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Research Article

Comparison Of Sagittal Condylar Angle Obtained Using Cone Beam Computed Tomography And Interocclusal Record Materials- An In Vivo Study

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Abstract: The sagittal condylar guidance angle (SCCA) is calculated by the condyle and articular disc traversing the contour of the glenoid fossa and the articular eminence. The condylar path is controlled by the shape of the fossa, the attachments of the ligaments, the biting load during movement (muscular influence), and the amount of protrusion. The SCGA on an articulator is determined using protrusive records of the patient. Intraoral registrations may compromise accuracy because of dimensional instability of registration materials and it becomes difficult for the dentist to select an appropriate material. The use of cone beam computed tomography (CBCT) has recently become much more common, and when measuring the SCGA using CBCT, more reliable results can be expected. This study was designed to compare the SCGA obtained using CBCT and protrusive interocclusal record made using polyvinyl siloxane and aluwax. Thirty dentulous subjects were selected. SCGA was calculated using CBCT scans for each subject. Intraoral protrusive records were made using polyvinyl siloxane and aluwax bite registration materials at 6mm of protrusion. Records were used to program the articulator and variation in the SCCA was noted. No significant difference was observed between right and left mean values of SCGA in CBCT, polyvinyl siloxane and aluwax. Positive correlation was found between all the three groups; however, significant difference was found in the mean values of SCGA between CBCT and polyvinyl siloxane, CBCT and aluwax (P=0.0001). No significant difference was found in the mean values of SCGA between polyvinyl siloxane and aluwax (P=0.9254). CBCT gave higher mean SCGA values than those obtained using polyvinyl siloxane and aluwax on semi-adjustable articulator in dentulous subjects; whereas mean SCGA values were comparable between polyvinyl siloxane and aluwax. The right and left SCGA values were comparable in each method.

Keywords: horizontal condylar guidance angle, horizontal condylar inclination, mandibular protrusion, sagittal condylar angle, sagittal condylar inclination

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1. INTRODUCTION

Condylar guidance is defined as mandibular guidance generated by the condyle and articular disc traversing the contour of the articular eminence (AE).[1] The likelihood of successful complex prosthodontic procedures is increased when the condylar path of the patient is simulated accurately on the articulator. Inappropriate recording of the condylar guidance may lead to occlusal interferences, causing increase in valuable chair side adjustment time resulting in inadequate patient satisfaction and a disharmonious occlusion.[2] After birth the AE is normally flat or could be considered absent which shows that the AE develops during the growth phase and under functional influences and dynamic occlusion.[3] Humphreys postulated that the eminence starts growing at the age of 6 years, at a very slow rate at the age of 10 years and then at this age grows quickly, especially between 10–11 years and it is almost complete at the age of 12 years.[4] The inclination then decreases after the age of 40 years old.[5,6] The sagittal condylar guidance angle (SCGA) is calculated from the angle of the AE and the Frankfurt horizontal plane (FH) or any other plane, such as the axis orbital plane (AOP). The difference between the measurements of these two planes (FH to AOP) is normally approximately 6°.[7-9] There are several ways to take measurements of the AE, such as using modeling clay, direct measurement, arthrograms, panoramic radiographs, tomographic radiographs, cephalometric radiographs, scaled topographs, cephalometry using intensifying screens, protrusive condylar path and wax impressions or using a jaw movement recording device. Some of these are more reliable than others.[10] The SCGA on an articulator is determined using either the protrusive or lateral interocclusal records of the patient.[11,12] Many materials such as dental waxes, metal oxide pastes (zinc oxide pastes), acrylic resins, and elastomeric materials, such as polyethers and addition silicones have been used for interocclusal records. These materials should possess attributes as similar as possible to the requirements for ideal bite registration material. Polyvinyl siloxane is an addition-reaction silicone without byproducts that possesses dimensional stability and has earned acceptance as an impression material and now is marketed as an interocclusal registration material.[14] Aluwax being the most commonly used bite registration material is being used in this study as a second interocclusal registration material. Studies have shown that the radiographic methods are more accurate than any other clinical methods as radiographic measurement involves stable bony landmarks and does not rely on the operator or patient's neuromuscular control.[12,13] The use of cone beam computed tomography (CBCT) has recently become much more common, and when measuring the SCGA using CBCT, more reliable results can be expected. The idea that the angle and lines of the bony fossa completely govern the path of the condyle is erroneous. A study of the anatomy and function of the joint reveals that the condylar path is governed partly in its shape and function by the meniscus. The path is controlled further by the shape of the fossa, the attachments of the ligaments, the biting load during movement (muscular influence), and the amount of protrusion. The registration may vary according to the biting pressure exerted after the mandible has been protruded. There does not seem to be much excuse for failure to register this path because it is not difficult or time-consuming in proportion to the results obtained.[15] Polyvinyl siloxane and aluwax are being routinely used for interocclusal protrusive records and adjusting condylar guide angle on an articulator, but which material gives accurate results is yet debatable. Therefore, this study was being carried out to measure and compare the values obtained by these two materials with CBCT.

