Original Article

A comparative study to correlate between clinically and radiographically determined sagittal condylar guidance in participants with different skeletal relationships

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Abstract

Context: Many authors have conducted studies that determine horizontal condylar guidance (HCG) using various methods, articulator systems, and recording materials. However, there is a dearth of literature on variability existing in HCG in individuals with different skeletal relationships. This study is an attempt to verify whether such a difference exists or not.

Aims: The aim of this study is to determine and correlate the HCG in individuals with Angle's Class I, Class II, and Class III malocclusion using radiographic and clinical methods.

Settings and Design: HCG was recorded for thirty individuals, ten of each class. For each individual, HCG was recorded clinically as well as radiographically.

Subjects and Methods: Clinically, HCG was recorded using protrusive check bites and a semi-adjustable articulator. Radiographically, two methods were employed. First, a "tangent method" wherein the angle made by a tangent to the posterior slope of articular eminence with the Frankfurt horizontal (FH) plane was considered as the HCG, and second, a "protrusive method" where the position of the condyle at maximum intercuspation and 6 mm protrusion were traced, and the angle this path made with the FH plane was recorded as the HCG.

Statistical Analysis: Descriptive statistical analysis along with Tukey's test and analysis of variance was used to calculate and compare the mean values. Pearson correlation coefficient was used to establish correlation between various means.

Results: A significant difference in the HCG of three skeletal relationships was seen, with Class II having a steeper angle than the other two. Among the various methods used, a correlation was found between the clinical and the protrusive method; however, the tangent method yielded greater values of HCG.

Conclusions: The average value of HCG should not be used as it differs according to the skeletal relationship. Radiographic method can be used to yield consistent HCG; however, the protrusive method should be employed.

Key Words: Angles malocclusion, horizontal condylar guidance, lateral cephalogram

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INTRODUCTION

One of the main aims of prosthetic dentistry is to restore missing tooth morphology and establish an optimum occlusion that is in harmony with the patient's stomatognathic system.[1,2] Of the five factors governing the laws of articulation as given to us by Hanau, the condylar inclination is one of the most important and necessary factors for securing balanced articulation and forms one of the end-controlling factors for articulation. The significance of the condylar guidance lies in how it influences posterior tooth morphology, both the vertical and horizontal components.[3]

The correlation between the morphology of the occlusal surfaces and the path traced by the condyle during mandibular movements has been well documented. Gysi (1910), Gilis (1926), and Gysi and Kohler (1929) were the first investigators to recognize the importance of determining the sagittal path of condyles while restoring occlusion in patients to avoid occlusal interferences[4] which has been associated with osseous resorption and dysfunction of the craniomandibular complex.[2] Such interferences also affect the stability of the prosthesis.

The earliest methods employed to register the horizontal condylar guidance (HCG) were the "protrusive wax check bites" introduced by Christensen (1905) and the graphic method introduced by Gysi (1908). Since then, several authors have carried out studies to determine the HCG using various methods and compare the variability between different registration methods, articulator systems, and recording materials.[4-17] The main drawback of the interocclusal wax records is the inherent dimensional instability of the recording medium, i.e., wax.[18] Limitations of Gothic arch recording include the effect of tissue resiliency and the requirements of proper ridge anatomy, sufficient interridge distance, stable denture bases, patient cooperation, and good neuromuscular coordination. The main drawback of graphic method is the difficulty in drawing a tangent to the curved condylar path.[14]

The radiographic method of recording the HCG was introduced in the 1970s by authors such as Corbett *et al*.,[19] Ingervall (1974),[20] and Christensen and Slabbert[21] to overcome the drawbacks of clinical methods. It has been suggested that radiographic methods record condylar guidance more accurately than other methods as they involve stable bony landmarks.[21] However, the values obtained using the radiographic methods have been found to be inconsistent with those obtained using the clinical methods, and the exact correlation between the two methods has not been established.[21] Few radiographic methods have been introduced to determine the HCG but which method determines the HCG most closely to the clinically obtained value has not yet been mentioned in the literature.

