

**EVALUATION OF LATERAL CONDYLAR GUIDANCE BY
CLINICAL AND RADIOGRAPHIC METHODS – HANAU’S
FORMULA REVISITED – INVIVO STUDY**

Dissertation submitted to

THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY

In partial fulfillment for the Degree of

MASTER OF DENTAL SURGERY



BRANCH I

PROSTHODONTICS AND CROWN & BRIDGE

2016 – 2019

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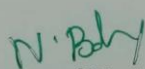
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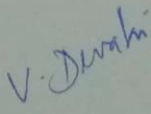
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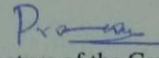
DECLARATION

TITLE OF DISSERTATION	Evaluation Of Lateral Condylar Guidance By Clinical And Radiographic Methods – Hanau's Formula Revisited – In Vivo Study
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List of Abbreviations

CG	Condylar guidance
HCG	Horizontal condylar guidance
LCG	Lateral condylar guidance
OPG	Orthopantomograms
CT	Computerised Tomography
SMV	Sub-mento-vertex
SPR	Right foramen spinosum
SPL	Left foramen spinosum
TSA	Trans-spinosum axis
MSA	Mid-sagittal axis
CoL	Condylion lateralis
CoM	Condylion medialis
CA	Condylar axis
L	Lilian
Pog	Pogonion
M	mei or midpoint
TPA	Trans-porionic axis
LCG-C	calculated values of LCG through Hanau's formula
LCG-M	measured angle of LCG in SMV projection
TMJ	Temporo-mandibular Joint
FH plane	Frankfort Horizontal plane
RP	Reference plane
ZOE paste	Zinc Oxide Eugenol paste
BP	Border paths
JMA	Jaw Motion Analyser
FB	Face bow

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INTRODUCTION:

The ultimate goal of a prosthetic rehabilitation is to fabricate a prosthesis that is harmonious with the patient's stomatognathic system.^[1] An accurate simulation of the condylar path of patient on an articulator leads to a successful complex prosthodontic treatment.^[2] None of the invented articulators, till date, satisfy the requirements in mimicking condylar movements. Even fully adjustable articulators have limitations pertained to elasticity of ligaments, Fischer's angle values, condylar surtrusion, etc. Movements are simulated in empty-mouth sliding motions and not in functional motions. Errors in tooling and errors resulting from metal fatigue and wear are neglected.

The most essential consideration in the oral rehabilitation of any patient is recording the inclination of the condylar path, which is an invisible component of occlusion. Inclination of the condylar path is one of the five elements of balanced occlusion, remaining being compensating curve, relative cusp height, incisal guidance, and plane of orientation.^[3] This is the only element that is not controlled by prosthodontist and should be duplicated with utmost accuracy. Condylar guidance [CG] by definition is the mandibular guidance generated by the condyle and articular disc traversing the contour of the glenoid fossa. CG is classified into two as horizontal condylar guidance [HCG] and lateral condylar guidance [LCG]. Horizontal condylar path is defined as the path of movement of the condyle-disk assembly in the joint cavity when a protrusive mandibular movement is made. Lateral condylar path is defined as the path of movement of the condyle-disk assembly in the joint cavity when a lateral mandibular movement is made.^[4]

Erroneously recorded condylar guidance will lead to occlusal interferences during mandibular movements. This increases the chair side denture adjustment time, which can be annoying for both the patient as well as the prosthodontist.^[5] 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 gross inaccuracies while accomplishing occlusion.^[6]

Programming of the semi-adjustable articulator is a mandatory step in the fabrication of quality biofunctional prosthesis. Programming of the semi-adjustable articulator refers to adjusting the HCG, LCG and incisal guidance.^[7] Mechanical limitations of a semi-adjustable articulator require least protrusion of 6mm to accustom HCG.^[8]

Various intra-oral and extra-oral methods have been used to register CG and adjust the articulator accordingly. Extra-oral methods are generally used in edentulous patients.^[9] HCG can be recorded through intraoral or positional wax method, graphic recordings, and functional recordings. In the graphic recordings, when the tangent to the functional portion of the tracing is drawn, significant criticism concerning errors occurs.^[10] Errors with interocclusal checkbite method can occur due to variation in the properties, and manipulation of the recording material. Patient's difficulty in closing precisely in protrusion is attributed to poor voluntary neuromuscular control. This may also lead to erroneous protrusive interocclusal record. Angle changes in HCG with protrusive interocclusal record represent a single point along the condylar path against the posterior slope of articular eminence, regardless of the material used. Factors such as neuromuscular control of patient, stability of record base and recording media affect the accuracy of graphic tracings^[7]. Nevertheless, the

registration of the condylar path changes when the patient moves the jaw laterally during protrusion.^[9]

The use of radiographic imaging may help in resolving the above mentioned troubleshoots and establish accurate registration of HCG.^[1] In the dental literature, lateral cephalograms, orthopantomograms [OPG], and tomographs are some of the imaging techniques used for measuring HCG. Numerous researches have been conducted to ascertain the existence of any correlation between clinically recorded HCG values and the one traced on radiographs. OPG, being the most commonly used diagnostic aid, has minimal radiation exposure and hence, it is preferred over CT for recording the HCG. ^[11]

The LCG in Hanau series of articulators are being calculated using Hanau's formula; $L = \frac{H}{8} + 12$. The exact derivation and mathematical proof of this formula is unknown till date. The denominator 8 and the +12 values were subjective to interrogation with respect to their origin. However, the current recommended average settings use this formula as a gold standard to calculate LCG in Hanau series articulators. The validity of this formula is questionable, and hence, reassessment is needed to verify the reliability of the formula.

A novel roentgenographic technique, submentovertex (SMV) projection, has been proposed in this present in-vivo study for arriving at LCG values in Hanau [closed track] Wide-View II arcon articulator. Berger was the first to use SMV projection in cephalometrics. The SMV cephalometric analysis has been developed to facilitate measurement of the craniofacial complex from the basilar view.^[12] The use of SMV projection to measure LCG yet has not been documented in the dental literature.

Anatomic landmarks and reference planes used in SMV projection in this present in-vivo study are geometric centres of right and left foramen spinosum [SPR and SPL]; trans-spinosum axis[TSA]: line joining SPR and SPL; mid-sagittal axis[MSA]: perpendicular line bisecting TSA; condylion lateralis[CoL]: most prominent lateral aspect of condyle bilaterally; condylion medialis[CoM]: most prominent medial aspect of condyle bilaterally; condylar axis[CA]: line through CoL and CoM bilaterally; lilion [L]: point on condylar axis at junction of lateral one-third and medial two-thirds of condylar length bilaterally; pogonion [Pog]: most prominent anterior point of mandibular symphysis; mei or midpoint [M]: midpoint of external auditory meatus from line parallel to MSA through L bilaterally; trans-porionic axis [TPA]: line passing through left and right M points. ^[12]

In current practice, digital computed tomography scans are safer, more accurate and cheaper resulting in their widespread application in many areas of prosthetic dentistry. It may be argued that application of advanced imaging is unwarranted in prosthodontics. However, the higher levels of safety, accuracy, and patient's benefit from advanced digital imaging suggest that time has to ripe for its complete consumption in the field of prosthodontics. ^[9]

The proposed null hypothesis for the present in-vivo study is that there shall not be any difference between the calculated values of LCG [LCG-C] through Hanau's formula and measured angle of LCG [LCG-M] in SMV projection.

AIM:

The aim of this present study is to compare the LCG angles calculated by Hanau's formula; $L = \frac{H}{8} + 12$, [LCG - C] to the angles measured in Sub-mento vertex radiographic tracings [LCG-M].

OBJECTIVES:

1. To compare and evaluate the right and left LCG-C
2. To compare and evaluate the right and left LCG-M
3. To compare and evaluate the LCG-C with LCG-M.

REVIEW OF LITERATURE:

1. Prasad DK, Shah N, Hegde C. in 2012^[1] correlated between sagittal condylar guidance obtained clinically by protrusive interocclusal records and radiographically by panoramic radiographic tracing methods in human dentulous subjects and concluded that Panoramic radiographic tracings of the sagittal condylar path guidance made relative to the Frankfurt's horizontal reference plane based on the outline of the articular eminence and the glenoid fossa of the temporal bone, the resulting condylar guidance angles are used to set the condylar guide settings of semi-adjustable articulators to overcome the problem of inaccuracies of the interocclusal record technique with inherent errors of up to 30°.

2. Shreshta P, Jain V, Bhalla A, Pruthi G in 2012^[2] compared the radiographic and clinical methods of measuring the horizontal condylar guidance (HCG) values and concluded that the right and left HCG values were almost similar. The CT scan of midfacial region showed higher HCG values than the clinical methods like Interocclusal wax record method, Lucia jig and Intra-oral tracer methods, values obtained from all the clinical methods were comparable. CT scans are considered superior in precision and as well as in standardization than all the other methods as error may creep in due to limitation of semi-adjustable articulator in mimicking condylar motion.

3. Hanau LR, in 1926^[3] defined, analyzed and formulated Articulation.

4. Pelletier LB, Campbell SD in 1991^[5], compared three groups of methods for recording the eccentric condylar pathway for programming the articulator to reproduce the complex mandibular motions in order to minimize occlusal

interferences in the prosthesis and summarised as: accurate and reproducible measurements of the protrusive condylar pathway by two simplified mandibular motion analyzers (Whip-Mix and Denar) and both mechanical and electronic pantography (Denar) and reproducible, accurate measurements of the immediate Bennett side shift by three simplified mandibular motion analyzers (Whip-Mix, Denar, and Panadent) and two pantographs (Denar), and reproduction of immediate Bennett side shift by polyether and zinc oxide interocclusal record materials but the measurements were less than those recorded by extra oral techniques. He concluded that the electronic pantograph (Denar) as the most accurate and reliable method.