2. MATERIALS AND METHODS

30 subjects referred for CBCT and those meeting the inclusion criteria were selected for the study. The study was reviewed and approved by the Institutional Ethical Committee of Pravara Institute of Medical Sciences and was in accordance with ICMR guidelines (PIMS/RDC/IEC/UG-PG/10-2019). Written informed consent was taken from the subjects participating in the study. The inclusion criteria was: Subjects of either gender, subjects with full complement of teeth or partially edentulous arch with stable occlusal contacts, subjects with overjet and overbite ranging from 0-4mm, no occlusal interferences, subjects between the age 12-80 years. The exclusion criteria was: Kennedy's class I, II and IV partially edentulous arch, subjects with traumatic injuries in the region of TMJ, subjects with TMJ pathology, subjects with severe attrition of teeth, subjects with neuromuscular disorder.

SCGA was calculated on CBCT and semi adjustable articulator using protrusive interocclusal record.

2.1 SCGA Using CBCT[20,21]:

A CBCT image of the midfacial region of each subject was obtained. Axial plane in 3D constructer of CBCT was made parallel to FH plane (Figure 1). In the coronal view of CBCT, section having superior most and medial most point of the glenoid fossa was determined[1]; similarly in the sagittal view of CBCT, section with superior most and anterior most point of the glenoid fossa was determined and was labelled as point A (Figure 2). In the sagittal view, the most inferior point on AE was labelled as point B. Point A and B was joined (line C). Line parallel to FH plane (line D) was marked. The angle that forms by intersection of line C and line D gave SCGA (Figure 3).