The glossary of prosthodontic terms defines condylar guidance as "mandibular guidance generated by the condyle and articular disk traversing the contour of the glenoid fossae." As the condyle moves out of the centric relation position, it descends along the posterior slope of the articular eminence of the mandibular fossa. The rate at which it moves inferiorly while the mandible is being protruded depends on the steepness of the articular eminence. If it is flatter, the condyle will take a path that is less vertically inclined. If it is very steep, the condyle will take a steep, vertically inclined path. The angle at which the condyle moves away from the horizontal reference plane is referred to as the condylar guidance angle.

Authors such as Corbett *et al*.[19] and Mack[22] have advocated that the condyle closely follows the contours of the inner surface of the glenoid fossa during mandibular movement. Hence, it would be unassuming to say that the morphology of the articular eminence dictates the sagittal condylar guidance angle to a considerable extent. Few authors have investigated the difference in the morphology of the articular eminence in different skeletal groups of people.[23-25] Although the number of such studies is few, the authors have reported a difference in the articular morphology of Class I, Class II, and Class III individuals.[22] Therefore, this study aims to ascertain whether or not a difference lies in the HCG of individuals with different skeletal relationships.

Hypothesis

Based on these reports, we can hypothesize that a variation in the condylar guidance values should exist among individuals with different skeletal jaw relations. The purpose of this study is to ascertain whether such an assumption is validated or not.

SUBJECTS AND METHODS

Before the commencement of the study, ethical clearance was obtained from the Institutional Ethical Board. The study population consisted a total of thirty fully dentate patients of either sex, aged between 20 and 40 years. The participants were further divided into three groups of ten each, based on the ANB angle as measured on the lateral cephalogram as Class I (ANB 2°–4°), Class II (ANB >4°), and Class III (ANB <2°). Exclusion criteria included patients with temporomandibular disorders, gross attrition,

major restorations or crowns, history of orthodontic treatment, known risk of radiation such as pregnancy, mucositis, radiation therapy, etc.

Condylar guidance values were recorded for all the patients clinically using interocclusal protrusive record and radiographically using digital lateral cephalogram. For the clinical registration of the condylar guidance, maxillary and mandibular alginate (Algitex, DPI, Mumbai, India) impressions were made, and casts were poured with Type III dental stone (BN Chemicals, Kolkata, West Bengal, India). Facebow (Hanau™ Spring Bow, Whip Mix Corporation, USA) registration was made with the orbitale as the anterior reference point which was used to mount the maxillary cast on the Hanau™ Wide-Vue Articulator (Whip Mix Corporation, USA). The mandibular cast was then mounted in maximum intercuspation with the maxillary cast. Protrusive bite registration was made at 6 mm protrusion[14,26,27] using a compound jig and polyvinyl siloxane (PVS) bite registration paste (Jet Bite, Coltene/Whaledent Inc., Switzerland) [Figure 1a-c]. The protrusive check bite was used to register the right and left HCG values on the articulator (Hanau™ Wide-Vue Articulator, Whip Mix Corporation, USA) [Figure 1d]. The values were recorded using all three sets of records, and the value that occurred most frequently was noted as the HCG for that particular participant.

For the radiographic determination of HCG, two sets of lateral cephalometric radiographs were made for each participant by the same technician using a Broadbent cephalostat to standardize the head positions. The first set of lateral cephalogram was made in maximum intercuspation while the second was taken at 6 mm protrusion. The impression compound jig, which was fabricated for registering the protrusive interocclusal record clinically, was used to standardize the 6 mm protrusion while taking the lateral cephalogram. This ensured that the clinical and the radiographic condylar guidance was recorded at the same amount of protrusion. Two methods were employed to measure the HCG radiographically. First, the lateral cephalograms were traced and overlapped along the Frankfurt horizontal plane (FH plane) [Figure 2]. The protrusive condylar path was obtained by joining the centers of the condyles in maximum intercuspation and in the protrusive position. The angle between the protrusive condylar path and the FH plane was measured and termed as the HCG by "protrusive method."[21] Second, HCG was determined as the angle between the tangent to the posterior slope of the articular eminence and the