5. Gilboa I et al, in 2008^[6] correlated between the anatomic shape of the eminence of the articular fossa and the corresponding panoramic radiographic image in dry human skull and concluded that panoramic radiographic image of the sagittal inclination of the articular eminence invariably replicated the eminence inclinations in the 25 human skulls with a mean difference of 7 degrees in inclination. The image of the articular eminences in a panoramic radiograph may be used to provide an indication of the degree of inclination of the articular eminence and used to set the condylar guidance in semi adjustable articulators.

6. Godavarthi AS et al, in 2015^[7], Determined Condylar Guidance by Panoramic Radiographs and Conventional Methods and Correlated and concluded Panoramic radiograph can be used as an alternative to interocclusal technique which has got its own difficulties and drawbacks in condylar guidance determination. This study was undertaken based on the anthropometric study showing the use of panoramic radiograph to determine the condylar guidance for programming the semi adjustable articulator.

8. Galagali G et al, in 2016^[8], conducted a study to evaluate and compare the correlation between sagittal condylar guidance obtained by protrusive inter occlusal records mounted on semi-adjustable articulator with panoramic and Lateral cephalograms radiographic tracings in dentulous population and concluded that Lateral cephalogram radiograph may be taken as an important reliable tool to rely upon for recording the Sagittal condylar guidance angle as it has got numerous advantages like less image distortion, less radiation dosage and so on.

9. Preti G. et al, in 1982^[9], conducted a clinical study of graphic registration(GR) of the inclination of the condylar path to conduct a statistical investigation of the values of the condylar sagittal path angles obtained with the GR method, to control the accuracy of the GR method, and checked the repeatability of the GR method.

10. Kumari VV, et al in 2016^[10], compared and correlated sagittal condylar guidance obtained by radiographic method and extraoral gothic arch tracing method in edentulous patients, which has been previously done on dentulous subjects and concluded that the use of orthopantomogram to set the condylar guidance on the semi adjustable articulator for complete denture therapy is questionable, as Radiographic error do occur despite standardization.

11. Shah K, Patel JR, Chhabra T, Patel P, IN 2014^[11], conducted a study to evaluate the reliability of programming the articulator using the radiographic and the interocclusal records by conventional arrow point tracing method made during Jaw relation and concluded that the condylar guidance values obtained from the panoramic view were higher than those obtained at the stage of jaw relation recording stage. He also found that the values obtained by the two methods were not correlated and to

check for the correlation of the guidance value obtained from the lateral cephalograms.

12. Uysal T, Malkoc S, in 2005^[12], conducted a study to establish the cephalometric norms from SMV radiographs for young Anatolian Turkish adults based on few literatures describing that the SMV cephalometric analysis has been developed to facilitate measurement of the craniofacial complex from the basilar view and to identify possible sex differences between male and female subjects and concluded that SMV cephalometric norms are useful in the diagnosis of mandibular asymmetries and the treatment of dentofacial orthopaedics, rapid maxillary expansion, and surgical procedures to correct asymmetry in Turkish patients.

12. Maglione M and Costantinides F, in 2012^[13], compared the reliability of two different methods for localization of the cranial midline through cephalometric analysis, one using craniostat ear rods, the other being spinosum foramina as reference points and validated that the midline traced using the spinosum foramina as references more closely approximates the ideal mid sagittal axis and represents the most reliable line to trace the coordinate system for identifying craniofacial asymmetry during cranial development on submentovertex radiograms with a lower error compared to non-fixed references such as ear rods.

13. Bhawsar SV, Marathe AS, Ansari SA, in 2016^[14], evaluated and compared the lateral condylar guidance obtained using the Hanau's formula and the computerized jaw tracking device (Kinesiograph) on the right and left sides. As there existed significant differences in the lateral condylar guidance values obtained using the Hanau's formula and computerized jaw tracking device and he concluded that dentist and dental technicians should consider reassessing the current recommended average

settings and use of the Hanau's formula for programming the semi-adjustable articulators. He also concluded saying that to minimize occlusal error in complete dentures balanced occlusion and in fixed partial denture occlusion, a semi-adjustable instrument programmed using the jaw tracking device may be used to minimize the time spent to harmonize occlusion while recognizing the shortcomings of the instrument.

14. Mishra A, Palaskar J, in 2014^[15], evaluated the effect of direct and indirect face-bow transfer on the horizontal condylar guidance(HCG) values set on the semi-adjustable articulator and found a statistically significant difference in HCG values obtained from direct and indirect face-bow transfer records. Lateral cephalograms used as control received higher mean HCG values than those obtained from protrusive records. Mean HCG values obtained from indirect face-bow transfers are significantly more than those obtained from direct transfers and are also closer to the values obtained from the lateral cephalograms. Hence he concluded that these types of face bow transfers are not identical and are not alternative to each other and increased sample sizes needed to be studied for detailed insight into the role of type of face bow transfer.

15. Silverman MM, in 1952^[16], explained the measurement of vertical dimension by the use of the speaking method, the physiologic phonetic method of measuring vertical dimension with the aid of the closest speaking space, which is measured before the loss of the remaining natural teeth to give us the patient's natural vertical dimension which can be recorded and used at later dates.

16. Silverman MM, in 1953^[17], by means of the speaking method of recording the natural vertical dimension, which is a scientific, accurate, and practical method for

every dentist without the need for any expensive equipment or instruments, proved scientifically that the vertical dimension must not be increased except for the exceptional patient.

17. Silverman MM, in 1956^[18], explained a method of determination of vertical dimension by phonetics.

18. Silverman MM, in 1967^[19], explained the causes of certain abnormal sounds, such as the whistle and swish sounds, that occur in the speech of patients wearing complete, fixed and removable partial dentures involving the anterior teeth. In addition suggested forms of treatment had been presented for these undesirable conditions. Ideally, artificial teeth should be located in the same position as occupied by the natural teeth they replace for proper phonetics.

19. Earl Pound, in 1977^[20], reviewed new guidelines for establishing the vertical dimension of occlusion. They were based upon the fact that the body of the mandible assumes an easily recordable, repetitive horizontal and vertical position when the patient is at the /S/ position during speech.

20. Gaston ML et al, in 1985^[21], conducted a study to determine the acceptability of lateral interocclusal records by the Hanau model H-2 articulator and concluded that, out of the 56 lateral interocclusal records made, 39 (70%) were accepted by the Hanau model H-2 articulator.

21. Javid, in 1974^[22], conducted studies to compare the sagittal and lateral condylar paths in different articulators and determined and compared the condylar guidance angles for protrusive and lateral progressive side shifts in three different kinds of articulators like Denar D4-A, Whip-Mix and Hanau model 130-28 and compared the

means of the condylar guidance adjusted with protrusive interocclusal records, with the means of the same condylar guidance adjusted with lateral interocclusal records

22. Marmary Y, Zilberman Y, Mirsky Y, in 1979^[23], used Foramen Spinosum to determine cephalometric skull midlines and concluded that the midline could be determined by the use of neural foramina, remained constant throughout cranial growth and development-the foramen spinosum, believed to be unaffected by environmental factors with the use of cephalometric basilar radiographic view.

23. Prajapati P, Sethuraman R, Naveen YG, Patel J, in 2013^[24], evaluated the effects of different anterior points of reference and two different articulator systems on condylar guidance and concluded that any change in anterior reference point in a face bow transfer caused a change in occlusal plane orientation and resulted in different protrusive condylar guidance values, the anterior point of reference has definitive influence on the condylar guidance on Arcon and Non-Arcon articulator, the casts were significantly closer to the anatomic position whenever orbitale was used as the third point of reference for mounting the casts to the articulator irrespective of type of articulator, Inferior annular groove can also be used as anterior point of the reference, Superior annular groove is not recommended anterior point of reference.

24. R. Venkateshwaran R, et al in 2016^[25], correlated the angle of horizontal condylar inclination obtained on a semi adjustable articulator and the corresponding angle traced on a temporomandibular joint (TMJ) radiograph in completely edentulous subject and the image of the articular eminences in a TMJ tomogram may be used to provide an indication of the degree of inclination of the articular eminence and may be of value as an aid in setting the condylar guidance in semi adjustable articulators.

25. Zamacona JM, Otaduy E, Aranda E^[26], Studied the sagittal condylar path in edentulous patients in 1992 and concluded that the inclination of the condylar path is variable. The comparison of their data with those of other authors does not reveal great differences. Among this group the partially edentulous patients had a slightly greater angulation than the totally edentulous. In most persons, there are important differences between the condylar inclination on the left and right sides. In only 12.5 % of the subjects were they the same, while in 21.4% the differences were more than 10 degrees. The graphic method makes it possible to obtain accurate measurements of the angulation of each side and recommended this method for determining the condylar path inclination in edentulous patients.

26. Mukesh Kumar Goyal, Shelly Goyal in 2011^[27], gave the comparative evaluation of sagittal condylar values of arcon and non-arcon articulators with cephalometric readings and to determine the amount of discrepancy in sagittal condylar guidance values between arcon and non-arcon articulators using same protrusive record and concluded that sagittal condylar guidance values obtained from non-arcon and arcon articulators was highly significant indicating a low level of reproducibility, non-arcon articulator and cephalometric tracings was statistically significant whereas no significant difference was found in the mean sagittal condylar values obtained from the arcon articulator and cephalometric tracings no significant difference in sagittal condylar guidance values on the right and left sides, however, slightly lesser values were obtained on the right side.^[36]

27. Raghunath Patil et al in 2015^[28], Correlated and analyzed the sagittal condylar guidance obtained by protrusive interocclusal records by extraoral Gothic arch tracing and panoramic radiograph tracing in edentulous subjects and concluded saying that by

considering the radiographic, clinical limitations the obtained angles by both the methods are similar without much difference (1.5 R, 2.7 L). Gothic arch tracing gave quite similar readings as suggested by the radiographic landmarks and can be continued to be used as a successful clinical method.

28. P. H. Dupas in 1990^[29], devised a method of registering centric relation and programming the semi-adjustable articulator using Lucia Jig and concluded that the Lucia jig method remains a rational method of positioning the mandible before recording mandibular positions with interocclusal records and the setting of semi adjustable articulators was also easier with the use of the universal jig.

