A clinical study of the variation in horizontal condylar guidance obtained by using three anterior points of reference and two different articulator systems

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Abstract

Background and Objectives: For mounting the maxillary cast to articulator, minimum three reference points not on single line, decide the plane to which maxillary cast is mounted. Variations exist in condylar guidance when different anterior reference points are used to mount the cast. Type of articulator may have influence on condylar guidance. A clinical study was planned to evaluate the effects of different anterior points of reference and two different articulator systems on condylar guidance.

Materials and Methods: Total 15 subjects were selected. Six sets of maxillary casts were obtained. Face bow record was made using orbitale as anterior point of reference and the record was transferred to the Arcon and Non-Arcon articulator. The second and third mounting on Arcon and Non-Arcon articulator were done using Superior and inferior annular groove on incisal pin of articulator. Protrusive interocclusal records were made for all the subjects. Two lateral cephalograms one in maximum intercuspation and the other in protrusion for left and right side were taken. Anatomic condylar guidance of the subject were obtained from radiograph tracing. Arcon and Non-arcon articulator were programmed with Protrusive interocclusal record of the subjects and the condylar guidance was tabulated for right and left side. The procedure was repeated for all three mountings for both the articulators. Results: The orbitale is the best reference point which mounts maxillary cast closer to anatomic position. Inferior annular groove can also be used as anterior point of the reference. The superior annular groove is not recommended anterior point of reference.

Keywords: Anterior point of reference, Arcon articulator, condylar guidance, Non-Arcon articulator

Introduction

Oral rehabilitation presents various clinical situations needing fabrication of prostheses satisfying the functional and aesthetic requirement of the patients. Fabricating these prostheses is often carried out indirectly in the absence of the patient on an articulator. Semi adjustable articulators are widely used due to their ease in programming compared with complex fully adjustable articulators. They are classified as Arcon and Non-Arcon type based on the basis of location of articulating fossa and condyles.

The Arcon and Non-Arcon principle in articulator design may be a factor affecting the perception of position of the jaws to the condyles. In an Arcon articulator, a constant relationship always exists between the maxillary occlusal plane and the condylar guides in any eccentric positions of the upper member.[1] Therefore, the distance between the hinge axis and mandibular teeth in the articulator remains the same as found in the patient’s mouth. Furthermore, the reproduction of mandibular movements is more accurate than with a Non-Arcon instrument and a harmonious occlusion is more easily achieved.[2,3] Contrary reports do exist that Arcon and Non-Arcon articulators produce the equivalent movements, and also that clinically the Arcon concept has no advantage.[1,4]

Prior to making of the prosthesis the jaws are to be positioned on the articulator in the three dimensions of space. This needs the recording of the orientation, vertical, and horizontal relation. Positioning the maxillary arch relationship to all condylar motion on the articulator is carried out by both arbitrary and scientific means. However, this orientation is performed to achieve two major objectives of restoration, i.e., occlusion and control of the form and the position of the teeth.

Mounting the maxillary cast arbitrarily on the articulator, with subconscious or decisive neglect will result in unnatural advent and damage to the supporting tissue.[5] The maxillary cast in the articulator is the base line from which all occlusal relationship starts, and it should be positioned in space by identifying three points, which are not located on the
same line. A three dimensional object must have at least three separate points of reference to orient and describe its position and motion. Two reference points located posterior to the maxilla are called posterior points of reference. These two posterior reference points along with the third point of reference, which is located anterior to maxilla, will determine the plane of orientation. The anterior point of reference, which is a physical requirement to form a plane, can be selected on the articulator or on the face of the patient. However, a variation in the supero inferior position of the casts on the articulator can decrease or increase the protrusive condylar guidance on the articulator making the reliability of these anterior reference points in orienting the maxilla on the articulator questionable.

With this background of uncertainty, a study was planned to evaluate the effect of three different anterior points of reference viz. the orbitale, superior annular groove on the articulator, inferior annular groove on articulator and two different designs of the Hanau articulators viz. Arcon and Non-Arcon on the protrusive condylar angulation as obtained on programming casts in the respective articulators.