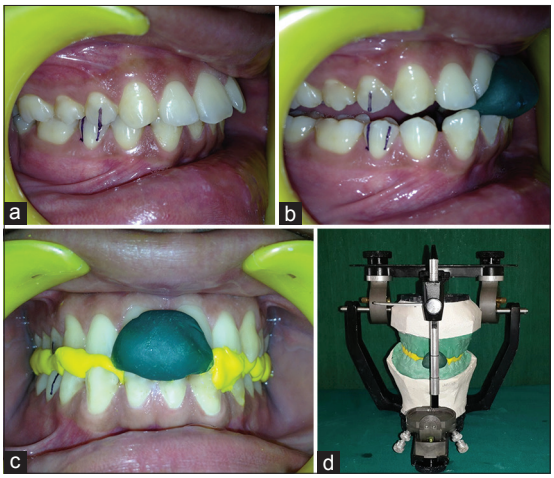


Figure 1: (a) Six millimeter guidelines at maximum intercuspation, (b) lines at 6 mm protrusion, (c) protrusive bite registration, (d) protrusive record placed between the maxillary and mandibular casts

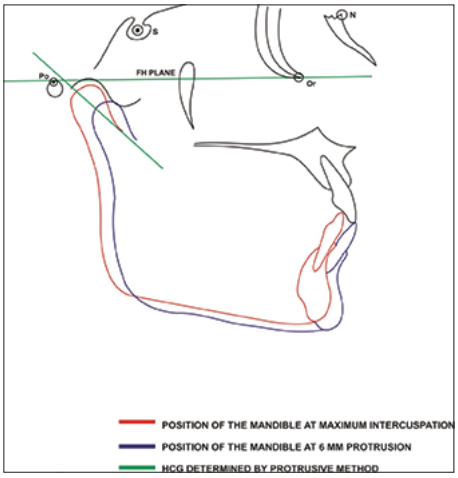


Figure 2: Protrusive method of horizontal condylar guidance determination

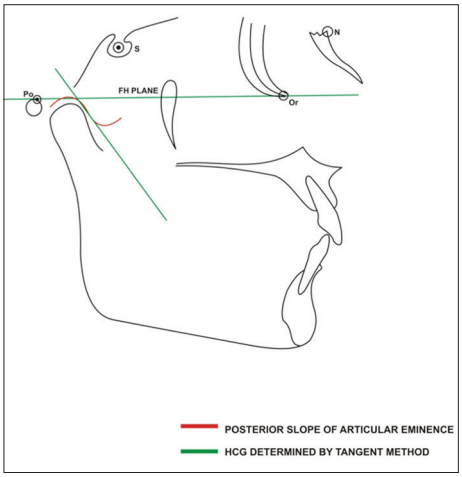


Figure 3: Tangent method of horizontal condylar guidance determination

FH plane. This was designated as the HCG by "tangent method"[8,28] [Figure 3].

Right and left condylar guidance values were registered for the clinical method, whereas only the right condylar guidance angle was considered for the cephalometric method.

RESULTS

The data obtained were subjected to statistical analysis, which was performed with the help of Epi InfoTM 3.5.3. (Jan 2011, CDC, Atlanta, Georgia, USA). Descriptive statistical analysis was performed to calculate the means along with their corresponding standard deviations. One-way analysis of variance (ANOVA) was used to analyze the difference between group means. Tukey's test was used in conjunction with ANOVA to compare mean values of the HCG obtained using various methods and to identify those mean values which were significantly different from each other. Table 1 shows the HCG values of Class I, Class II, and Class III participants recorded using the cephalometric and the clinical methods. While analyzing the mean values obtained by the cephalometric tangent and protrusive methods, ANOVA showed that there was significant difference in the three classes ($F_{2,27} = 4.10$; $P < 0.05$ and $F_{2,27} = 8.07$; $P < 0.01$), respectively. As per the critical difference (CD), the mean of cephalometric measurements of Class III was significantly lower than that of other two classes ($P < 0.01$) [Graphs 1 and 2]. Clinical determination of HCG also showed a significant difference between the three classes as per the ANOVA. The CD further demonstrated a significantly higher mean for the Class II participants.