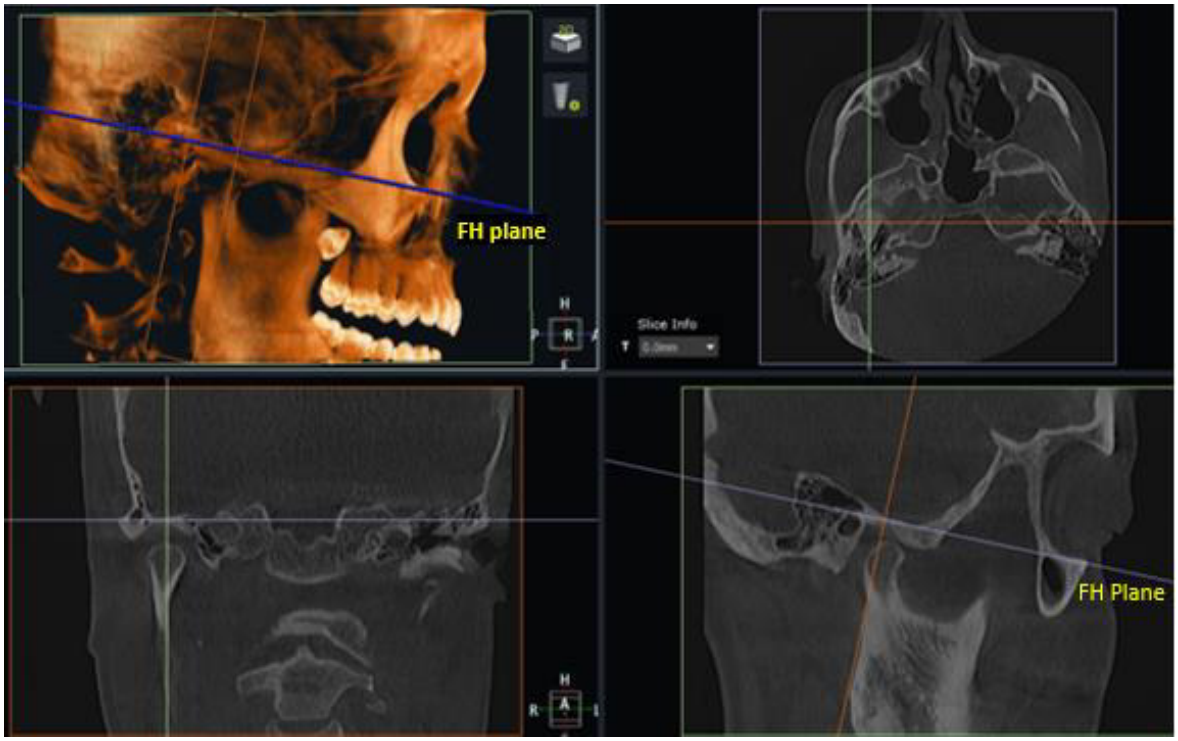

Fig 1: *CBCT showing axial plane parallel to FH plane*

Fig 2: *CBCT* showing section having superior most and medial most point in the coronal view and superior most and anterior most point in sagittal view as point A.

Fig 3: *Sagittal section of CBCT. Superior most and anterior most point of glenoid fossa marked as 'A', inferior most point on articular eminence marked as 'B', line joining A and B marked as 'Line C' and line parallel to FH plane marked as 'Line D'. The internal angle between 'Line C' and 'Line D' is sagittal condylar guidance angle.*

2.2 *Procedure For Recording Protrusive Bite*

Protrusive bite registration of each of 30 dentulous subjects was recorded using polyvinyl siloxane bite registration material (ChemSil BITE Blu, polyvinyl siloxane impression material, B & E KOREA CO. LTD.) and aluwax (Maarc bite registration wax, aluminium filled) at 6mm protrusion.[26,27] Anterior stop for 6mm protrusion was fabricated using cold cure acrylic on a wooden stick. Cold cure acrylic was added on the upper side of wooden stick and placed intraorally, subject was guided to centric relation, a line was marked on the lower side of wooden stick where the mandibular central incisors touch. Another line was marked 6mm ahead of the first line and acrylic stop made at this marking. Wooden stick was placed back intraorally ensuring that the acrylic stop on the upper side of stick is in contact with maxillary central incisors and subject asked to protrude the mandible till mandibular central incisors come in contact with the stop on the lower side of the wooden stick (Figure 4). Subject was trained to close at this protruded jaw position. Polyvinyl siloxane bite registration material was injected on the mandibular posteriors, wooden stick placed in the manner described and subject was asked to close in protruded jaw position using the stop on the lower side of wooden stick as a guide (Figure 5 and Figure 6). Similar procedure was carried out for protrusion using aluwax (Maarc bite registration wax, aluminium filled). Figure 7 shows right and left protrusive records. Records of each individual were labelled as 1AR, 2AR...etc. for protrusion of right side using polyvinyl siloxane; 1AL, 2AL…etc. for protrusion of left side using polyvinyl siloxane and 1BR, 2BR…etc.; 1BL, 2BL…etc. for protrusion of right and left side respectively using aluwax.