**Materials and Methods**

Fifteen subjects, with an age range of 20-30 years (mean) of age, with a full complement of teeth and without any history of orthodontic treatment, temporomandibular disorders and extractions were chosen for this study. Formal permission to conduct the study was obtained from the Institutional Ethics Committee of K. M. Shah Dental College and Hospital, Sumandeep Vidyapeeth, Vadodara, Gujarat, India. Subjects were recruited with proper informed consent. Six sets of stone casts were obtained for each patient from irreversible hydrocolloid impressions.

Two different articulator system used in the study were Hanau Wide Vue (Arcon type) and Hanau H2 (Non-Arcon type). Both these articulators accept a spring bow record and have the provision to transfer a facebow record with the three anterior points of references namely, orbitale of patient, Superior annular notch and Inferior annular notch on the incisal pin of the articulator.

The right orbitale was located over the notch present in the lower orbitale rim and marked with indelible pencil. This marking was used as the anterior point of reference and external auditory meatus were used as posterior point of reference for the face bow transfer using a face bow (Hanau Spring-Bow, Teledyne Water Pik, Fort Collins, Colorado, USA). This face bow record was used to mount first set of casts on both Hanau Wide Vue and Hanau H2 articulators [Figure 1a].

A new facebow record was made without considering the anterior reference point on the patient’s face. The second and the third set of casts were mounted using the new face bow record on both articulators. The face bow was adjusted by using an anterior elevator (no. 010358-000, Teledyne Water Pik, Fort Collins, Colorado, USA) to locate the incisal edges of the maxillary casts at the level of superior and inferior annular groove of the incisal guide pin respectively [Figure 1b and c]. The mandibular casts were then mounted in maximum intercuspation with the maxillary cast by hand articulation. The same procedure was followed to mount the casts of all 15 patients in the three different resultant reference planes and two different articulator systems.

Three sets of protrusive interocclusal records were made using the Polyether Bite Registration Material (Ramitec, 3M ESPE, St. Paul, MN). The articulator was programmed using each of the interocclusal records, and mean protrusive condylar guidance angle for each mounting was calculated and recorded in observation sheet. The procedure was carried out for both Arcon and Non-Arcon articulator for each patient. The condylar guidance of the articulator shows the interval of minimum 5°. To accurately measure the condylar guidance the protractor was modified and attached to the condylar shaft of the articulator. After programing the articulator, the condylar guidance was recorded by using the modified protractor with minimum 1° accuracy [Figure 2].

Lateral cephalometric radiographs were made in maximum intercuspation and protrusive positions. The lateral cephalogram were made for both right and left sides using a Broadbent cephalostatto regulate the head positions using standard parameter. For making the lateral cephalograms, Kodak 8000 C digital panoramic and cephalometric system was used with 77 Kv and 10 mA.

The digital cephalograms were imported into the Adobe Photoshop software. The center of the condyles were
marked using the circle tool of Adobe Photoshop software. The Frankfort horizontal plane was marked with the line tool from orbitale to porion. Print out were taken of all the cephalograms on transparent paper.

The cephalograms were traced and overlapped for left and right sides using maxillary central incisor, first vertebra, and sella as guides. The centers of the condyles in overlapped cephalograms in maximum intercuspation and in the protrusive position were joined to produce the protrusive condylar path. The angle between protrusive condylar path and the Frankfort horizontal plane was measured and recorded as protrusive condylar angle [Figure 3].

**Results**

The observations were tabulated and various statistical tests were applied for comparison between the various anterior points of reference and also between Arcon and Non‑Arcon articulators.

The summary statistics of the right and left condylar guidance of all subjects is tabulated in Table 1.

Summary statistics of condylar guidance obtained using orbitale superior annular groove and inferior annular groove as the third point of reference on Arcon and Non‑Arcon articulator are tabulated in Tables 2 and 3 respectively.