Table 1: Mean±standard deviation for horizontal condylar guidance of various classes of participants recorded using the cephalometric and clinical methods

Mean±SD	Class I	Class II	Class III
Cephalometric tangent method	41.90±5.52	43.90±4.43	37.60±5.05
Cephalometric protrusive method	34.10±6.41	38.95±5.60	27.20±7.53
Clinical method (right)	31.30±7.31	40.70±4.37	26.00±8.89
Clinical method (left)	31.80±6.44	41.00±3.59	25.20±8.54

SD: Standard deviation

Table 2 shows the Pearson correlation values between the various parameters evaluated in the current study. In the Class I and Class III group, the correlation between cephalometric measurements (protrusive method) and clinical measurements (right) was found to be significant ($P < 0.05$), whereas the correlation between cephalometric measurements (tangent method) and clinical measurements (right) was found to be nonsignificant ($P > 0.05$).

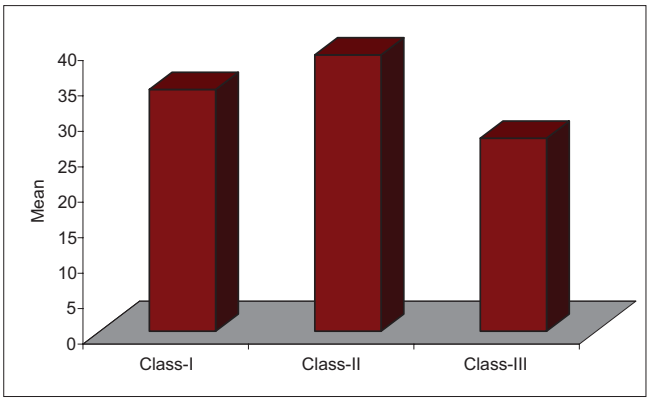
The tangent method resulted in statistically higher values than the other two methods. In the Class II group, the correlation between both the cephalometric methods and the clinical method was found to be nonsignificant [Graphs 3 and 4]. The difference in mean between the protrusive method and clinical method was only 1.75° whereas that between the tangent method and the clinical method was 3.20°. However, the correlation for both the methods was nonsignificant.

Comparison between the means of the right and the left side for all classes of participants showed that although a difference existed between the two sides, the mean of the right and left sides was positively correlated, i.e., the difference was statistically insignificant. The mean difference between the right and left side in Class I participants was 2.3°.

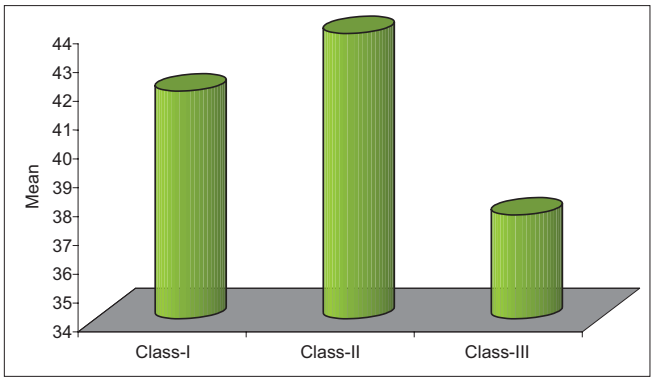
Table 2: Pearson correlation values between the parameters