29. Knap and Ziebert^[30] have suggested a technique in oral reconstruction using the Hanau model 130-28. In their technique, protrusive and lateral interocclusal records are used to determine the condylar guidance elements. A similar technique can be used in the construction of complete dentures.

30. Craddock F. W. and Dunedin M.S.D., in 1949^[31] decided the accuracy and practical value of records of condyle path inclination and summarised the use of intraoral wax records of eccentric jaw relations for the adjustment of horizontal condylar guidance on anatomic articulators has been shown to be invalid and unreliable. Roentgen evidence is presented of various phenomena associated with normal temporomandibular joint function, and the possibility of determining condyle path inclination by roentgenographic means has been tentatively established.^[39]

31. Javid N S and Porter M R , in 1975^[32] explained the importance of the Hanau formula in construction of complete dentures and found that the range of means of lateral condylar guidance of Hanau articulators using the Hanau formula was small. This small possibility of variation in the lateral condylar guidance would suggest the

use of lateral interocclusal records when precise restorative procedures are necessary.^[40]

32. Harcourt J. K. in 1973^[33] Despite accurate registration techniques sources of error arise in laboratory procedures because of instability of materials and changes during their setting or polymerization.

33. Berger H in 1961^[34] has mentioned that it was Schueller in 1905 explained the roentgenologic technique of Basilar view cephalograms who used the term “Submento-vertical position”. Two ways were recommended for this view. Either lying on his back or sitting. The first method has been adopted to ensure immobility of the patient.

34. William A. Eichhold, and William A. Welker in 1986^[35] explained a formula to determine the lateral condylar guidance from intraoral needlepoint tracing based upon intraoral lateral border paths (BP) was derived: $L = 1.06 \text{ BP} - 46$, determined L based on a BP can be made through geometric drawings.

35. A. G. Celar & K. Tamaki in 2002^[36] assessed the accuracy of an electronic hinge axis tracing device (Cadiax compact) in measuring the horizontal condylar inclination (HCI) and the Bennett angle and concluded that electronic registrations used to set articulator controls are helpful in clinical practice within limitations.

36. Hernandez AI in 2010^[37], determined the symmetry of Sagittal and Horizontal condylar path angles and concluded that condylar path angles were steeper and Bennett angles were lower than suggested average for setting semi-adjustable articulators, also found no significant asymmetry in either the condylar inclination or in the Bennett angle on the right and left sides. Hence concluded saying that dentist

and dental technicians should always consider reassessing the current recommended average settings for semi-adjustable articulators. Thus by modifying the recommended averages or using electronic recording methods, articulators condylar settings are set to mimic patients condylar pathway to result in successful outcome in clinical and laboratory levels.

37. Tannamala PK in 2012^[38] conducted a study and compared the sagittal condylar angles set in the Hanau articulator by using an intraoral protrusive record to those angles obtained using a panoramic radiographic image and concluded that the protrusive condylar guidance angles obtained by panoramic radiograph were not statistically significant when compared with the angles obtained by protrusive interocclusal record method. Hence the records thus obtained by this method could be used to program the semi-adjustable articulator to obtain clinically acceptable restorations.

38. Ralph H. Boos in 1951^[39], described a technique which marked the beginning of a study on roentgenographic method of recording condylar path. He explained a procedure for providing the transfer of the registration of the condylar path of the patient on to the articulator. The method described permitted the use of the adjustable articulators, without a need for a new design of articulator, unless the path of the condylar path is curved.

39. E. Fanucci in 2008^[40] compared the values of the Bennett angle measured using an average value articulator with those which were measured by a 64 slices Computed Tomography (CT) and concluded that CT scanning is a useful method, alternative to conventional procedures, as the average value articulator for Bennett angle

measurements, and it could become an important diagnostic tool in the gnathological and rehabilitative area.

MATERIALS AND METHODS:

This study was conducted in the Department of Prosthodontics and Crown & Bridge, Vivekanandha Dental College for Women, Tiruchengode. Completely edentulous patients (n=20) reported to the department were screened to select the subjects for the study. No attempt was made to maintain a fixed male-to-female ratio. Patient's inclusion criteria were: Patient's age between 40 - 60 years, Patient's with favourable maxillary and mandibular ridges, patients who do bilateral and adequate protrusive movement and patients with no clinical signs of TMJ dysfunction like pain, clicking sound, deviation, difficulty in opening mouth. Exclusion criteria were, patient's with signs of alveolar bone loss, patient's whose condition contraindicates radiographs and patients who refuse to give informed consent for the study.^[14]

Basic information about the study was explained in brief to the patient. A signed informed consent form was obtained from each patient.