Comparison between the control group values (radiographic value) and right and left condylar guidance values obtained using three different anterior reference points on the Arcon articulator yielded a $P$ value of 0.182 and 0.259 for right and left side condylar guidance when the orbitale was used as the third point of reference, which is not statistically significant ($P < 0.05$). The right and left condylar guidance values on Arcon articulator when the inferior annular groove on the incisal pin of the articulator was used as the third point of reference were tested with that of the control group a statistically significant difference and the $P$ value was 0.014 and 0.005 respectively, which are statistically significant. While the condylar guidance obtained on the Arcon articulator by using the superior annular groove on the incisal pin of the articulator gave $P$ value of 0.000 for both right and left side, which is highly significant [Table 4].

For Non‑Arcon articulator, orbitale as the anterior point of reference gave $P$ value of 0.063 and 0.043 for right and left side respectively, which are not significant statistically. For other two-third point of reference the test shows the significant values [Table 5].

The comparison of Arcon and Non‑Arcon articulators was done through the Mann Whitney test. The statistical result of the test are not significant for all three points of reference used in the study for both the Arcon and the Non‑Arcon articulator used in the study [Table 6].

To evaluate the effect of articulator and anterior point of reference on the condylar guidance, Kruskal Wallis test was performed. The result of this test shows that the anterior point of reference has influence on the condylar guidance in both Arcon and Non arcon articulator especially when the superior annular groove ($P$ value 0.000 for right and left side) and inferior annular groove ($P$ value 0.007 and 0.001 for right and left side) were used as the anterior point of reference [Graph 1]. The orbitale does not show a significant difference for Arcon and Non‑Arcon articulator ($P$ value 0.147 and 0.116 for right and left side) [Table 7].
Discussion

The maxillary cast in the articulator is the baseline from which all occlusal relationships start, and it should be positioned in space by identifying three points, which cannot be on the same line. When three reference points are used the position can be repeated, so that different maxillary casts of the same patient can be positioned in the articulator in the same relative position. The plane is formed by two points located posterior to the maxillae and one point located anterior to them. Often the two posterior points are located by measuring prescribed distances from the skin surface landmarks. There are various anterior points of reference used for mounting the maxillary cast on the different type of articulator systems. The condylar guidance may be influenced by the selection of different anterior point of reference or by the type of articulator design. Keeping all these things in mind this study was planned with a Null hypothesis that all the anterior points of reference register the same condylar guidance on articulator irrespective of its design.

In the study, three different anterior reference points were used i.e., orbitale, superior annular groove present on the incisal pin of the articular and inferior annular groove present on the incisal pin of the articular. Two different articulators used in the study were an Arcon type Hanau Wide Vue and Non-Arcon type Hanau 96 H2.

Orbitale is the recommended anterior point of reference when the Hanau spring bow is used. Two annular grooves

Table 2: The summary statistic of the right and left condylar guidance of the Arcon articulator

| Particular | ROA  | LOA  | RSA  | LSA  | RIA  | LIA  |
|------------|------|------|------|------|------|------|
| Mean       | 35.53| 34.53| 26.27| 23.87| 32.20| 29.67|
| Median     | 35.00| 35.00| 25.00| 23.00| 32.00| 30.00|
| Mode       | 30\* | 30   | 25   | 32   | 30   | 30   |
| Skewness   | -0.185| -0.611| 1.095| 0.459| -0.045| 0.289|
| Standard error of skewness | 0.580| 0.580| 0.580| 0.580| 0.580| 0.580|
| Kurtosis   | -1.045| 0.234| 1.172| -0.395| -1.070| -0.237|
| Standard error of kurtosis | 1.121| 1.121| 1.121| 1.121| 1.121| 1.121|

ROA: Value of condylar guidance of right side when orbitale was used as third point of reference on Arcon articulator; LOA: Value of condylar guidance of left side when orbitale was used as third point of reference on Arcon articulator; RSA: Value of condylar guidance of right side when superior annular groove was used as third point of reference on Arcon articulator; LSA: Value of condylar guidance of left side when superior annular groove was used as third point of reference on Arcon articulator; RIA: Value of condylar guidance of right side when inferior annular groove was used as third point of reference on Arcon articulator; LIA: Value of condylar guidance of left side when inferior annular groove was used as third point of reference on Arcon articulator.