Parameters	Pearson correlation (*r*)	*P*	Significance
For Class I			
Cephalometric measurements (protrusive method) and clinical measurements (right)	0.796	0.006 (<0.05)	S
Cephalometric measurements (tangent method) and clinical measurements (right)	0.435	0.209 (>0.05)	NS
Clinical measurements (right) and clinical measurements (left)	0.906	0.0001 (<0.05)	S
For Class II			
Cephalometric measurements (protrusive method) and clinical measurements (right)	0.296	0.406 (>0.05)	NS
Cephalometric measurements (tangent method) and clinical measurements (right)	0.254	0.427 (>0.05)	NS
Clinical measurements (right) and clinical measurements (left)	0.637	0.048 (<0.05)	S
For Class III			
Cephalometric measurements (protrusive method) and clinical measurements (right)	0.630	0.051 (<0.05)	S
Cephalometric measurements (tangent method) and clinical measurements (right)	0.326	0.358 (>0.05)	NS
Clinical measurements (right) and clinical measurements (left)	0.963	0.00001 (<0.05)	S

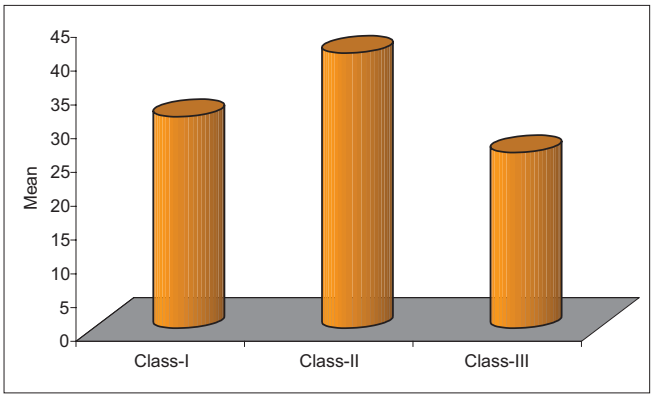
NS: Not significant, S: Significant



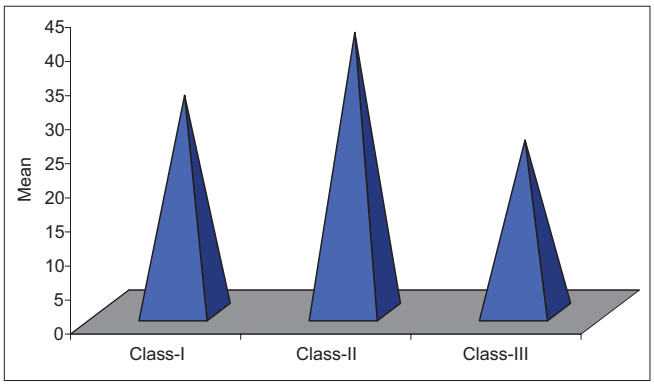
Graph 1: Cephalometric measurements (protrusive method) of the three classes of participants



Graph 2: Cephalometric measurements (tangent method) of the three classes of participants



Graph 3: Clinical measurements for right side of the three classes of participants



Graph 4: Clinical measurements for left side of the three classes of participants

DISCUSSION

The success of prosthodontic treatment lies in the fabrication and delivery of prosthesis that is in harmony with the stomatognathic system of the patient. This is largely influenced by the precision to which the articulator can simulate the patient's mandibular movements which in turn depends on the correct registration of centric and eccentric records used to program the articulator. The HCG is one such factor. This angle is a relative measure and not an absolute value, which is related to the angle of the eminence of the temporomandibular joint (TMJ).

Many practitioners rely on average values of condylar guidance, which ranges from 22° to 65°.[29,30] If the individual inclination of the articular eminence is very steep or flat, guidance derived from the mean value settings may vary sufficiently leading to incorporation of inaccuracies while accomplishing particular clinical objectives such as posterior disocclusion or balanced occlusion.[15,31]

Angle (1948) had proposed that the sagittal condylar guidance coincided more or less with the height and slope of the posterior surface of the articular tubercle. The author stated that "an arbitrary plane of motion of the mandibular condyle was set as a line from the apex of the articular eminence tangent to the fossa-eminence transition zone." This line was labeled the eminence slope. Many authors reported that TMJ morphology had a strong correlation with skeletal morphology.[26,32] Akahane *et al.* reported a small angle of eminence to FH plane in Class III individuals.[24]

The results of the present study were in accordance with these findings. In general, it was seen that participants with Class II skeletal relation have a significantly higher angle of HCG which was in accordance with the reports of Ingervall (1974)[20] and participants with Class III skeletal relation had a significantly lower angle of HCG as compared to the Class I participants.