Chart 1: Schematic representation of the methodology

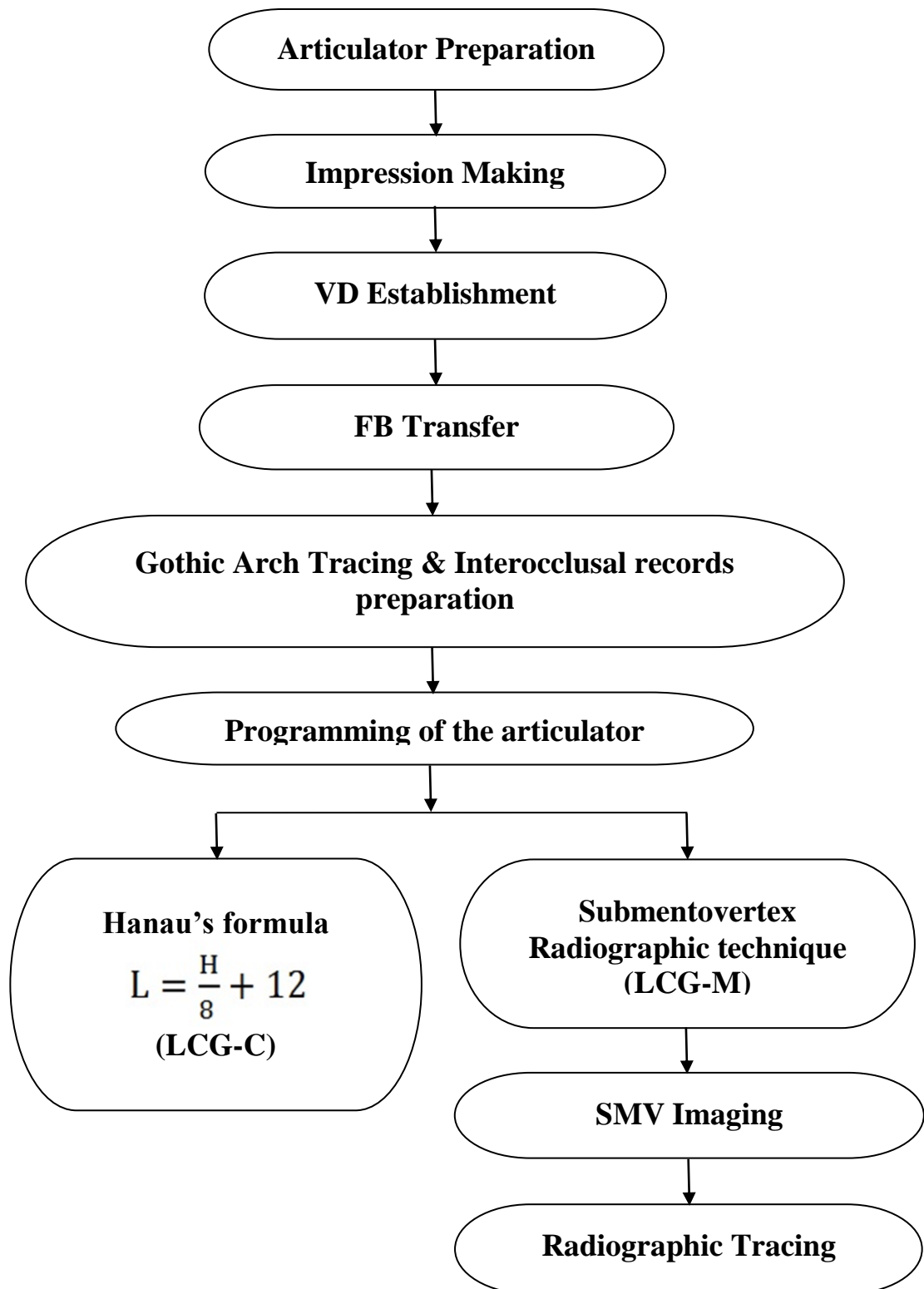


Chart 2: Grouping of LCG-C

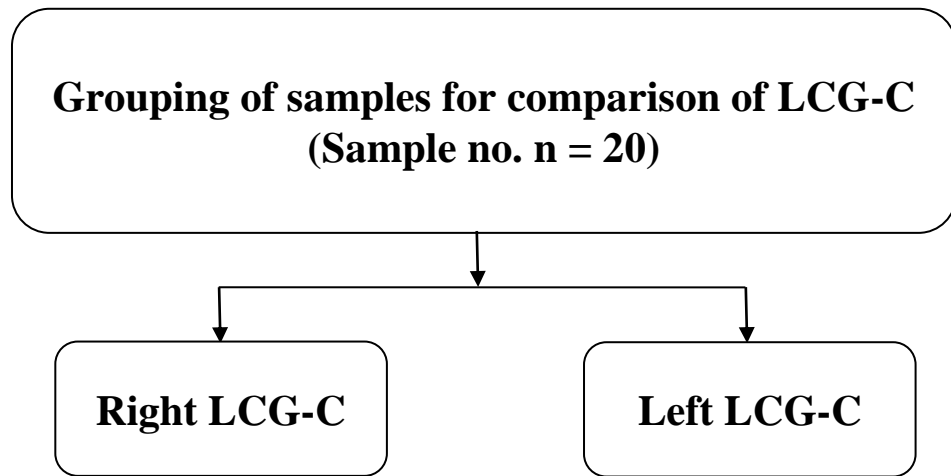


Chart 3: Grouping of LCG-M

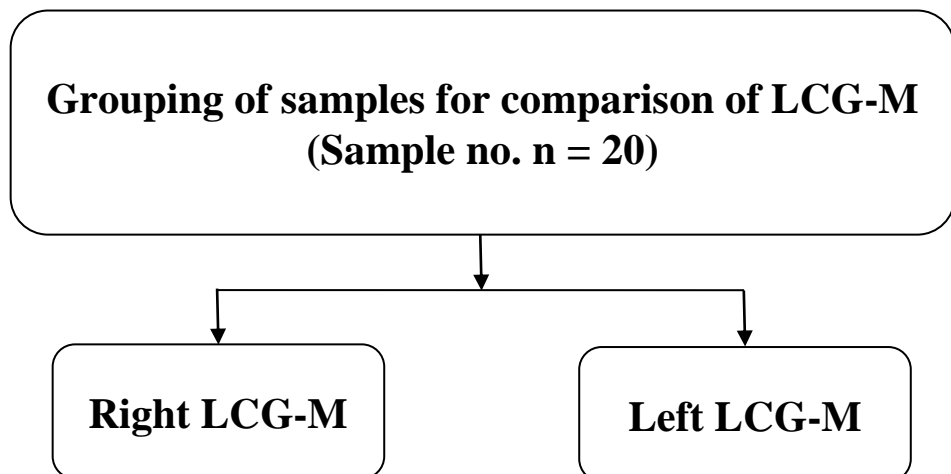
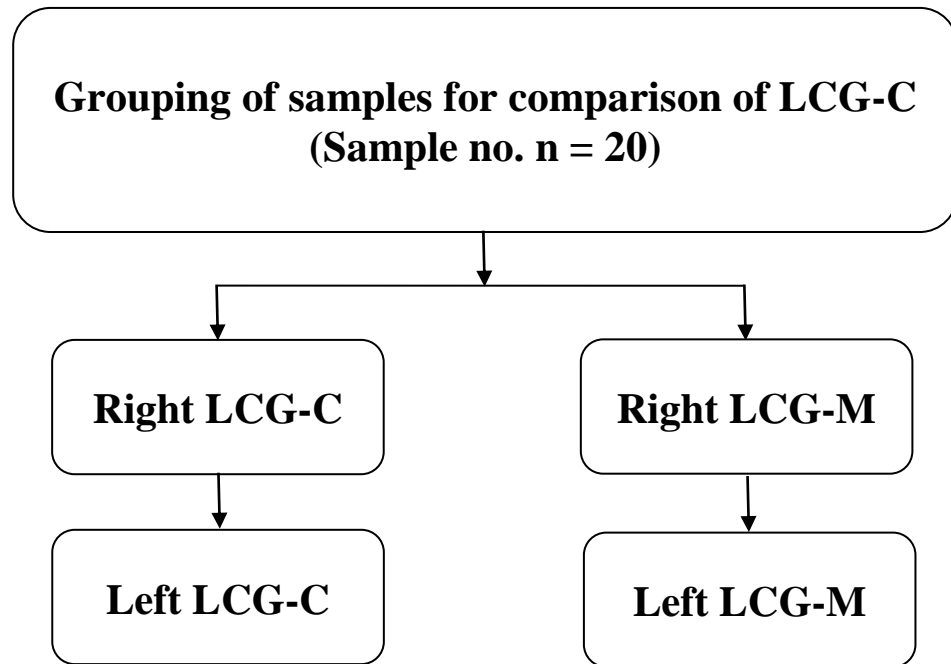


Chart 4: Grouping of samples between LCG-C and LCG-M



Step 1: Articulator preparation:

The semi-adjustable articulator (HANAU™ Wide-View Articulator, WhipMix Corporation, USA) has a HCG and Bennett angle calibration which is graduated at 5° intervals (horizontal condylar path [-20° to +60°] and Bennett's angle [0° - 30°]). In order to obtain more accurate readings, sectioned modified protractors, graduated at per degree interval, were attached onto the inner side of the graduated markings on the condylar element, in alignment with the markings bilaterally. L-shaped extenders made from 23 gauge orthodontic wire were attached onto the reference zero line bilaterally.^[15] Another set of sectioned modified protractors, graduated at per degree interval, were attached at Bennett calibration on each side. L-shaped extenders were attached to the calibration in a similar manner as described previously.



Fig 1: Modified articulator – Superior view



Fig 2: Modified articulator –Lateral view

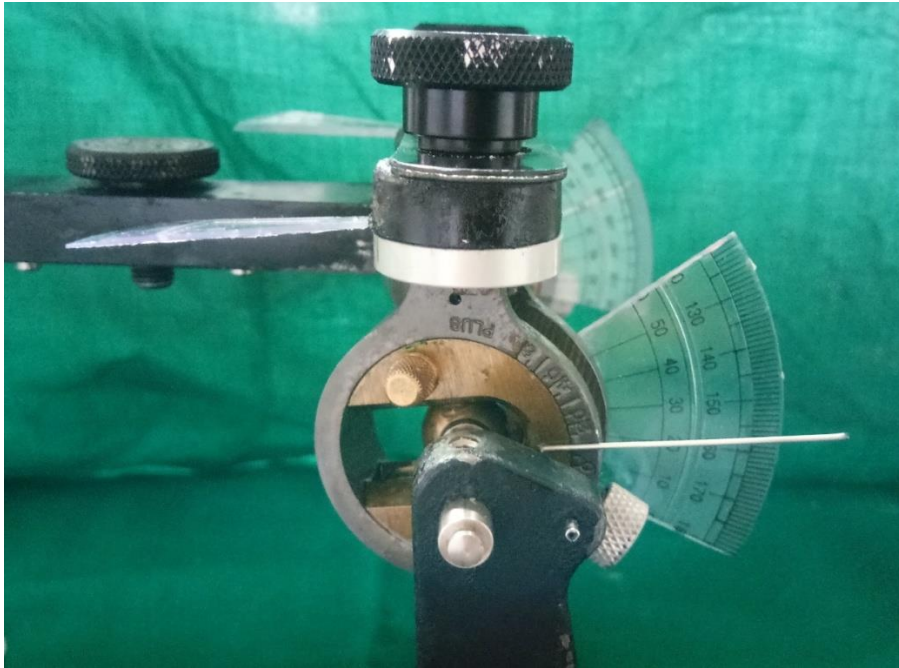


Fig 3 : Modified articulator -

Step 2: Impression making:

Maxillary and mandibular master casts were procured after primary and secondary impression procedures.



Fig 4: Primary Impression

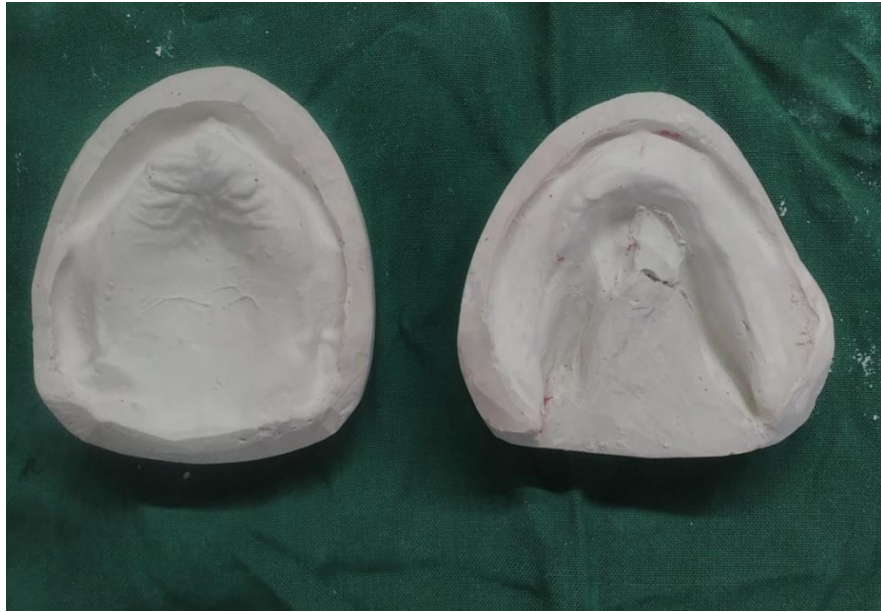


Fig 5: Primary Cast

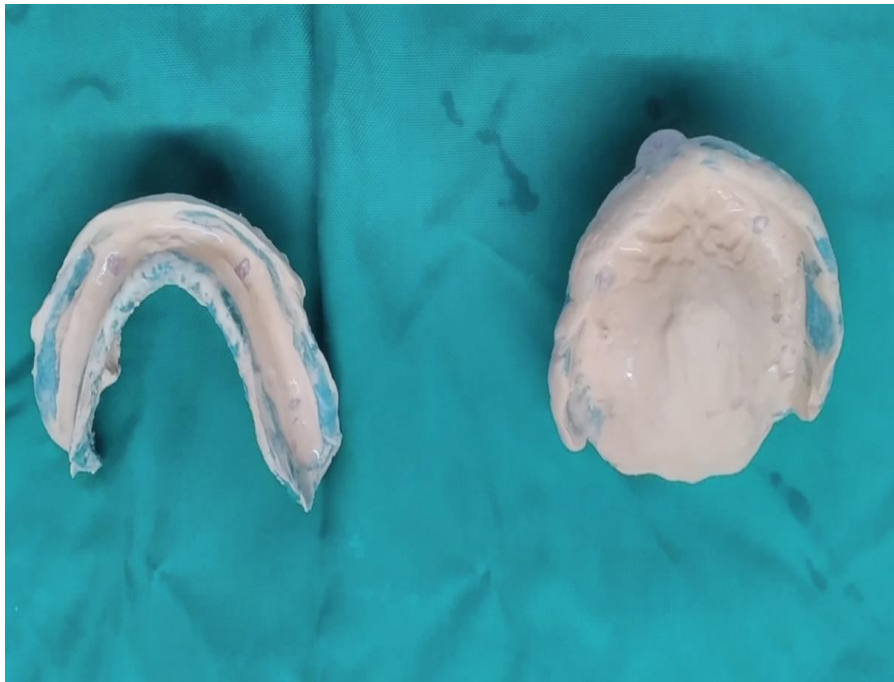


Fig 6: Definitive impression



Fig 7: Definitive cast

Step 3: Vertical dimension establishment:

The occlusal rims were constructed over permanent acrylic record base. The occlusal rims were inserted into the patient's mouth and the vertical dimension at occlusion was recorded by phonetics method as described by M.M.Silverman^{[16],[17],[18],[19]} and E.Pound^[20] using the syllables /S/, /ch/, /jh/. This method of determining the vertical dimension of a patient is scientific, accurate, and practical for every practitioner in the office, without the need of expensive equipment or instrument.^[16] The measured vertical dimension was cross verified by Niswonger's method by using two anatomical landmarks one at the tip of the nose and the other on the chin directly below the nose marking.