Table 3: The summary statistic of the right and left condylar guidance of the Non-Arcon articulator

| Particular | RON  | LON  | RSN  | LSN  | RIN  | LIN  |
|------------|------|------|------|------|------|------|
| Mean       | 34.13| 32.60| 24.40| 20.47| 30.27| 27.20|
| Median     | 35.00| 31.00| 25.00| 20.00| 30.00| 28.00|
| Mode       | 35\* | 30   | 25   | 15   | 30   | 30   |
| Skewness   | -0.263| -0.103| 0.710| 0.977| 0.199| 0.606|
| Standard error of skewness | 0.580| 0.580| 0.580| 0.580| 0.580| 0.580|
| Kurtosis   | -0.838| -0.035| 0.551| 0.419| -0.658| 0.279|
| Standard error of kurtosis | 1.121| 1.121| 1.121| 1.121| 1.121| 1.121|

RON: Value of condylar guidance of right side when orbitale was used as third point of reference on Non-Arcon articulator; LON: Value of condylar guidance of left side when orbitale was used as third point of reference on Non-Arcon articulator; RSN: Value of condylar guidance of right side when superior annular notch was used as third point of reference on Non-Arcon articulator; LSN: Value of condylar guidance of left side when superior annular groove was used as third point of reference on Non-Arcon articulator; RIN: Value of condylar guidance of right side when inferior annular groove was used as third point of reference on Non-Arcon articulator; LIN: Value of condylar guidance of left side when inferior annular groove was used as third point of reference on Non-Arcon articulator.
Table 4: The test statistic of condylar values of control with that of Arcon articulator obtained with three different anterior points of reference

| Particular | ROA | LOA | RSA | LSA | RIA | LIA |
|------------|-----|-----|-----|-----|-----|-----|
| Mann-Whitney U | 80.500 | 85.500 | 19.500 | 24.000 | 53.500 | 44.500 |
| Wilcoxon W | 200.500 | 205.500 | 139.500 | 144.000 | 173.500 | 164.500 |
| Z | −1.334 | −1.128 | −3.886 | −3.685 | −2.461 | −2.828 |
| Asymp. Sig. (2-tailed) | 0.182 | 0.259 | 0.000 | 0.000 | 0.014 | 0.006 |

ROA: Value of right condylar guidance on Arcon articulator when orbitale as third point of reference; LOA: Value of left condylar guidance on Arcon articulator when orbitale as third point of reference; RSA: Value of right condylar guidance on Arcon articulator when superior annular groove as third point of reference; LSA: Value of left condylar guidance on Arcon articulator when superior annular groove as third point of reference; RIA: Value of right condylar guidance on Arcon articulator when inferior annular groove as third point of reference; LIA: Value of left condylar guidance on Arcon articulator when inferior annular groove as third point of reference.

Table 5: The test statistic condylar values of control with that of Non-Arcon articulator obtained with three different anterior points of reference

| Particular | RON | LON | RSN | LSN | RIN | LIN |
|------------|-----|-----|-----|-----|-----|-----|
| Mann-Whitney U | 68.000 | 64.000 | 13.500 | 10.000 | 37.000 | 26.500 |
| Wilcoxon W | 188.000 | 184.000 | 133.500 | 130.000 | 157.000 | 146.500 |
| Z | −1.861 | −2.019 | −4.119 | −4.259 | −3.154 | −3.574 |
| Asymp. Sig. (2-tailed) | 0.063 | 0.043 | 0.000 | 0.000 | 0.002 | 0.000 |

RON: Value of right condylar guidance on Non-Arcon articulator when orbitale as third point of reference; LON: Value of left condylar guidance on Non-Arcon articulator when orbitale as third point of reference; RSN: Value of right condylar guidance on Non-Arcon articulator when superior annular groove as third point of reference; LSN: Value of left condylar guidance on Non-Arcon articulator when superior annular groove as third point of reference; RIN: Value of right condylar guidance on Non-Arcon articulator when inferior annular groove as third point of reference; LIN: Value of left condylar guidance on Non-Arcon articulator when inferior annular groove as third point of reference.

