyzed by SPSS 20.0.1 (IBM SPSS Statistics) and GraphPad prism versions 5 (www.graphpad.com). Data had been summarized in Table 1 as mean and standard deviation (SD) for numerical variables and count and percentages for categorical variables (up to four decimal for better accuracy of the results). Two-sample *t*-tests, Paired *t*-tests, and one-way ANOVA were done to compare means of three or more samples for numerical data (using the F distribution). Each of these statistics was used to carry out either a one-tailed test or a two-tailed test. If the calculated *P* value is below the threshold chosen for statistical significance, the null hypothesis is rejected in favor of the alternative hypothesis. *P* ≤0.05 was considered for statistically significant.

In this study, HCG values range from 21° to 43° in the right sides and 17°–45° in the left sides recorded by the clinical protrusive interocclusal method, whereas 28°–47° in the right sides and 27°–46° in left sides were recorded by the panoramic radiographic method. Lateral cephalogram tracing produced HCG values ranging from 31° to 50° at right sides [Table 1].

Three different results of mean HCG ± SD were obtained by three different methods. HCG ± SD was 28.17° ± 5.99° for interocclusal protrusive record, while cephalometric tracing and OPG method yielded 38.95° ± 4.77° and 35.2° ± 4.94°, respectively [Table 1 and Figure 3].

A statistically significant positive correlation (*P* < 0.0001) was found amongst these three methods rejecting the null hypothesis [Table 2].

Figures 4-6 represent the scatter diagrams of the variables evaluated in the present study. In these graphs, the band formed by the cluster of points run in straight upward direction. The values of the Y-axis increase as the values of the X-axis increase. This is indicative of a positive correlation.

DISCUSSION

Precise recording of patient’s mandibular movement and registering it on a semi-adjustable articulator with accuracy is the fundamental step of fabrication of any full mouth prosthesis including fabrication of balanced, complete denture.

HCG angle determination using protrusive interocclusal records is a procedure involving multiple clinical steps which require precise expertise and experience. Thus, many practitioners rely on average values (i.e., 33°) for setting

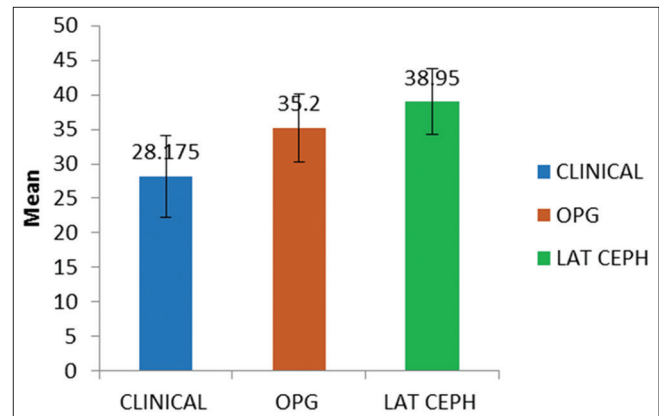


Figure 3: Distribution of mean horizontal condylar guidance values by clinical method, cephalometric tracing of orthopantomogram and lateral cephalogram

Table 1: Distribution of mean, median, standard deviation, minimum and maximum horizontal condylar guidance values (in degrees) in Group I, II, and III

