Evaluation of Sagittal Inclination of Occlusal Plane and Horizontal Condylar Guidance Using Various Anterior Reference Points on Arcon and Nonarcon Articulators

Abstract

Aim: The aim of the study was to determine the effect of different anterior reference points during facebow transfer, on sagittal inclination of occlusal plane (SIOP) and horizontal condylar guidance (HCG) values obtained on arcon and nonarcon articulators.

Materials and Methods: Facebow records of 25 participants were made and transferred to Hanau Wide-Vue (WV) and Hanau H2 (H2) articulators using conventional indirect transfer (CIT), superior annular groove (SAG), and inferior annular groove (IAG) as anterior reference points. Maxillary casts were mounted on each articulator followed by mandibular mountings. Protrusive interocclusal record was used to determine HCG, and SIOP was measured as an angle between the occlusal plane of mounted maxillary cast and upper member of the articulator. Both, HCG and SIOP were measured on a digital lateral cephalogram and the values obtained were compared with previously determined values from both the articulators. Intergroup comparison was done by analysis of variance and pair-wise comparison by Tukey post hoc test.

Results: Values of SIOP significantly (P = 0.00) changed on both the articulators when CIT, SAG, and IAG were the anterior reference points. The ratio of SIOP and HCG on both articulators was comparable to that of the cephalogram for CIT, IAG, but it was substantially low for SAG. Conclusions: The variation of anterior reference point changes the value of SIOP recorded on Hanau WV and H2 articulators; however, it had no effect on HCG values recorded on both the articulators. The angle between SIOP and HCG changed with variations in superior-inferior position of the mountings on both articulators.

Keywords: Annular groove, anterior reference point, horizontal condylar guidance, indirect transfer, sagittal inclination of occlusal plane

Introduction

A semi-adjustable articulator is a device that allows adjustments to simulate average mandibular movements. It can be classified as arcon and nonarcon type based on the location of articulating fossa and condyles. It is believed that an arcon articulator can reproduce more precise mandibular movements than nonarcon to achieve a harmonious occlusion. Weinberg believed that both the articulators generate similar movements and that arcon articulator has no clinical advantage over nonarcon. However, contrary reports exist regarding the supremacy of arcon over nonarcon articulators.

In order to obtain a successful dental restoration, an accurate transfer of records from the patient to the articulator should be made. The transfer of three-dimensional spatial relationship of the maxillary arch to the cranial structures, and the mandible to the arc of opening, is then simulated on an articulator. This transfer is made with a facebow using two posterior reference points and an anterior reference point to accurately position a maxillary cast on an articulator. When the Frankfort plane is parallel to the floor, a facebow provides the effect of orienting the occlusal plane (OP) to the opening axis of an articulator in the same way that it is viewed in the mouth. Hanau Wide-Vue (WV) and Hanau H2 (H2) articulators have superior (37 mm) and inferior (54 mm) annular grooves on the incisal guide pin below the Frankfort Horizontal Plane (FHP). The 37 mm groove is based on part on the Bonwill Triangle and results in a horizontal
appearing OP. The 54 mm groove is based on the research by Frank R. Lauciello and Marc Appelbaum. Manufacturers of Hanau articulators have claimed that these grooves can be used as arbitrary vertical landmarks for orientation of the incisal edge of the maxillary centrals while making a facebow transfer.

Wilkie stated that the use of the anterior reference points must be well coordinated in order to avoid inadvertent changes in the sagittal inclination of occlusal plane (SIOP). Many clinicians have stated that the appropriate selection of an anterior point of reference on the FHP is vital in prosthetic procedures for esthetic reasons and also for establishing a correct OP. An inaccurate reproduction of steepness of the OP can significantly affect function and esthetics and possibly result in an unstable prosthesis.

Weinberg noted that, as the OP is elevated, the condylar guidance decreases and when the OP is lowered, the horizontal condylar guidance (HCG) increases. Inclination of HCG can be recorded by various intra- and extra-oral methods. It can be recorded indirectly using the patient’s protrusive interocclusal records on the articulator or by radiographic methods. Among them, lateral cephalograms precisely denote the outline of the articular eminence and thus can be used as an aid in setting condylar guidance inclination of a semi-adjustable articulator.