Fig 4: *Anterior stop for 6mm protrusion fabricated using cold cure acrylic on a wooden stick*

Fig 5: Subject asked to close in trained protrusive position using acrylic stop as a guide- Frontal view

Fig 6: Subject asked to close in trained protrusive position using acrylic stop as a guide- Lateral view

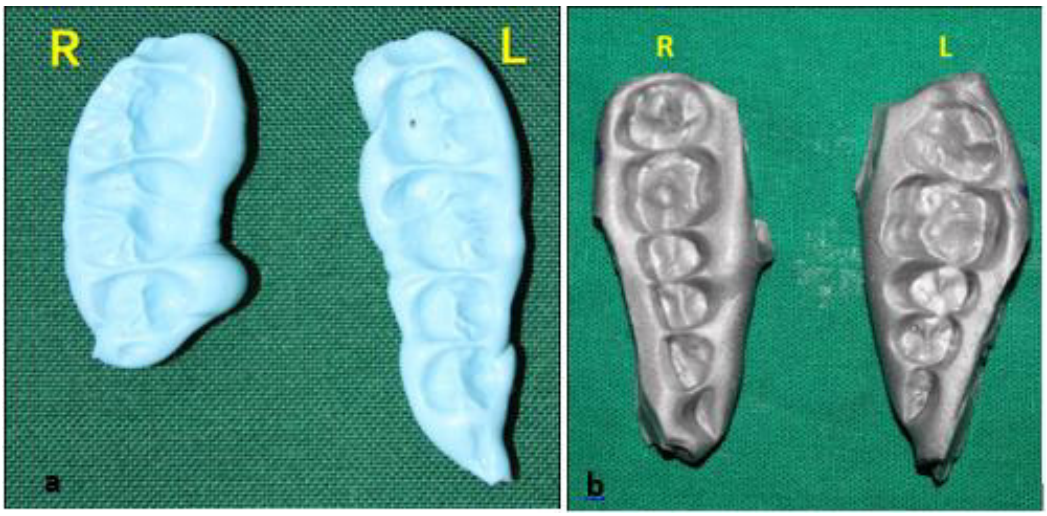

Fig 7: *Right and left protrusive record. a- polyvinyl siloxane protrusive records. b- aluwax protrusive records*

2.3 SCGA Calculation Using Bite Registration Material On The Articulator

Maxillary and mandibular dentulous impressions were made using irreversible hydrocolloid impression material (Zhermack tropicalgin, normal setting) and casts were poured using type III dental stone. Maxillary cast was articulated on a semi adjustable articulator (HANAU™ Wide-Vue Articulator, Whip Mix Corporation, USA) through a facebow transfer (HANAU™ Spring Bow, Whip Mix Corporation, USA) (Figure 8). Mandibular cast was articulated using centric record (Figure 9). Protrusive bite registration of each of 30 subjects was recorded using polyvinyl siloxane (ChemSil BITE Blu, polyvinyl siloxane impression material, B & E KOREA CO. LTD.). Centric locks and the thumbnuts on the articulator were loosened for adjusting horizontal inclination of the condylar guidance. Protrusive interocclusal relation record was seated onto the occlusal surface of mandibular cast, the upper member of the articulator was carefully guided into protrusion, lightly engaging the maxillary occlusal surfaces into the imprint of the protrusive relation record. The right and left guidances were rotated back and forth using thumbnuts to accurately seat the maxillary cast into the protrusive relation record. The casts were seated without rocking in or deforming the record and the thumbnuts were tightened for horizontal inclination. The values obtained on the articulator guidances on right and left sides were sagittal condylar guide angle obtained using polyvinyl siloxane for right and left sides respectively (Figure 10). Same procedure was followed using aluwax (Maarc bite registration wax, aluminium filled) for each of 30 subjects (Figure 11).