Widman had reported an inverse relation between the angle of the articular eminence and the occlusal and mandibular planes.[26] The steeper the articular eminence, the more horizontal the occlusal and the mandibular planes. These results suggested that brachycephalic facial types tend to have more vertical articular eminence angles, and

dolichocephalic facial types would tend to have a more flattened articular eminence angle which supported the findings of this study.

In the present study, the HCG was registered by two cephalometric methods, namely, the protrusive and tangent method and the protrusive check-bite method. The difference in the values obtained by the three methods supports the findings of authors such as Brewka[5] who reported that radiographic methods and clinical methods are in much disagreement and Christensen and Slabbert[21] who reported that "no radiographically determined sagittal condylar guidance angle coincided with that obtained with the use of intra-oral records. The radiographically determined angle showed a greater mean value than that determined by intra-oral records." While comparing the two cephalometric methods, a closer correlation to the clinical method was found by the protrusive method of HCG determination [$P < 0.05$, Table 2]. Condylar paths are determined by the (1) bony fossae, (2) the tone of the muscles responsible for mandibular movements and their nerve controls, (3) the limitations imposed by the attached ligaments, and (4) the shape and movements of the menisci.[33] The tangent method of HCG determination does not take these factors into account, which could be the reason for the greater amount of discrepancy [$P > 0.05$, Table 2].

In the present study, a number of measures were observed to standardize the study and to reduce the sources of errors. First, additional PVS registration paste (Jet Bite, Coltene/Whaledent Inc., Switzerland) was used to minimize the time-dependent distortion of wax as a recording media. The elastomers have been reported to be the most reliable interocclusal recording material and wax the least.[34] The major disadvantage of using elastomers as interocclusal recording material is that any compressive force exerted on these materials during manipulation may cause inaccuracies during the mounting of the casts and while programming the articulator. Second, 6 mm protrusive jig used for the clinical method was also used for the cephalometric method to standardize the 6 mm protrusion in both the methods. Many authors have reported that HCG changes with amount of protrusion as articular eminence are strongly convex, anteroposteriorly, and slightly concave, mediolaterally.[16,27,35] This profile leads to variation in inclination from point to point.

Third, the cephalometric tracings were performed with much caution to identify the landmarks precisely. When viewing the region of the temporal bone on a lateral cephalogram, two radiopaque lines are apparent, the lighter and superior one depicting the articular eminence and fossa, and the heavier and more inferior one representing the inferior border of the zygomatic arch.[26] The radiographs were repeated when the form of the articular eminence was not discernable.

A number of factors could account for the difference in registered values between the clinical and the radiographic methods with the latter yielding higher values. The difference could be partly due to errors of the clinical method and cephalometric method. Errors of the clinical method can be attributed to the error in the registration technique employed and errors of the articulator. Errors during registration were attempted to be nullified by the use of protrusive jig and the use of silicon bite registration material (Jet Bite, Coltene/Whaledent Inc., Switzerland). The main source of error could perhaps be attributed to the inherent limitations of the articulator used. Semi-adjustable articulator was used in the study for receiving the records from the clinical methods. They are limited in their capabilities to accurately simulate the TMJs, the jaws, and their movements because of the fixed intercondylar distances and the straight condylar pathways, which is reported to cause errors, especially in the horizontal and frontal plane.[36] Semi-adjustable articulators have condylar element glide-in-slots to provide a rectilinear stimulation of the curvilinear path of the condyle, thus producing a difference between the existing biological situation and the mechanical articulator. Sometimes, frictional inhibition of movement of the condylar components of the articulator also introduces errors in the values of the condylar guidance.[17] Moreover, instruments have scale increments of 5°. If the mark falls in between, the angle is estimated with an automatic error of approximately 1.25°.[9] The interplay of subjective variables such as how hard the operator presses between the maxillary and mandibular articulator members, the position at which pressure is applied and the sensitivity of the adjustment mechanisms could account for the variability seen in the present study.