| Method | n | Mean±SD | Minimum | Maximum | Median | P |
|------------------------|----|----------------|---------|---------|---------|---------|
| Mean total | | | | | | |
| Clinical | 20 | 28.1750±5.9940 | 20.0000 | 44.0000 | 26.5000 | <0.0001 |
| OPG | 20 | 35.2000±4.9482 | 27.5000 | 46.5000 | 34.2500 | |
| Lateral cephalogram | 20 | 38.9500±4.7736 | 31.0000 | 50.0000 | 38.0000 | |
| Mean right side | | | | | | |
| Clinical | 20 | 28.3500±5.6221 | 21.0000 | 43.0000 | 27.5000 | <0.0001 |
| OPG | 20 | 35.6000±4.9778 | 28.0000 | 47.0000 | 34.0000 | |
| Lateral cephalogram | 20 | 38.9500±4.7736 | 31.0000 | 50.0000 | 38.0000 | |
| Mean left side | | | | | | |
| Clinical | 20 | 28.0000±6.8518 | 17.0000 | 45.0000 | 27.0000 | <0.0001 |
| OPG | 20 | 34.8000±5.1769 | 27.0000 | 46.0000 | 34.0000 | |
| Lateral cephalogram | 20 | 38.9500±4.7736 | 31.0000 | 50.0000 | 38.0000 | |

SD: Standard deviation, OPG: Orthopantomogram

Table 2: Pearson correlation values among different parameters of three methods

| Methods | Clinical right side | Clinical left side | Clinical total | OPG right side | OPG left side | OPG total | Lateral cephalogram right side |
|--------------------------------|---------------------|--------------------|----------------|----------------|---------------|-----------|--------------------------------|
| Clinical right side | | | | | | | |
| <i>r</i> | | 0.846** | 0.952** | 0.940** | 0.869** | 0.927** | 0.899** |
| <i>P</i> | | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Remarks | | Positive | Positive | Positive | Positive | Positive | Positive |
| Clinical left side | | | | | | | |
| <i>r</i> | 0.846** | | 0.968** | 0.816** | 0.936** | 0.900** | 0.877** |
| <i>P</i> | <0.0001 | | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Remarks | Positive | | Positive | Positive | Positive | Positive | Positive |
| Clinical total | | | | | | | |
| <i>r</i> | 0.952** | 0.968** | | 0.907** | 0.943** | 0.949** | 0.923** |
| <i>P</i> | <0.0001 | <0.0001 | | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Remarks | Positive | Positive | | Positive | Positive | Positive | Positive |
| OPG right side | | | | | | | |
| <i>r</i> | 0.940** | 0.816** | 0.907** | | 0.899** | 0.974** | 0.945** |
| <i>P</i> | <0.0001 | <0.0001 | <0.0001 | | <0.0001 | <0.0001 | <0.0001 |
| Remarks | Positive | Positive | Positive | | Positive | Positive | Positive |
| OPG left side | | | | | | | |
| <i>r</i> | 0.869** | 0.936** | 0.943** | 0.899** | | 0.976** | 0.962** |
| <i>P</i> | <0.0001 | <0.0001 | <0.0001 | <0.0001 | | <0.0001 | <0.0001 |
| Remarks | Positive | Positive | Positive | Positive | | Positive | Positive |
| OPG total | | | | | | | |
| <i>r</i> | 0.927** | 0.900** | 0.949** | 0.974** | 0.976** | | 0.979** |
| <i>P</i> | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | | <0.0001 |
| Remarks | Positive | Positive | Positive | Positive | Positive | | Positive |
| Lateral cephalogram right side | | | | | | | |
| <i>r</i> | 0.899** | 0.877** | 0.923** | 0.945** | 0.962** | 0.979** | |
| <i>P</i> | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | |
| Remarks | Positive | Positive | Positive | Positive | Positive | Positive | |

**Denotes statistically significant result. OPG: Orthopantomogram

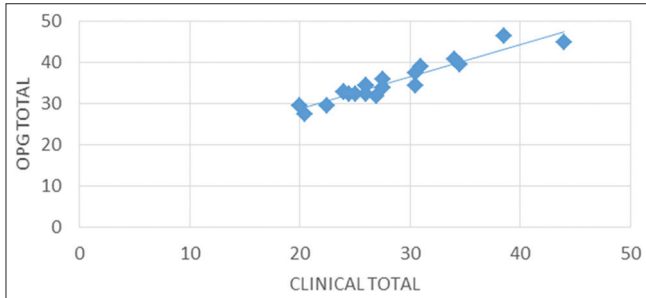


Figure 4: Correlation between horizontal condylar guidance values by cephalometric tracing of orthopantomogram and clinical measurements