Table 6: Test statistics of the condylar values of Arcon versus Non-Arcon articulator obtained with three different anterior points of reference

| Particular | OR | OL | SR | SL | IR | IL |
|------------|----|----|----|----|----|----|
| Mann-Whitney U | 96.000 | 88.000 | 89.000 | 81.500 | 90.500 | 82.000 |
| Wilcoxon W | 216.000 | 208.000 | 209.000 | 201.500 | 210.500 | 202.000 |
| Z | −0.688 | −1.029 | −0.987 | −1.292 | −0.921 | −1.271 |
| Asymp. Sig. (2-tailed) | 0.492 | 0.304 | 0.324 | 0.196 | 0.357 | 0.204 |

OR: Test statistic when right orbitale was used as anterior point of reference; OL: Statistical values when left orbitale was used as anterior point of reference; SR: Statistical values of right condylar guidance on articulator when superior annular groove was used as anterior point of reference; SL: Statistical values of left condylar guidance on articulator when superior annular groove was used as anterior point of reference; IR: Statistical values of right condylar guidance on articulator when inferior annular groove was used as anterior point of reference; IL: Statistical values of left condylar guidance on articulator when inferior annular groove was used as anterior point of reference.

Table 7: Test statistic of comparison of the condylar values of control group, Arcon and Non-Arcon articulator obtained with three different anterior points of reference

| Particular | OR | OL | SR | SL | IR | IL |
|------------|----|----|----|----|----|----|
| Chi-square | 3.833 | 4.315 | 22.166 | 22.371 | 9.932 | 15.025 |
| Df | 2 | 2 | 2 | 2 | 2 | 2 |
| P value | 0.147 | 0.116 | 0.000 | 0.000 | 0.007 | 0.001 |

OR: Test statistic when right orbitale was used as anterior point of reference; OL: Statistical values when left orbitale was used as anterior point of reference; SR: Statistical values of right condylar guidance on articulator when superior annular groove was used as anterior point of reference; SL: Statistical values of left condylar guidance on articulator when superior annular groove was used as anterior point of reference; IR: Statistical values of right condylar guidance on articulator when inferior annular groove was used as anterior point of reference; IL: Statistical values of left condylar guidance on articulator when inferior annular groove was used as anterior point of reference.

Irrespective of the condylar fossa mechanism, the semi-adjustable articulators are classified as Arcon and Non-Arcon instruments. The articulators used in the study were Hanau Wide Vue arcon articulator and Hanu Model.
96 H2 Non-Arcon articulator. These two articulator were selected for the study because they both are manufactured by the same manufacturer and they both represent the different type of articulator design mechanism and both of them accept the face bow record made with Hanau spring bow and they both have provision for three anterior point of reference selected for the study. For face bow transfer on Hanau Wide Vue articulator, which is Arcon type, which has its condylar guidance mechanisms attached to the upper member and the condylar spheres to the lower member, the Nylon earpieces were suspended directly over the auditory pins, which are 12 mm posterior to the condylar center. To use the Hanau spring bow on Hanau Model 96 H2 Non-Arcon articulator zeroing of condylar guidance was carried out at 70° because it makes auditory pins 12 mm posterior to the condylar center.

Subjects selected for the study who did not undergone any tooth extraction or any kind of temporomandibular disorders, which can influence the protrusive movement of the mandible, subjects with any prosthesis and restoration were not included in the study to avoid any error in protrusive movement of the mandible due to any interference of the restorations.

Three protrusive interocclusal records were made to program the articulator because if three separate protrusive jaw relation are secured and the condylar guidance on an articulator is adjusted according to them, they may yield three different condylar guidance values i.e., three different records can yield three different reading of condylar guidance. The condylar guidance can be changed as the protrusion change. So, in this study, two records were made if they gave same reading then the third record was not made and if the reading were different then third record was made and an average value was calculated.