Fig 8: Tentative jaw relation

Step 4: Face-bow transfer:

The bite fork of Hanau ear-piece face bow was attached 2 mm above the maxillary occlusal plane which was established previously by using alar-tragal line and Fox plane occlusal analyzer. After the orientation of the bow with the FH plane of the patient using orbitale pointer, the spring-bow was unscrewed from the transfer assembly. The mounting jig was secured on the lower member by the cast support. The transfer assembly was secured onto the mounting platform, and then the maxillary cast is mounted. The mandibular cast was mounted in tentative centric relation position obtained from the patient.



Fig 9: Face bow transfer

Step 5: Gothic Arch Tracing and Interocclusal records preparation:

Central bearing plate and device were attached to maxillary and mandibular occlusal rims along with the Hight's extra oral tracing device. Training exercises were conducted and when the patient is efficient in performing mandibular movements, tracing plate was prepared with eugenol flames and the tracing was recorded by eliciting protrusive, right and left lateral excursive movements. With definite gothic arch tracing, the centric point record and protrusive relation record were made at a distance of 6 mm from the centric relation point on the protrusive tracing by poly vinyl-siloxane material (Jet bite). Right and left lateral interocclusal records were obtained with dental plaster on the basis of the distance travelled from the centric relation point [5 mm] and the placement of the tracing needle point on the previously scribed border movement line.^{[21],[22]}



Fig 10: Gothic arch tracing



Fig 11: Lower occlusal rim with tracing



Fig 12: Arrow point tracing

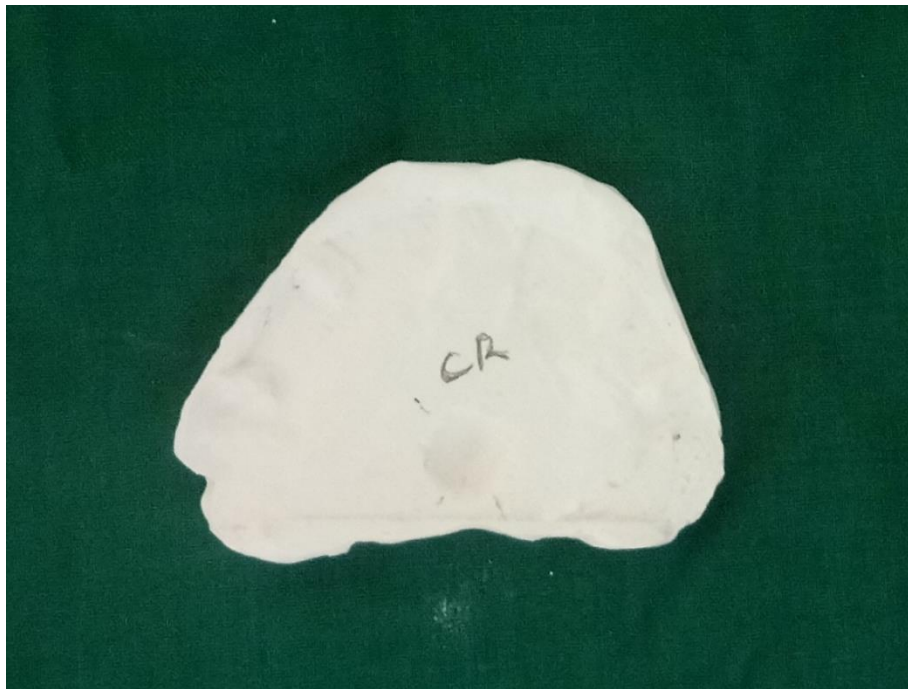


Fig 13: Centric interocclusal record

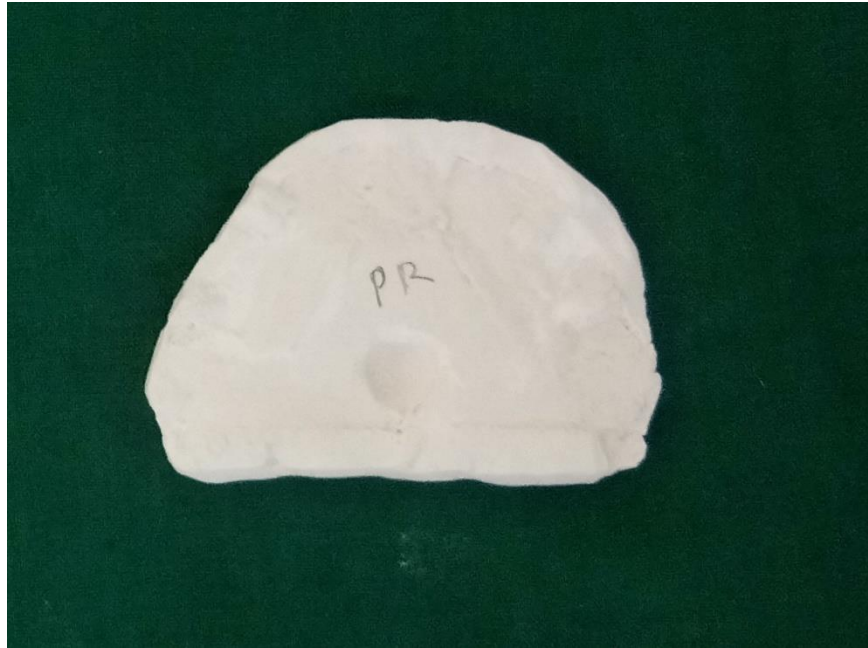


Fig 14: Protrusive interocclusal record

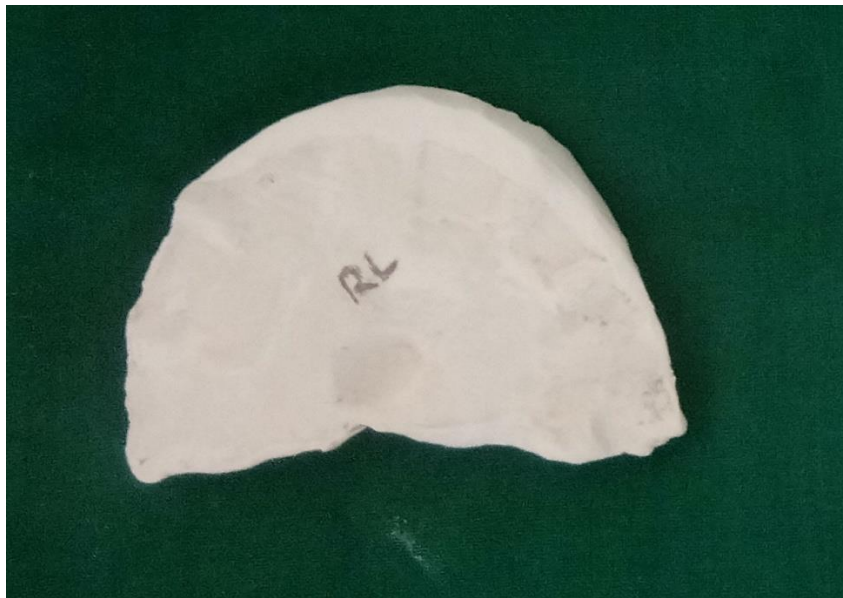


Fig 15: Right lateral interocclusal record

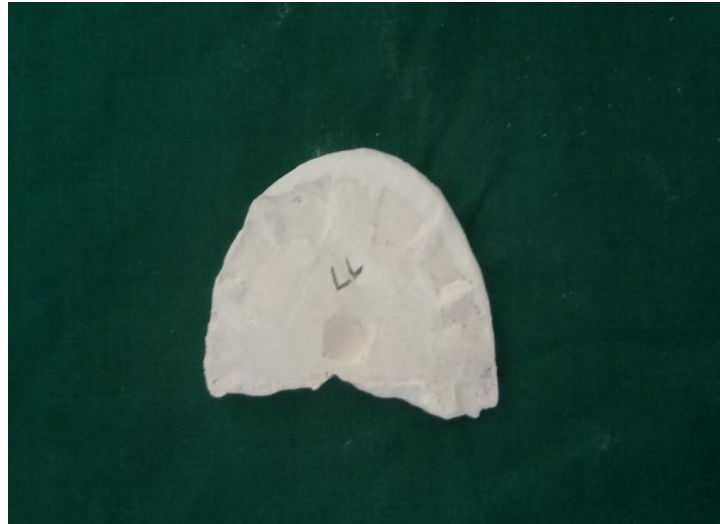


Fig 16: Left lateral inter occlusal record

Step 6: Programming the articulator:

With the protrusive records, the horizontal condylar guidance [H] was adjusted and the Bennett's angle [L] was calculated using the formula $L = \frac{H}{8} + 12$. Plaster of Paris (Orthokal) was used to make protrusive interocclusal records which were then used to program the articulators. Lateral interocclusal records were used to program the Lateral condylar guidance using the value derived from SMV and used to check for occlusal interferences during insertion without much time required which would be annoying for the patient. Another factor added to the objectivity and reduced error was the use of split cast which allowed the observer to accurately ascertain that there was indeed no gap between the two rigid surfaces while programming the articulator.