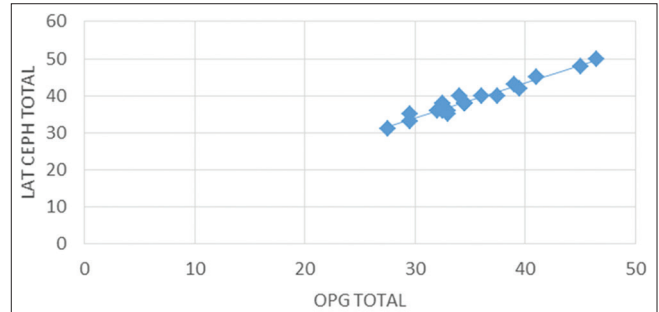


Figure 5: Correlation between horizontal condylar guidance values by cephalometric tracing of lateral cephalogram and orthopantomogram

HCG to avoid this cumbersome clinical methods though the general range varies from 22° to 65°. [18-20] Mean value settings may result in inaccuracies and hamper the balanced occlusion when this horizontal condylar path inclination is very flat or very steep. [15,21]

The present study was attempted to validate the accuracy of radiographic method of HCG determination by comparing it with conventional protrusive record method. For standardization of the study, all radiographs were taken with the same digital cephalostat operated by a single operator following manufacturer's recommendations to eliminate image distortion and magnification errors. To standardize the mouth opening, acrylic resin bite block was

used according to the built of the individual (20 mm-bite block was used for both average and robust build individual while 16-mm bite block was used for short build individual to restrict the condylar head from crossing the articular eminence) which eliminates the superimposition of condylar head and glenoid fossa in the radiographs. [14]

Impression plaster was taken as interocclusal record material because it is most dimensionally stable and capable of more accurate transfer as recommended by Rothstein. [22] Numerical scale of condylar element of Hanau™ Wide-Vue articulator with 5° increment was modified with a protractor to obtain the accurate readings up to 1°.

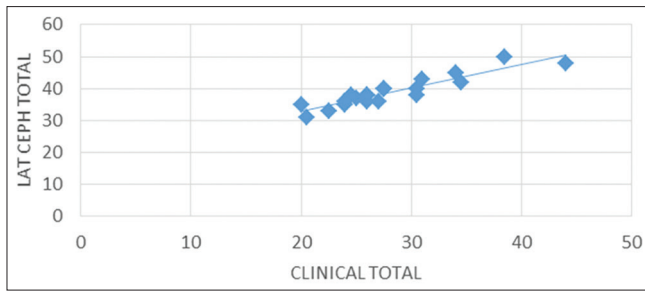


Figure 6: Correlation between horizontal condylar guidance values by cephalometric tracing of lateral cephalogram and clinical measurements

In this study, a statistically significant positive correlation was formed between mean HCG angles obtained from protrusive interocclusal record and panoramic radiographic tracing, but the mean HCG difference between panoramic radiographic tracing and protrusive interocclusal records was 7.03° . Gilboa *et al.* found same mean difference of 7° ; whereas Tannamala *et al.* and Kumari *et al.* claimed the radiographic values were on average 4° and 13° greater, respectively.^[6,15,16] These inconsistencies occur due to overlapping of the mandibular notch, coronoid process, zygomatic arch around TMJ in an OPG. Without using any accessory aid, it is difficult to distinguish between these two closely approximated radiopaque lines, one depicting the outline of the articular eminence and fossa, the second one indicating the inferior border of the zygomatic arch.^[23]