It is critical to record accurate condylar guidance during the fabrication of a dental restoration, else it can cause occlusal interferences in the prosthesis during mandibular movements. This may lead to an increase in chair-side denture adjustment time, which can be frustrating for both the patient and the dentist. The literature available on the effect of using different anterior reference points on condylar guidance and sagittal plane of occlusion in arcon and nonarcon articulators is scarce. Thus, this study aimed to evaluate the effect of using conventional indirect transfer (CIT), superior annular groove (SAG), and inferior annular groove (IAG) as anterior reference points, on SIOP and HCG in Hanau WV and H2 articulators. The null hypothesis was that the variation in anterior reference point had no effect on SIOP and HCG values.

Some authors have stated that the relationship between the HCG and SIOP does not change with change in the SIOP. This was evaluated by checking the ratio of the angles between the SIOP and HCG for all anterior reference points.

Materials and Methods

In the present study, 25 dentulous participants, from 18 to 30 years age of either sex, were enrolled. The sample size for the study was determined by convenience sampling procedure. Ethics approval was obtained from the Research Ethics Committee of the institute. The inclusion criteria for selection included participants with full complement of teeth (with or without third molars), Angle’s Class I molar relation, and those who consented for the study. Participants with temporomandibular disorders, progressive periodontal disease, and gross attritions were excluded from the study.

The study was performed in two parts. In the first part, two sets of irreversible hydrocolloid impressions (Zelgan 2002; Dentsply Sirona) were made for each of the 25 participants and poured in Type III dental stone (Dental Stone: Kalabhai). The protrusive interocclusal records of all the participants with the teeth in maximum intercuspal position and edge-to-edge position were made using polyvinyl siloxane bite registration material (Orangebite; Medicept). The facebow was recorded using the Hanau Spring-Bow (Whip Mix Corp), which was transferred onto Hanau WV and H2 (Whip Mix Corp) articulator by CIT [Figure 1a and b], SAG [Figure 2a and b], and IAG [Figure 3a and b] as anterior reference points, respectively. One set of maxillary cast was mounted on a Hanau WV and the other on H2 using a mounting platform (Item no. 010342-000, Whip Mix Corp) with CIT as an anterior point of reference. The mandibular cast was then mounted using an interocclusal record in maximum intercuspal position. HCG was determined using protrusive interocclusal record. The left HCG angles obtained on both the articulators were recorded [Figure 4a]. The OP was denoted as the line extending from the incisal edge of the maxillary central incisor to the mesiobuccal cusp tip of the first molar. The inclination of the maxillary OP is the angle formed between the OP and upper member of the articulator. A digital protractor (Digital level and protractor; Insize Corp) was used to measure this angulation. The protractor was regulated so that the horizon equaled 0.0°. A glass slab was held against the teeth of the maxillary mounted cast, the digital protractor was placed on the glass slab, and the displayed value was recorded [Figure 4b].

The same set of cast and facebow was then mounted on Hanau WV and H2 articulator using SAG (37 mm) as
an anterior point of reference. The facebow was adjusted using an anterior elevator (Item no. 010358-000, Whip Mix Corp) to confine the incisal edges of the maxillary cast at the level of SAG of the incisal guide pin. The cast support was elevated to contact the bitefork and locked in site by the thumbscrew to stabilize and carry the weight of the cast. Similar procedure was followed for mounting the same set of maxillary cast on Hanau WV and H2 articulators using IAG as an anterior reference point. The procedures for programming and recording values of SIOP and HCG were similar to those performed for CIT on both the articulators.

In the second part of the study, two standardized left side lateral cephalograms were taken for each participant— one at maximum intercuspal position and the other at edge-to-edge position. The lateral cephalograms were subjected to the dolphin imaging software (Dolphin Imaging and Management Solutions) for analysis. On each digital lateral cephalogram, the outline of the overlapped condyles was traced with the help of annotations and measurement tool. The superior most point of the traced outline on both the condyles was identified, and a line was drawn joining the two points. The midpoint of condyle on this line was considered as the condylyon. Digitization of the image was carried out by tracing the landmarks which were porion, orbitale, and condylyon. It was standardized by tracing the images with fixed X and Y axis millimetric settings available in the Dolphin software, and these settings were kept same for each participant. After digitization, both the images were superimposed with the help of overlay tool. FHP and OP were traced on superimposed lateral cephalograms and the reading obtained was noted down as value of SIOP [Figure 5]. For measuring the value of HCG, the condylyon at both the condyles, i.e., at maximum intercuspal position and edge-to-edge position, were identified and a line was drawn joining the two points. The angle that formed between FHP and this line was recorded as HCG [Figure 6]. The above procedure for measuring the value of SIOP and HCG was repeated three times by the same operator, and the mean was calculated and recorded.
The SIOP and HCG values obtained from the lateral cephalogram were compared with previously measured SIOP and HCG values on the Hanau WV and H2 articulators. Data were compiled in a spreadsheet (Excel 2010; Microsoft Corp). Ratio of SIOP and HCG was calculated for each patient and compared. The measures of SIOP and HCG on the Hanau WV, H2 articulators, and lateral cephalograms were subjected to statistical analysis using statistical software (SPSS v 21.0, Armonk, NY: IBM Corp). Descriptive statistics such as frequencies and percentage for categorical data and mean and standard deviation (SD) for numerical data have been depicted. Normality of numerical data was checked using Shapiro–Wilk test, and it was found that the data followed a normal curve; hence, parametric tests were used for comparisons. Intergroup comparison (>2 groups) was done using one-way analysis of variance (ANOVA) followed by pair-wise comparison using Tukey posthoc test. For all the statistical tests, \( P < 0.05 \) was considered statistically significant, keeping \( \alpha \) error at 5% and \( \beta \) error at 20%, thus giving a power to the study of 80%.