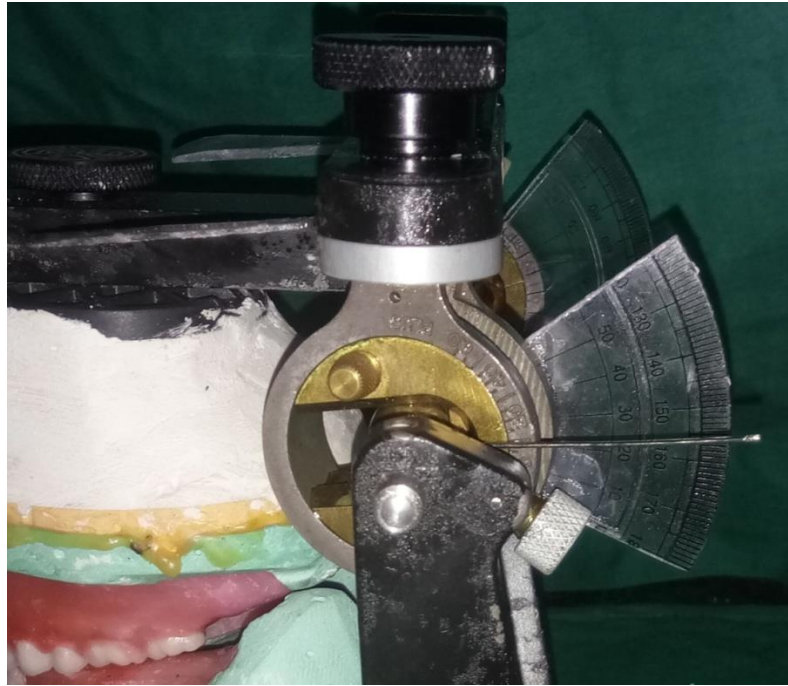


Fig 17: Programmed articulator

Step 7: Sub-Mento-Vertex imaging:

With the tracing device in mouth, cranial radiographs in SMV projection was obtained with Simplex X-ray Equipment ID: G-XR-17931, DX-300. The ear rods were positioned and each patient was asked to rotate the head posteriorly until the FH plane become parallel to the film-cassette. This position was fixed with the aid of the craniostat to allow for reproducibility in the assessment of cranial structure in the horizontal plane ^[12]. An X-ray film inserted in an intensifying cassette was placed next to the vertex of the skull perpendicular to the central beam. The source of radiation was placed at a fixed distance of 150 cm from the centre of cephalostat. The patient was asked to occlude in centric relation record under light pressure during exposure. In the same head position, thereafter the patient was asked to occlude in right lateral interocclusal record and exposed. Similar exposure was done with left lateral interocclusal record. Radiographs were made using an exposure of 60 kV, 15 mA for 0.8 sec and then processed in an automatic processor ^[23].



Fig 18: Extra oral radiographic machine



Fig 19: Extra oral radiographic machine – Closer view



Fig 20: Sub mento vertex radiographic exposure

Step 8: Tracing Bennett's angle:

Each radiograph was traced on the transparent acetate tracing sheet. The centres of the foramina spinosa [trans-spinosa axis: TSA] were connected, and the mid-perpendicular line was drawn to serve as the midline of base of skull ^{[13],[23]} The midline was projected as a parallel line through right and left condylion medialis [R-CoM and L-CoM] which was served as a reference plane [RP] to trace the balancing medial condylar movement. The tracings with lateral condylar position was overlapped on the centric condylar position tracing sheet using the midline. The CoM in centric and balancing positions served as two points for a line. The angle formed between this line and the RP was measured and recorded as Bennett's angle [L].

The Bennett angle obtained from both formula and radiographic tracings were tabulated and subjected to statistical analysis.



Fig 21: Centric SMV view



Fig 22: Right lateral SMV view



Fig 23: Left Lateral SMV view

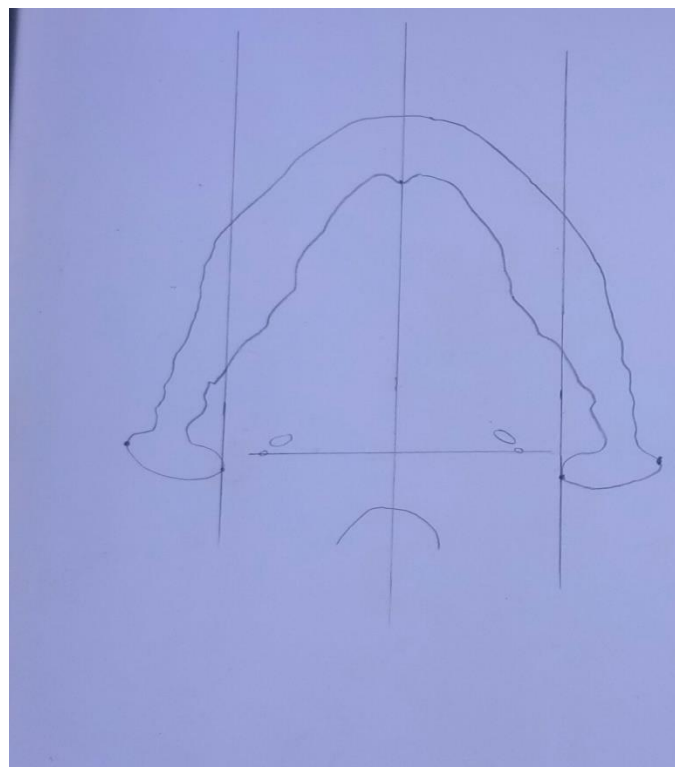


Fig 24: Centric Tracing

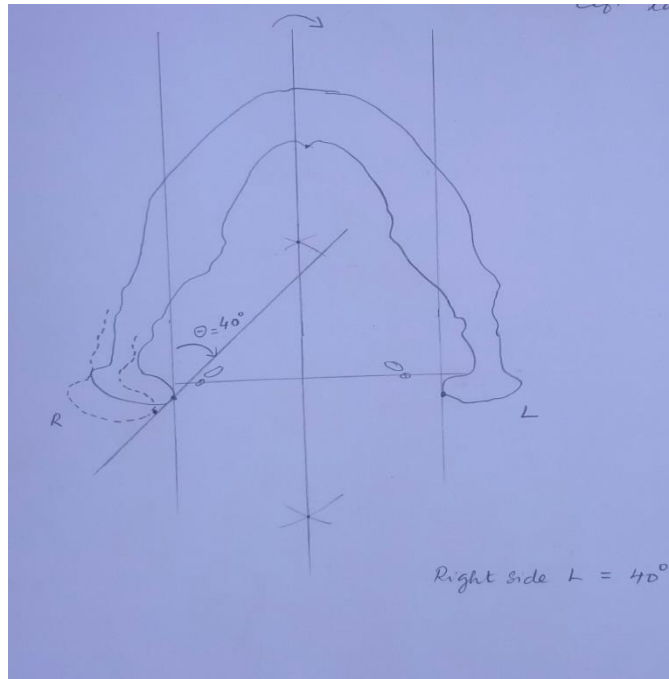


Fig 25: Right Lateral Tracing

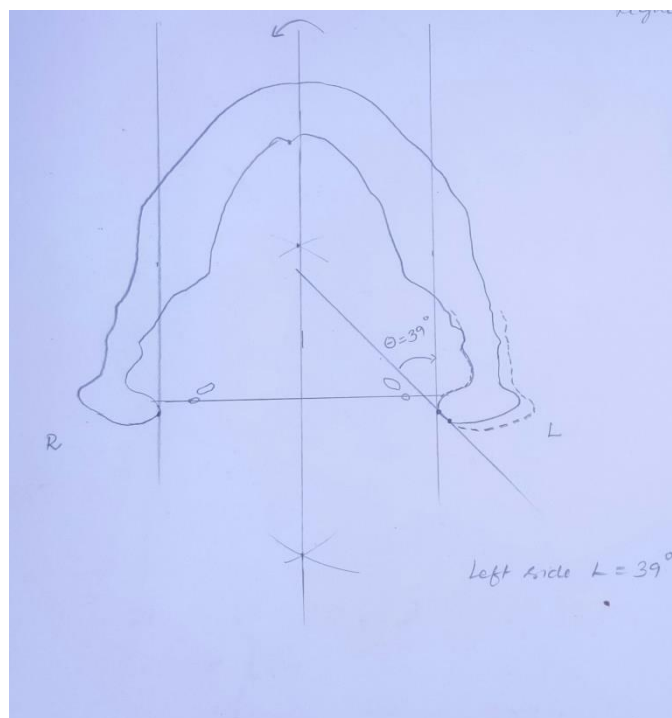


Fig 26: Left Lateral Tracing

RESULT:

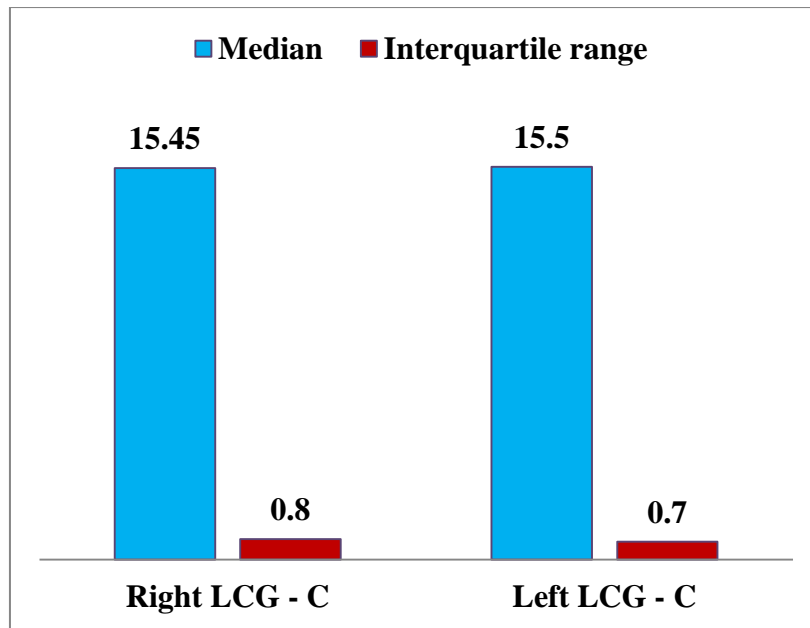
Statistical analyses were performed using Statistical Package for the Social Sciences SPSS software [ver. 18.0; SPSS Inc., Chicago, IL, USA]. The obtained values of LCG, were subjected to normality test and found to be skewed. Hence, Mann-whitney-U test was applied to compare LCG-C & LCG-M on both right and left sides. A p-value less than 0.05 was considered to be statistically significant.