Mean HCG angle values were found to be higher in lateral cephalogram tracing when comparing with panoramic radiograph and clinical method and they were 3.75° and 10.78° higher respectively. These results differed with the findings of Galagali *et al.* (2016), where they found that panoramic radiographs showed a higher HCG value than that of lateral cephalogram.^[24] This anomaly may be explained by the fact that these investigators had taken into account separately two lateral cephalograms of either side in dentulous population, while the present study attempted the tracings on lateral cephalograms which showed overlapping of the right and left sides as the sensor was present only in the right side. Reference measurement procedure based on unilateral image of lateral cephalogram may have directly affected on results in this study creating discrepancies with other two methods. Information from the left side would have been useful for a better understanding and accuracy of the results.^[25]

In the present study, HCG values determined by protrusive method were 17° – 45° , whereas cephalometric tracing of panoramic radiographs and lateral cephalogram yielded HCG values ranging from 27° to 47° and 31° – 50° , respectively. This wide variation is in agreement with the

findings of previous investigators like Zamacona and Woelfel JB where they found HCG angulations ranging from 5° to 55° .^[26,27]

In the present study, mean HCG values obtained from panoramic radiographic tracing and interocclusal protrusive records for the right side were 35.6° and 28.35° with a mean difference of 7.25° ; 28.0° and 34.8° for left side with a mean difference of 6.80° , respectively, showing statistically and clinically significant results. These results were in accordance to the study by Prasad *et al.*, who found the mean difference of 1.97° for the right side and 3.18° for the left side with the radiographic values being higher.^[28] These results were incongruent with the findings of the studies by Tannamala *et al.* where they got a statistically insignificant result.^[6] However, values from radiographic method were found to be lower in the study by Patil *et al.*^[29] This variability may be explained by the fact that quantitative measurements on OPG or lateral cephalogram are difficult because of magnification differences, image distortions and are dependent on operator's perception.

Condylar pathways are not solely dictated by the bony contour of articular eminence of TMJ but may be influenced by the soft-tissue attachments, thickness, and shape of articular disc and ligaments.^[5,30] Thus, the accuracy level of HCG determination by radiographic method becomes questionable as differentiation in soft-tissue imaging is indiscernible both in OPG and lateral cephalogram. Christensen and Slabbert in a review mentioned this inconsistency of radiographic method comparing with the intraoral clinical method of HCG determination where radiographic method is always greater.^[11]

Traditional imaging methods have been questioned because of a higher probability of errors due to head positioning of individual, reference plane orientation, and structure superposition.^[20] Errors of manual cephalometric tracing might arise at tracing stage, during landmarks identifications and misreading of measurements as cephalometric analyses are dependent to human judgment.^[31] Hence, Sing *et al.* advocated for clinical method as radiographic method yielded a consistent greater value as compared to clinical method.^[32] Clinical protrusive method for each individual is mandatory to determine accurate HCG values. Cephalometric tracing of diagnostic radiographs can delineate an idea about HCG angle before any clinical step, which will help the operator to choose the type of articulator and select posterior teeth. It cannot be used independently for programming articulator due to its inability of soft-tissues imaging, unreliability of

determining landmarks, image distortion, and structural superimposition.

Limitations of the study included as follows:

1. Smaller sample size
2. Inability to accurately distinguish the right and the left sides of the individual in the two-dimensional lateral cephalometric image.
3. Use of standard vertical dimension for each individual during taking radiographs
4. Manual cephalometric tracing method was used instead of digital imaging software.

CONCLUSION

Within the limitations of the study, the following conclusions can be drawn:

Radiographic method yielded greater value of HCG as compared to clinical values. On an average, HCG values were 7° higher in case of panoramic radiograph and about 11° higher for lateral cephalogram when compared with protrusive method. Average values of HCG should not be used for programming semi-adjustable articulator, as wide variations in value exist amongst individuals. All three methods showed no significant difference between the right and left condylar inclination.

However, HCG determination needs to be further investigated using similar studies incorporating a larger sample size, different articulator systems, newer imaging modalities such as cone beam computed tomography and magnetic resonance imaging.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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