Errors of the cephalometric method could arise due to difference in head and reference plane orientation, radiographic distortion, and difficulty in identifying the landmarks. These are also the limitations of the radiographic method, which could arise despite of the use of cephalostat and natural head position to standardize the head and reference plane orientation. One of the major sources of errors could be ambiguity of the right and the left sides of the radiographic image. Although the sensor of the lateral cephalogram was placed on the right side of the participant and the more distinct image was considered to be of the right side, errors could be induced due to this

assumption. Furthermore, overlapping of the right and left condyles with each other could lead to false marking of the center of the condyle which yields different values. Although the radiographic parameters were standardized, it is not possible to get an exact overlap of the right and the left sides over each other due to anatomic variation and asymmetry. Inability to distinguish the articular eminence from the outline of the zygomatic arch could also account for some differences.[26]

The discrepancy between the FH plane and the axis-orbital plane could also be a potential source of error between the two methods. Gonzalez and Kingery observed the lack of parallelism between the FH plane and the axis-orbital plane.[37] In the cephalometric method, the plane of reference was the FH plane, whereas the facebow transfer is done with reference to the axis-orbital plane. Porion does not come into play during the facebow transfer. The posterior reference point instead is Beyron's point, which has been shown to be on an average 7 mm below porion. This difference is accounted for by the compensatory mechanism of the Hanau™ Wide-Vue Articulator where the condylar horizontal axis is 7 mm below orbital index.[38] However, morphological variation among the participants can account for difference greater or lesser than 7 mm between the two posterior reference points which could again account for errors between the two methods.

The instrumental limitations which include the size of the point of the pencil used in tracings and the limit of the measurement of the protractor graduated in one degree, which restricted the measurement accuracy to the nearest 1°, can also be considered as sources of error of the cephalometric method.

Finally, a comparison was also made between the right and left HCG values determined clinically. The mean for the right side of Class I, Class II, and Class III individuals was 31.30°, 40.70°, and 26.00° and the mean for the left side was 31.80°, 41.00°, and 25.20°, respectively. In all three classes, the Pearson correlation was found to be significant [Table 2]. Therefore, it can be inferred that although a difference exists between the right and left condylar guidance values, the difference is insignificant. Several authors have reported a difference in the right and left condylar guidance values obtained using clinical methods, but such differences cannot be determined radiographically using lateral cephalogram which remains a limitation of this method.[4] However, radiographically, right and left HCG can be determined using orthopantomograms or computed tomography scans.[39-41]

CONCLUSIONS

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

- Radiographic method yielded greater value of HCG as compared to clinical method
- In all three classes of participants, significant correlation between the radiographic and clinical method was found when protrusive method was used
- The correlation was nonsignificant when "tangent method" was used. It resulted in statistically higher values than the clinical method
- Among the three skeletal classes, a significant difference was seen in the HCG values. In general, Class II group yielded higher values and Class III group had less steep condylar inclination as compared to Class I group
- Average values of HCG should not be used as wide variations in value exist among individuals with different skeletal relationships
- No significant difference was noted between the right and left condylar inclination.

The present study, given its limitations, was a small effort to simplify prosthodontic treatment by substituting the inconsistent clinical method of HCG determination by cephalometric method. As the cephalometric method involves stable bony landmarks, inconsistencies occurring during the clinical registration can be eliminated. Furthermore, a new range and average value of HCG can be introduced based on the sagittal skeletal relationship rather than a general range of 22°–65° and an average value of 33°. However, this needs to be further investigated by means of similar studies incorporating a larger sample size as well as by considering the limitations of the present study. Finally, whether or not the same can be inferred for completely edentulous population still requires a similar study on the completely edentulous group.

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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