Table -1: Comparison between Right LCG-C and Left LCG-C

Group	Median	Interquartile Range (IQR)	p - value
Right LCG-C	15.45	0.8	0.9
Left LCG-C	15.50	0.7	

* $p > 0.05$, statistically insignificant

Table-1 describes the median (IQR) of right & left LCG-C obtained from the subjects, which were 15.45 (0.8) and 15.50 (0.7) respectively. The difference between right and left LCG-C was not statistically significant ($p=0.9$). This was pictographically represented in Graph-1.



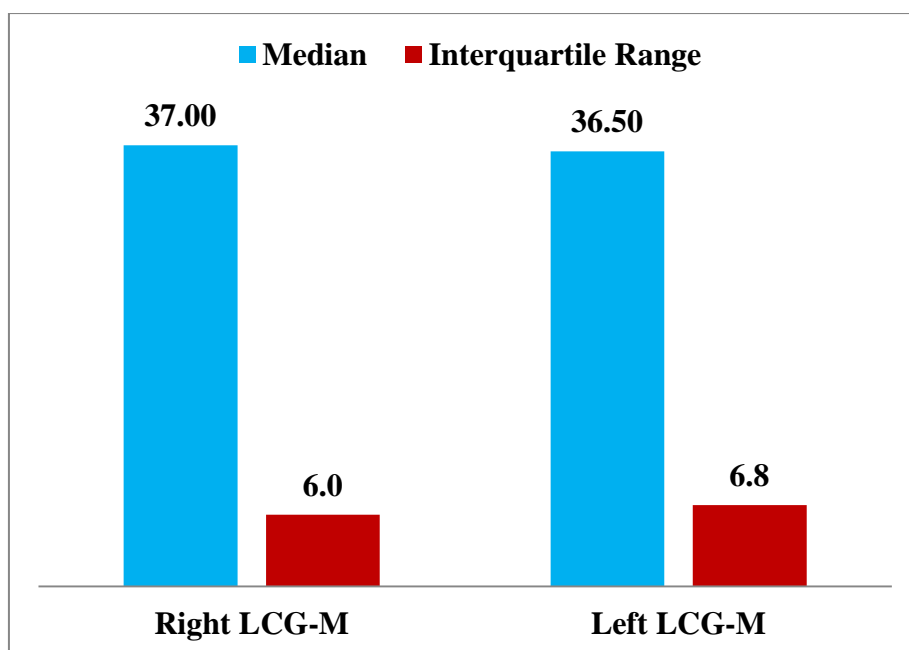
Graph -1: Comparison between Right LCG-C and Left LCG-C

Table – 2: Comparison between Right LCG-M and Left LCG-M

Group	Median	Interquartile Range (IQR)	p - value
Right LCG-M	37.00	6.0	0.63
Left LCG-M	36.50	6.8	

* $p > 0.05$, statistically insignificant

Table-2 describes the median (IQR) of right & left LCG-M obtained from the subjects, which were 37.00 (6.0) and 36.50 (6.8) respectively. The difference between right and left LCG-M was not statistically significant ($p=0.63$). This was pictographically represented in Graph-2.



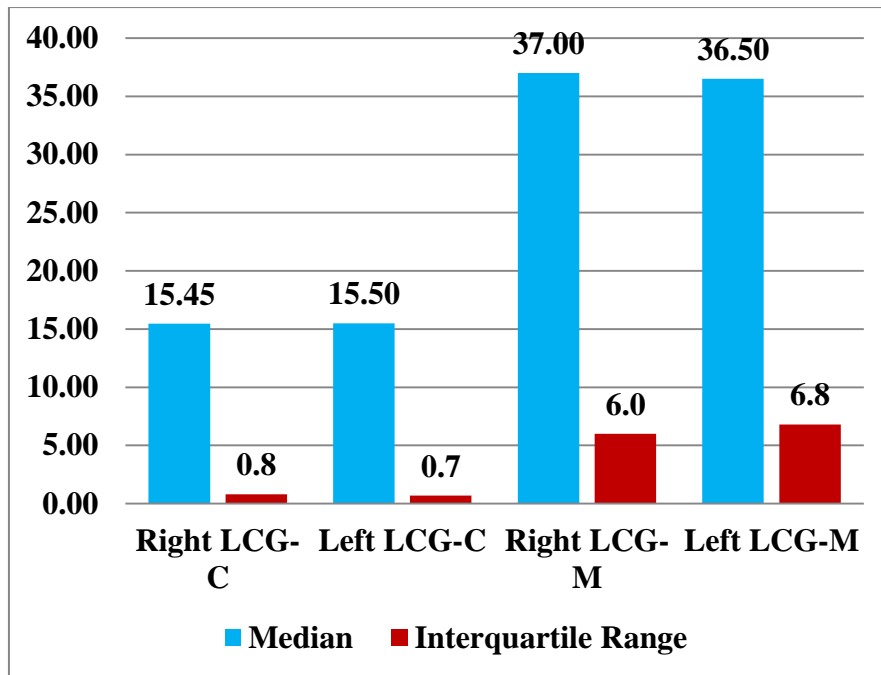
Graph – 2: Comparison between Right LCG-M and Left LCG-M

Table – 3: Comparison between LCG-C & LCG-M on right and left side

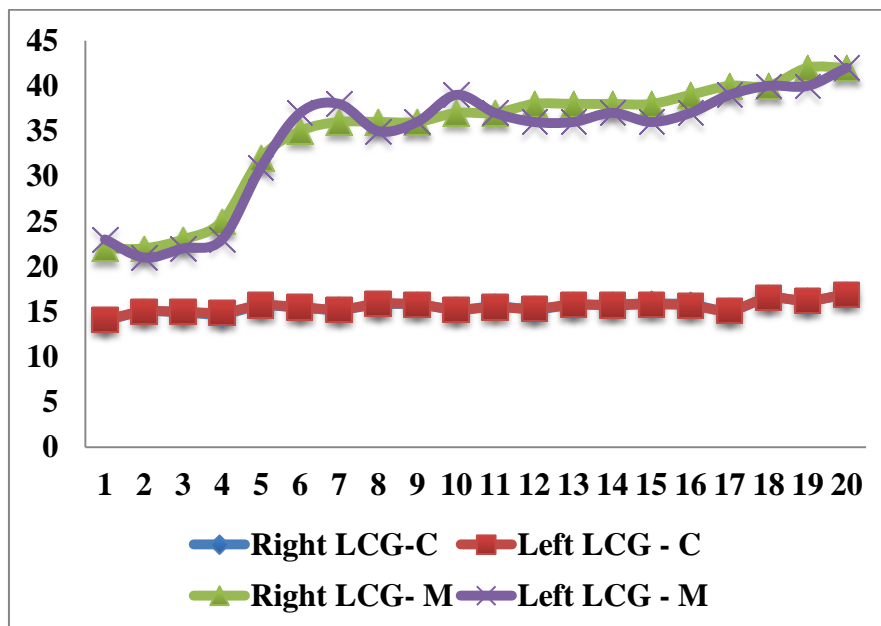
Group		Median	Interquartile Range (IQR)	p - value
Right	LCG-C	15.45	0.8	0.000*
	LCG-M	37.00	6.0	
Left	LCG-C	15.50	0.7	0.000*
	LCG-M	36.50	6.8	

* $p < 0.05$, statistically significant

Table-3, describes the median (IQR) for right LCG-C and LCG-M to be 15.45 (0.8) and 37.00 (6.0) respectively and left LCG-C & LCG-M to be 15.50 (0.7) and 36.5 (6.8) respectively. There exist a statistically significant difference between LCG-C and LCG-M on both sides ($p=0.000$). This was pictographically represented in Graph -3.



Graph – 3: Comparison between LCG-C & LCG-M on right and left side



Graph – 4: Graphical analysis of lateral condylar guidance values obtained using LCG-C and LCG-M on right and left sides

DISCUSSION:

Bennett's angle and movement are directly proportional to the lateral side-shift. Based on the analysis of effects that they have created on morphology of occlusion, it was inferred that greater being the lateral side-shift, more distal will be the working and balancing grooves and fossa in the maxillary teeth, lower will be the cuspal angulation/height of the posterior teeth, and the greater will be the palatal concavity of the maxillary anterior teeth. Contradictorily, the smaller is the lateral side-shift, the higher will be the cuspal angulation/height of the posterior teeth. Therefore, there exist a close relationship between the LCG and the anatomy of the teeth since during the movement, the cusps must not interfere with the antagonist. However, they must move through some well-identified escape-ways which are actually present between grooves and cusps. All the above findings determine the ultimate importance of the registration and the clinical evaluation of the LCG.^[40]

Hanau, in a research, concluded that there was a definite relationship between the inclinations of the horizontal and lateral control settings in articulator. He found that the LCG settings to consistently range approximately around 15°. Stern substantiated that the "Formula" was not exact ever. Hanau presumed more accurate records could be made once all teeth were set to occlusion. He further proposed that remounts [laboratory/clinical] and occlusal grindings were mandatory to refine the occlusion. Hanau, an engineer, did not want to reveal the profession to set the LCG simply at 15°. That would suggest a step back to an use of mean-value articulator.^[41]

Based on the results, prosthodontist and dental laboratory technicians should consider reassessing the present recommended average settings and use of the Hanau's formula for programming the semi-adjustable articulators by means of further research. Eichhold^[35], introduced a formula $[L=1.06 BP - 46]$ to determine the

LCG from intraoral needle-point tracings on a Hanau model H-2 articulator based upon intraoral lateral border paths. Determination of LCG based on a border path can be made through geometrical tracings/drawings.