Split casts were made for maxillary arch to mount on the articulator. It is easy to seat the maxillary cast with primary base in the indentation on the protrusive interocclusal record. Then, the secondary base can be easily placed over the primary base and evaluation can be carried out to check the proper seating of two bases with each other. Any gap in between can be easily corrected, perfect seating of maxillary cast with primary base on the indentation of protrusive record is possible with a reasonable amount of stability of the cast. The split cast technique give accurate condylar guidance because the lower cast, inter occlusal record and the maxillary cast with primary base act as a single unit while the secondary base act as second unit; hence, it is easy to program the articulator without any error.

The analysis of the data obtained from the study did not support the null hypothesis that all anterior points of reference register the same condylar guidance on both articulators. The analysis showed that all three different anterior point of reference used in the study recorded different condylar guidance.

For Arcon articulator, the mean condylar guidance obtained using the orbitale as the anterior point of reference were 35.53 and 34.53 [Table 2] for right and left side respectively, which were closer to the anatomic condylar guidance of the subject obtained by radiographic tracing, which were 37.93 and 36.6 for right and left side [Table 1]. The difference between condylar guidance by orbitale as the third point of reference and the anatomic condylar guidance were 2.4° and 2.07° for right and left side. The difference of condylar guidance suggest that the orbitale mounts the maxillary cast more accurately to the FHP, when it is used as the anterior point of reference.

For Non-Arcon articulator the condylar guidance of right and left side achieved by using the orbitale as the anterior point of reference were 34.13 and 32.60 respectively [Table 3], which is again closer to the radiographic condylar guidance values of right and left side of the patient.

The inferior annular groove on the incisal pin of the articular was used to mount the casts in the articulator. The condylar guidance when inferior notch was used as the third point of reference were 32.2 and 29.67 [Table 2] for right and left side for Arcon articulator, the condylar guidance for the Non-Arcon articulator were 30.27 and 27.20 [Table 3] for right and left side respectively.

When the superior annular groove on the incisal pin of the articulator was used as the third point of reference to mount the maxillary cast on Arcon articulator, the condylar guidance obtained were 26.27° and 23.87° [Table 2]. The Non-Arcon articulator gave condylar guidance of 24.4° and 20.47° [Table 3] for right and left side. The condylar guidance of Arcon or Non-Arcon articulator showed the difference of 10-16° with that of radiographic values of condylar guidance.

The means that when the orbitale and the inferior annular groove present on the incisal pin of the articulator are used as the anterior point of reference to mount the maxillary casts they mount the cast close to the anatomic position. Between this two the orbitale is the one which mount the maxillary casts closest to the anatomic position.

The superior annular groove as the anterior point of reference, mounts the maxillary casts not so accurately to anatomic position. The difference of condylar guidance values obtained by superior annular notch present on the incisal pin of the articulator as the third point of reference and that of radiographic values was very high, which interpreted that this notch did not mount the casts closer to anatomic position.

The protrusive condylar path angles changed proportionately with the plane of orientation on mountings using the different anterior points of references. The casts were found to be...
closer to the radiographic position in relation to the Frankfort Horizontal plane when mounted using orbitale as the third point of reference.

The mountings with the inferior annular groove present on the incisal pin of the articulator registered the condylar guidance values closer to the radiographic values than did those with the superior annular notch present on the incisal pin of the articulator was used as the third point of reference. This comparison supports the finding of Lauciello and Appelbaum.\(^7\)

Gonzales and Kingery\(^9\) observed the lack of parallelism between the Frankfort Horizontal plane and the axis-orbitale plane. The 7 mm correction was suggested by them when using the orbitale as the third point of reference. However, the orbitale pointer is placed 7 mm above the level of the condylar plane in the newer Hanau models so the correction was not required when the orbitale was used as the third point of reference.