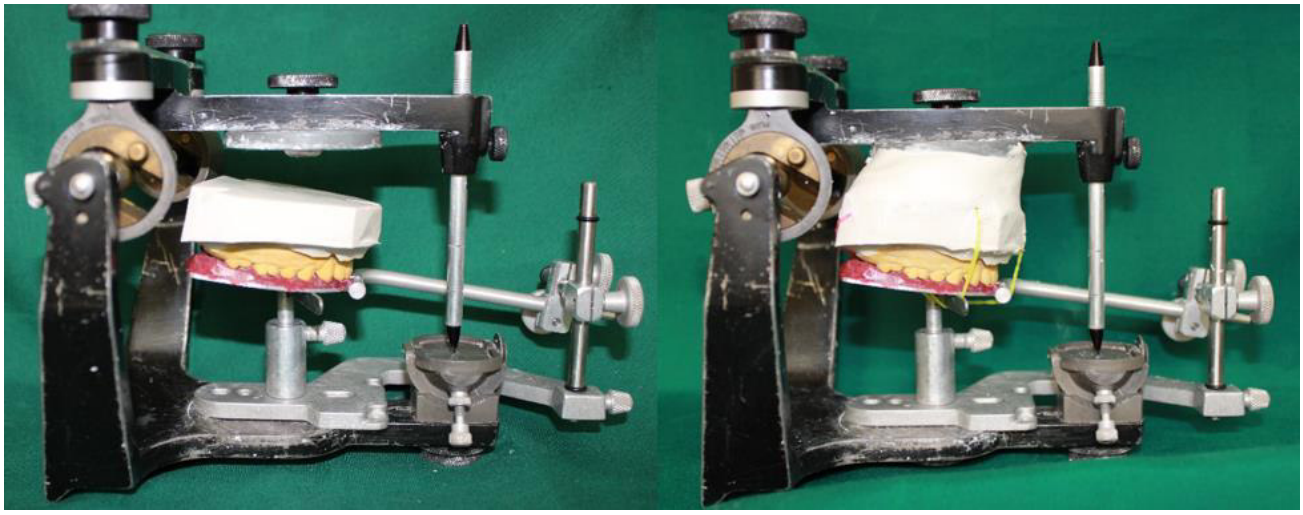

Fig 8: Mounting of maxillary cast on a semi-adjustable articulator using indirect technique of facebow transfer