**Results**

The mean and SD measures of SIOP and HCG values recorded using the three anterior reference points on Hanau WV and H2 articulators, and values obtained on lateral cephalogram are presented in Table 1.

Results of ANOVA show statistically high significant difference for the values between the groups for SIOP \( (P = 0.000) \) and statistically significant difference for the values between the groups for HCG \( (P = 0.031) \) [Table 1] recorded using CIT, SAG, and IAG as anterior reference points on Hanau WV and H2 articulators and values obtained on lateral cephalogram.

Statistically significant difference was observed between SIOP values obtained on CIT Hanau WV (mean 11.48°) and CIT H2 (mean 11.04°) with lateral cephalogram (mean 8.32°) \( (P < 0.05) \), while there was a statistically nonsignificant difference for the values between CIT Hanau WV and CIT H2 \( (P > 0.05) \) [Graph 1].

Statistically significant difference was seen between SIOP values obtained on SAG Hanau WV (mean: 3.95°) and SAG H2 (mean: 5.18°) with lateral cephalogram (mean: 8.32°) \( (P < 0.05) \), while there was a statistically nonsignificant difference seen for the values between SAG Hanau WV and SAG H2 \( (P > 0.05) \) [Graph 1].

The SIOP values obtained on Hanau WV and H2 articulators using IAG and lateral cephalogram show statistically significant difference between IAG Hanau WV (mean 12.30°) and IAG H2 (mean 12.87°) with lateral cephalogram (mean 8.32°) \( (P < 0.05) \), while there was a statistically nonsignificant difference seen for the values between IAG Hanau WV and IAG H2 \( (P > 0.05) \) [Graph 1].

The HCG values obtained on Hanau WV by CIT (mean 41.68°), SAG (mean 41.60°), and IAG (mean 45.24°) and on H2 by CIT (mean 44.92°), SAG (mean 44.24°), and IAG (mean 50.76°) when compared to lateral cephalogram, (mean 46.26°) nearly gave similar results, and the difference between them was not significant \( (P > 0.05) \). The difference between Hanau WV and H2 articulators was insignificant in all the groups for HCG.

A ratio of SIOP and HCG values of each subject obtained using different anterior reference points on Hanau WV and H2 articulators and lateral cephalogram was calculated. These ratios were compared and evaluated for any variation.

**Discussion**

The variation in anterior reference point exhibited significant difference in the value of SIOP obtained on Hanau WV and H2 articulators when compared with lateral cephalogram; therefore, the null hypothesis was rejected. The variation in anterior reference point showed no significant difference in the HCG values which satisfied the null hypothesis.

Hanau Spring-Bow utilizes orbitale as an anterior reference point and it can be transferred directly or indirectly on Hanau WV and H2 articulators. These articulators also have superior and IAGs on the incisal guide pin. The manufacturers of Hanau articulator state that these points have superior and IAGs on the incisal guide pin. The manufacturers of Hanau articulator state that these points can also be used alternatively as anterior reference points.[7] A total of three anterior reference points are suggested by the manufacturers – CIT, SAG, and IAG. The effect of this variation in anterior reference points on SIOP and HCG has been evaluated in the present study.