A statistically significant difference exists between LCG-C using Hanau's formula and LCG-M using SMV projection method. Thus, the data supports rejection of the null hypothesis. The variations in these obtained values will definitely affect the balanced occlusion in the patient's mouth, assuming a wider variation exists in the patient's oral cavity.

There are numerous researches that have been executed produced similar inferences with different techniques. Bhawsar in 2016 ^[14], evaluated and compared the LCG by using the Hanau's formula and the computerized jaw tracking device (Kinesiograph) on the right and left sides. Celar and Tamaki ^[36] demonstrated statistically significant differences between articulator setting and Cadiax compact measurement ($P < 0.05$) and concluded Cadiax compact to have reasonable accuracy for the clinical application. Ratzmann et al. using the JMA electronic recording system found out that the mean horizontal condylar guidance value recorded was significantly higher compared to the values of the protrusive wax record and no agreement found between the different methods.^[42]

LCG-M values exhibited no variation on both sides and there is no significant difference. Thus, the data supports rejection of the null hypothesis for this variable also. It can be assumed that the TMJ anatomy exhibited asymmetry on the right and left sides of the patient. The asymmetry observed may be due to the effect anatomy of the TMJ, laxity of ligaments, and masticatory muscles.^[43] Similarly, Zamacona et al. also found angular differences in the inclination of the condylar path between the left and right sides of their subjects.^[26] Hernandez et al. found no significant differences

between right and left LCG. ^[37] The condylar guidance values obtained using the kinesiograph may be considered more reliable to determine the condylar guidance as it possesses certain advantages over the conventional Gothic arch tracing method used.

Few studies regarding the use of radiograph such as OPG and lateral cephalograph ^[1, 2, 7, 8, 10, 11, 28] for recording the HCG have been documented in the literature. The present study can be a step toward evaluating the validity of the conventionally followed protocols in prosthodontics to record LCG by using SMV projection radiograph and to find more reliable means to overcome their shortcomings. Use of SMV radiography for measuring LCG has not been documented in the literature yet.

To minimize occlusal error in complete dentures that require balanced occlusion and in fixed partial denture occlusion, a semi-adjustable articulator programmed using the LCG-M measured from SMV may be used while recognizing the shortcomings of the articulator, so that less chair-side time is spent to harmonize occlusion.

There are some limitations of the radiographic method such as magnification, distortion, orientation of head and reference planes, and difficulty in distinguishing the anatomical landmark outlines especially with respect to foramina and condylar poles. Though there were difficulties, the landmarks were traced out of the SMV projection radiographs.

However, further research is needed on a larger sample size. If this holds true, more accurate methods using accurate devices such as kinematic face-bow and fully adjustable articulator can be used for further evaluation. Even a semi-adjustable articulator should be considered as diagnostic articulator when used for fixed dental

prosthetic rehabilitation procedures. Similar study can be carried out in dentulous patients. Evaluation on the accuracy of restorations fabricated using the condylar settings obtained from the computerized jaw tracking device also has to be carried out. Comparison of LCG measured by lateral check bite, computerized jaw tracking device and SMV radiograph can be useful for clinicians for further conclusion.

SUMMARY:

An exact mimicking of condylar guidance is of utmost importance for an accurate occlusion for both removable and fixed prosthetic rehabilitation. The condylar guidance can be classified into horizontal [HCG] and lateral guidance [LCG].

HCG is measured from the protrusive records of the patient made in a recording medium and used to programme the semi-adjustable articulator. From the obtained HCG value of the patient LCG is calculated using Hanau's formula $L=H/8+12$. Hence, for a longer time there is always a doubt regarding the reliability and acceptability of the Hanau's formula for L derivation. A novel roentgenographic technique, submentovertex (SMV) projection, has been proposed in this present in-vivo study for arriving at LCG values in Hanau [closed track] Wide-Vue II arcon articulator.

Though in the literature there are numerous techniques to arrive at HCG, using radiographic methods besides clinical methods using inter occlusal records, there is no evidence for derivation of LCG using methods other than the Hanau's formula, except for a technique using electronic jaw tracking device. No one has documented the use of radiographic methods in the derivation of LCG so far. So the main aim of this in vivo study is to arrive at LCG using a innovative technique of SMV radiographic method.

Literature shows the use of SMV radiographic technique in arriving at the midline of the skull drawn perpendicular to the line connecting the right and left foramen spinosum. The mandibular medial pole is well visualized in this view to arrive at LCG of corresponding condyle. This view is chosen as a reliable view as the foramen is the constant structures undergoing no changes throughout life.

Total of twenty completely edentulous patients of age group 40 to 60, without sex differentiation are chosen for the study. Inter-occlusal records like centric and protrusive were made as per the usual protocol. Using protrusive records, HCG value was set, LCG-C is derived from Hanau's formula, thus horizontal and lateral condylar guidance of the semi adjustable articulator were adjusted and programmed. The condylar guidance of the articulator shows the interval calibrated at 5° interval. To accurately measure the condylar guidance and Bennett angle, the protractor was sectioned and modified and attached to the condylar shaft of the articulator. After the programming of the articulator, the condylar guidance and Bennett values were set using the modified protractor with minimum 1° accuracy. The values of right and left sides for twenty patients were tabulated for comparison.

For SMV technique 3 radiographs at centric, right and left positions were made. Using a transparent acetate tracing sheet, the centric, right and left X-rays were overlapped and tracing along the transverse line passing through either foramen spinosa was drawn from both the tracings and mid perpendicular line to this transverse lines is drawn. The same mid line was projected to the balancing condyle for which LCG value was to be derived passing through the most prominent point on the medial pole through the setsquare. The angle between the perpendicular line passing through the condyle and line joining the condylar medial pole at centric, right and left lateral positions were found. Thus the derived LCG-M measured from SMV view were tabulated for both sides for comparison.

Within the limitations of the study, a statistically significant difference between the methods to determine Bennett angle is a good indicator to ascertain Bennett angle radiographically and minimizing the errors in complete dentures caused by the calibration and an arbitrary formula calculation for L. The lateral inter occlusal

records obtained in this study can further be used in the Hanau™ Wide-View articulator to check and correct the occlusal errors by remounting the lower casts with right and left lateral records positioned and corrected for any occlusal interferences, thereby reducing the chair side denture adjustment time and obtaining a successful balanced complete dentures.^[15].

CONCLUSION:

Within the limitations of the study, the following conclusions were deduced;

1. There is no significant difference between the right and left LCG-C and LCG-M.
2. There exist a huge difference between the LCG calculated from the conventional Hanau's formula and LCG measured from the SMV projection radiographs.

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ANNEXURES:

SL. NO.	OP.NO.	PATIENT'S NAME	AGE /SEX	LCG-C		LCG-M	
				Rt	Lt	Rt	Lt
1.	295309	Mr.Thangavel	56/M	15.1	15.3	40	39
2.	266513	Mrs.Selvarani	43/F	15.0	15.1	37	39
3.	257214	Mrs.Janaki	59/F	14.7	14.8	25	23
4.	274084	Mrs.Ponnammal	57/F	15.8	15.8	36	36
5.	273017	Mr.Ponnusamy	56/M	15.3	15.4	32	31
6.	283488	Mr.Rajalingam	60/M	16.0	15.8	42	40
7.	276568	Mr.Chandrasekaran	50/M	15.4	15.5	35	37
8.	265781	Mrs.Susila	51/F	15.7	15.6	38	37
9.	275452	Mr.Duraisamy	55/M	15.7	15.6	39	37
10.	270058	Mr.Kuppusamy	58/M	16.3	16.0	42	42
11.	289448	Mrs.Mariayee	60/F	15.7	15.8	38	36
12.	279831	Mr.Ramasamy	60/F	14.0	14.1	22	23
13.	237983	Mr.Kumarasamy	60/M	15.2	15.2	36	38
14.	267345	Mr. Chinnappaiyyan	60/F	15.2	15.3	38	36
15.	284774	Mrs.Bakyam	60/F	16.3	16.0	40	40
16.	312442	Mr.Govindhan	60/M	14.5	14.2	22	21
17.	313068	Mrs.Suseela	54/F	15.5	15.5	37	37
18.	275690	Mrs.Marayee	60/M	15.7	15.8	36	35
19.	278456	Mr.Kaliyannan	60/M	15.9	15.8	38	36
20.	273485	Mr.Muthusamy	59/M	14.1	14.5	23	22



INSTITUTIONAL ETHICS COMMITTEE VIVEKANANDHA DENTAL COLLEGE FOR WOMEN

SPONSORED BY : ANGAMMAL EDUCATIONAL TRUST

Ethics Committee Registration No. ECR/784/Inv/TN/2015 issued under Rule 122 DD of the Drugs & Cosmetics Rule 1945

Baby John	Chair Person	Dr. (Capt.) S. Gokulanathan	Member Secretary
K. Jayaraman	Social Scientist	Mr. A. Thirumorthy	Legal Consultant
R. Jagan Mohan	Clinician	Dr. N. Meenakshiammal	Medical Scientist
M. T. Suresh	Scientific Member	Dr. R. Natarajan	Scientific Member
Arasu Philip	Scientific Member	Mr. Kamaraj	Lay Person

No: VDCW/IEC/39/2016

Date: 05.11.2016

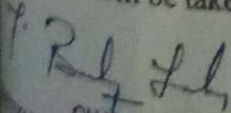
TO WHOMSOEVER IT MAY CONCERN

Principal Investigator: Dr. K.Praveena

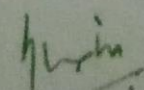
Title: Evaluation of lateral condylar guidance by clinical and radiographic methods – Hanau's formula revisited.

Institutional ethics committee thank you for your submission for approval of above proposal .It has been taken for discussion in the meeting held on 25 .10.16.The committee approves the project and it has no objection on the study being carried out in Vivekanandha Dental College For Women.

You are requested to submit the final report on completion of project. Any case of adverse reaction should be informed to the institutional ethics committee and action will be taken thereafter.


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