Inferior annular groove present on the incisal pin of the articulator was recommended by Lauciello and Appelbaum,\(^7\) which is based on the average value, mount maxillary cast closer to the anatomic position, but the difference of condylar guidance was greater than that of the values when orbitale was used as the anterior point of reference.

The condylar slot in the Arcon articulator is constant in angulation to the maxillary dental arch. Arcon principle seems to reflect physiologic conditions more truly than the Non-Arcon type articulator. Both the Arcon and Non-Arcon instrument produce the same motion because condylar guidance is the result of interaction of a condylar ball on an inclined plane. One without the other is ineffective. Reversing the relationship does not change the guidance produced. Mathematical evidence supports the view that neither instrument has any specific advantages over the other.\(^1\)

The result also showed that the accurate condylar guidance is dependent on the type of the third point of reference point used to mount the maxillary cast on the articulator. There was no significant different was observed between the Arcon type of articulator and Non-Arcon type of articulator. This supports Weinberg’s statement that the Arcon concept has no clinical advantage. Weinberg\(^1\) observed that a 9° decrease in the condylar path inclination resulted in 0.2 mm reduction in the non-working cusp height. Hence, a variation of less than 9° would be clinically not significant. This means that the superior annular groove if used as the anterior point of reference will produce an error more than 0.2 mm on the balancing side.

The sequence of accurate third point of reference used in this study can be given as follows, the orbitale as the third point of reference when used with Arcon articulator mount the casts to the most closest to the anatomic position, the second is the orbitale when used with Non-Arcon articulator, which also mount the maxillary casts closer to anatomic position.

Next is inferior annular groove present on the incisal pin of the articulator as the third point of reference with Arcon and Non-Arcon articulator mount the maxillary cast with reasonably close to the anatomic position.

The superior annular groove present on the incisal pin of the articulator as the third point of reference gave a wide range of difference with anatomic values; they are least accurate to mount the casts to anatomic position.

Irrespective to the type of articulator the orbitale is most accurate as the third point of reference; the second one is the inferior annular groove present on the incisal pin of the articulator.

The superior annular groove present on the incisal pin as the third point of reference mount the maxillary casts with greater difference with condylar guidance of subject and the position of the cast is differ from the anatomic position. So, the use of the superior annular groove as the third point of reference is questionable.

**Limitation of the study**

The method used in this study to calculate the anatomic condylar guidance was overlapping of the lateral cephalograms in maximum intercuspation and in protrusion. The anthropological method if used can calculate the condylar guidance perfectly, but that cannot be employed in living subjects. The method used in this study to calculate the anatomic condylar guidance was cephalometry need to follow equal radiographic parameter to take all radiographs to standardize the method. Overlapping of right and left condyles with each other sometime leads to false marking of the center of the condyle, which yields different value. Though the radiographic parameters were standardized, it is however not possible to get an exact overlap of the right and the left sides over each other due to anatomic variations and asymmetry. This may induce an error and may be considered a limitation of the study.

**Conclusion**

Within the limitation of this study, the following conclusions were drawn:
- A change in anterior reference point in a face bow transfer caused a change in orientation of the occlusal plane 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 cast to the articulator irrespective of type of articulator

- The inferior annular notch present on the incisal pin of the articulator can be used as the third point of reference; it is second precise third point of reference, which mounts the maxillary cast close to anatomic reference position after the orbitale as the third point of reference.
- The superior annular notch present on the incisal pin of the articulator shows significantly different condylar guidance than that of radiographic values so it gives different condylar guidance than the anatomic condylar guidance of the subject when used as the third point of reference to mount the maxillary cast on the articulator, so it should not be used as the third point of reference.
- The superior annular notch reference point registered lowest condylar guidance angles, and the values differed significantly from the radiographic values.
- Arcon and Non-Arcon articulator show no significant different in condylar guidance, it is the third point of reference rather than the type of the articulator which decides the condylar guidance angle.
- Type of articulator whether Arcon or Non-Arcon has no effect on the condylar guidance, the Arcon articulator has an advantage of simulating the mandibular movements, which are easily understand by the operator.

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