The findings of the present study revealed that the values of SIOP obtained using CIT, SAG, and IAG as reference points on Hanau WV and H2 articulators were significantly different when compared to SIOP values obtained from lateral cephalogram as shown in Table 1. Shetty et al. Nazir and Sujesh. in their respective studies found that the SIOP value on the Hanau WV was closer to the individual’s OP.
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as measured on the cephalogram.\textsuperscript{[16,19]} Nazir and Sujesh also stated that the reproducibility of SIOP on an articulator by a facebow was not exact.\textsuperscript{[19]} In the present study, the SIOP value obtained by Hanau WV and H2 articulator using CIT was found to be closer to the cephalometric SIOP value. The difference in the mean value of SIOP obtained on Hanau WV and H2 articulators was statistically nonsignificant.

The values of HCG obtained using CIT, SAG, and IAG as reference points on Hanau WV and H2 articulators showed no significant difference when compared to HCG values obtained from lateral cephalogram as shown in Table 1. This finding is in accordance with the finding of Prajapati \textit{et al.}, wherein, he concluded that arcon and nonarcon articulators showed no significant difference in condylar guidance values when different anterior reference points were used.\textsuperscript{[14]} In the present study, on using IAG, highest protrusive condylar guidance value was obtained, which is in accordance with the findings of Prajapati \textit{et al.}\textsuperscript{[14]} and Nooji and Suresh.\textsuperscript{[18]} In the present study, HCG values obtained on Hanau WV using IAG and on H2 using CIT were closer to the cephalometric HCG value. According to a previously reported study, the angle between SIOP and HCG remains constant irrespective of the supero-inferior position of the mounted casts.\textsuperscript{[17]}

In the current study, when the ratio of SIOP and HCG of each patient recorded on Hanau WV articulator and lateral cephalogram were compared, it was observed that 17 patients (68%) had nearly similar ratios (+0.07) for CIT and IAG, whereas for SAG, it was substantially low.

**Table 1: Comparison of sagittal inclination of occlusal plane and horizontal condylar guidance values recorded on articulator and lateral cephalogram**

|          | Minimum | Maximum | Mean   | SD      | $F$   | $P$ of one-way ANOVA |
|----------|---------|---------|--------|---------|-------|----------------------|
| SIOP     |         |         |        |         |       |                      |
| CIT WV   | 7       | 17      | 11.48  | 2.784   | 42.056| 0.000**              |
| CIT H2   | 7       | 17      | 11.04  | 3.273   |       |                      |
| SAG WV   | 1       | 8       | 3.95   | 2.139   |       |                      |
| SAG H2   | 2       | 15      | 5.18   | 2.731   |       |                      |
| IAG WV   | 7       | 17      | 12.30  | 2.946   |       |                      |
| IAG H2   | 7       | 20      | 12.87  | 2.914   |       |                      |
| Lat. Ceph| 4       | 14      | 8.32   | 2.261   |       |                      |
| HCG      |         |         |        |         |       |                      |
| CIT WV   | 10      | 58      | 41.68  | 11.936  | 2.378 | 0.031*               |
| CIT H2   | 22      | 60      | 44.92  | 10.140  |       |                      |
| SAG WV   | 15      | 66      | 41.60  | 11.969  |       |                      |
| SAG H2   | 14      | 60      | 44.24  | 12.289  |       |                      |
| IAG WV   | 30      | 60      | 45.24  | 8.987   |       |                      |
| IAG H2   | 38      | 60      | 50.76  | 7.055   |       |                      |
| Lat. Ceph| 34      | 57      | 46.26  | 6.400   |       |                      |

*Statistically significant difference (\(P<0.05\), **Statistically highly significant difference (\(P<0.01\), *Non significant difference (\(P>0.05\).

SIOP: Sagittal inclination of occlusal plane; HCG: Horizontal condylar guidance; CIT: Conventional indirect transfer; SAG: Superior annular groove; IAG: Inferior annular groove; Lat. Ceph: Lateral cephalogram; WV: Hanau Wide-Vue articulator; H2: Hanau H2 articulator; SD: Standard deviation; ANOVA: Analysis of variance

![Graph 1: Intergroup comparison of sagittal inclination of occlusal plane values obtained articulator and lateral cephalogram](image1)

![Graph 2: Intergroup comparison of horizontal condylar guidance values obtained on articulator with lateral cephalogram](image2)
in 24 patients (96%). Similarly, when the ratio of SIOP and HCG recorded on H2 articulator were compared to that obtained from lateral cephalogram for each patient, it was found that 19 patients (76%) showed nearly similar ratio (+0.07) for CIT and IAG, whereas for SAG, it was substantially low in 19 patients (76%). These findings suggest that if the maxillary cast is mounted superiorly on an articulator, the ratio of SIOP and HCG will decrease considerably and the angle between SIOP and HCG will increase. It can be implied that the angle between the SIOP and HCG does not remain the same when the supero-inferior position of the mounting is changed. Thus, the accurate reproduction of reference plane using third point of reference is required for mounting in both the articulators.

Conclusions

Based on the findings of this clinical study, the following conclusions can be drawn:

1. The variation of anterior reference points significantly changes the value of SIOP obtained on Hanau WV and H2 articulators. However, this variation does not affect the HCG values obtained on both the articulators. The value of SIOP recorded on Hanau WV and H2 articulators using CIT was closer to the SIOP value obtained on the lateral cephalogram.

2. The value of HCG recorded on Hanau WV using IAG and on H2 using CIT was closer to the HCG value obtained on lateral cephalogram.

3. The angle between SIOP and HCG changes with change in the supero-inferior position of the mounting in WV and H2 articulators. Thus, it signifies the need of using third point of reference for mounting maxillary cast in both articulators.

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Conflicts of interest

There are no conflicts of interest.

References

1. Ferro KJ, Morgano SM. The glossary of prosthodontics terms, edition nine. J Prosthet Dent 2017;117:e1-05.
2. Heartwell CM Jr., Rahn AO. Syllabus of Complete Dentures. Philadelphia: Lea and Febiger; 1975. p. 113.
3. Bergstrom G. On the reproduction of dental articulation by means of articulators. Acta Odontol Scand Suppl 1950;9:3-149.
4. Prajapati P, Sethuraman R, Naveen YG, Patel J. A clinical study of the variation in horizontal condylar guidance obtained by using three anterior points of reference and two different articulator systems. Contemp Clin Dent 2013;4:162-9.
5. Bailey JO Jr., Nowlin TP. Evaluation of the third point of reference for mounting maxillary casts on the Hanau articulator. J Prosthet Dent 1984;51:199-201.
6. Gordon SR, Stoffer WM, Connor SA. Location of the terminal hinge axis and its effect on the second molar cusp position. J Prosthet Dent 1984;52:99-105.
7. Whip Mix Corporation. Illustrated Instruction Manual for HANAU™ WIDE-VUE Articulators. Fort Collins: Waterpik Technologies; 2008.
8. Wilkie ND. The anterior point of reference. J Prosthet Dent 1979;41:488-96.
9. O’Malley AM, Milosevic A. Comparison of three facebow/semi-adjustable articulator systems for planning orthognathic surgery. Br J Oral Maxillofac Surg 2000;38:185-90.
10. Weinberg LA. An evaluation of face-bow mounting. J Prosthet Dent 1961;11:32-42.
11. Shreshtha P, Jain V, Bhalla A, Pruthi G. A comparative study to measure the condylar guidance by the radiographic and clinical methods. J Adv Prosthodont 2012;4:153-7.
12. Goyal MK, Goyal S. A comparative study to evaluate the discrepancy in condylar guidance values between two commercially available arcon and non-arcon articulators: A clinical study. Indian J Dent Res 2011;22:880.
13. Singh S, Das S, Bhattacharyya J, Ghosh S, Goel P, Dutta K. A comparative study to correlate between clinically and radiographically determined sagittal condylar guidance in participants with different skeletal relationships. J Indian Prosthodont Soc 2017;17:175-82.
14. Chitre V. Need for an anterior point of reference in face bow transfer: The changing viewpoint. Changing concepts regarding anterior reference point. J Indian Prosthodont Soc 2006;6:112-4.
15. Ercoli C, Graser GN, Tallents RH, Galindo D. Face-bow record without a third point of reference: Theoretical considerations and an alternative technique. J Prosth Dent 1999;82:237-41.
16. Shetty S, Shenoy KK, Sabu A. Evaluation of accuracy of transfer of the maxillary occlusal cant of two articulators using two facebow/semi-adjustable articulator systems: An in vivo study. J Indian Prosthodont Soc 2016;16:24852.
17. Palaskar JN, Joshi N, Gullapalli P, Shah P. Comparative evaluation of sagittal inclination of the occlusal plane with Frankfort horizontal plane in face bow transfers to semi-adjustable and fully adjustable articulators. J Prosthet Dent 2020;123:299-304.
18. Nooji D, Suresh Sajjan MC. The third point of reference and its effect on the protrusive condylar guidance angles obtained in semi-adjustable articulator. J Indian Prosthodont Soc 2008;8:71-7.
19. Nazir N, Sujesh M, Kumar R, Sreenivas P. Accuracy of two face-bow/semi-adjustable articulator systems in transferring the maxillary occlusal cant. Indian J Dent Res 2012;23:437-42.