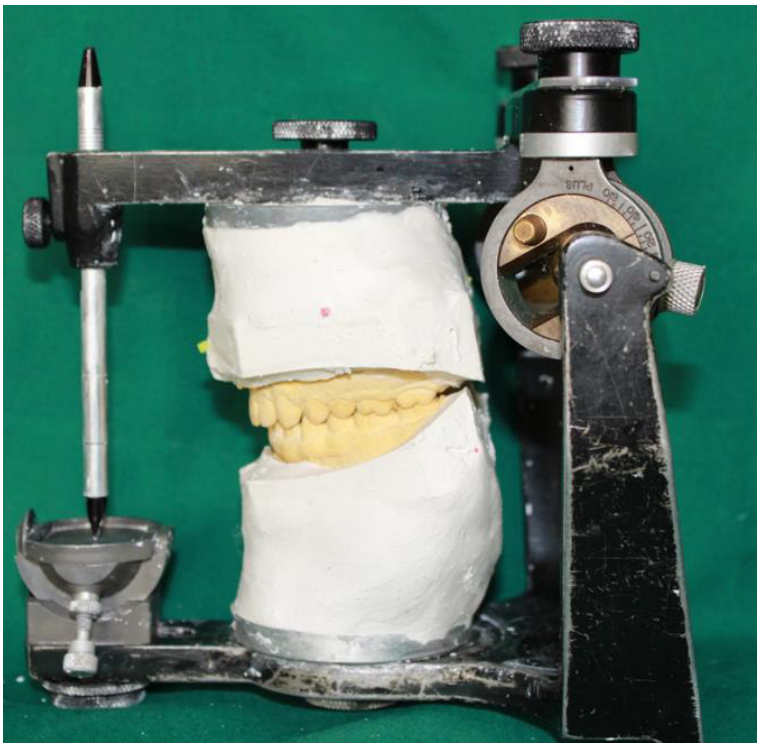

Fig 9: *Mounting of mandibular cast*

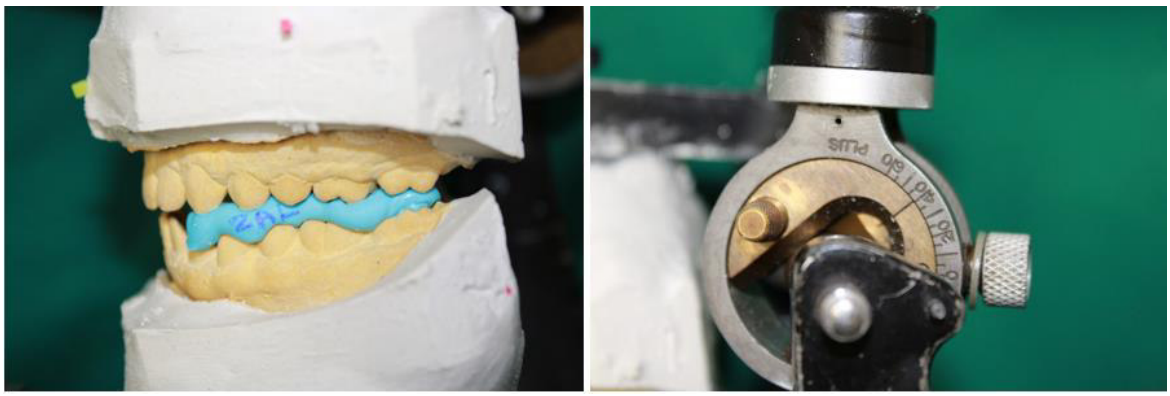

Fig 10: *Recording condylar guide angle on a semi-adjustable articulator by placing the polyvinyl siloxane protrusive bite record passively on the casts.*

Fig 11: Recording condylar guide angle on a semi-adjustable articulator by placing the aluwax protrusive bite record passively on the casts.

3. STATISTICAL ANALYSIS

Statistical analysis was done by descriptive statistics as mean, SD and percentage etc. Comparison of SCGA of right and left sides was done by applying Student's Unpaired 't' test at 5% (P=0.05) and 1% (P=0.001) level of significance. The reliability of the measurements was confirmed using Cronbach's α values.The correlation of SCGA between CBCT and polyvinyl siloxane, CBCT and aluwax & polyvinyl siloxane and aluwax was done by Pearson correlation test at 5% (P=0.05) and 1% (P=0.001) level of significance. Comparison of SCGA between CBCT and polyvinyl siloxane, CBCT and aluwax & polyvinyl siloxane and aluwax was done by applying Student's Unpaired 't' test at 5% (P=0.05) and 1% (P=0.001) level of significance. The statistical analysis software, SYSTAT version 12 was used to analyse the data.

4. RESULTS

By applying Student's Unpaired 't' test there was no significant difference between right and left mean values of SCGA in CBCT, polyvinyl siloxane and aluwax (Table 1). Positive correlation was found between all the three groups (Table 2, Figure 12-14). By applying Student's Unpaired 't' test there was a significant difference in the mean values of SCGA between CBCT and polyvinyl siloxane, CBCT and aluwax (P=0.0001), however no difference was found in the mean values of SCGA between polyvinyl siloxane and aluwax (P=0.9254) (table 3).

Table 1: Comparison of right and left SCGA within each group using Student's Unpaired 't' test

Groups	SCGA				
	Right side Mean ± SD	Left side Mean ± SD	Student's Unpaired 't' test value	'p' value and significance	Cronbach's α
CBCT	46.87° ±8.16°	47.86° ±8.40°	0.4660	P=0.6430, not significant	0.899
POLYVINYL SILOXANE	34.87° ±6.17°	34.87 °±6.83°	0.000	P>0.05, not significant	0.797
ALUWAX	33.30° ±7.53°	32.60° ±7.21°	0.3677	P=0.7145, not significant	0.689

Table 1 illustrates insignificant difference between mean of right and left SCGA within each group, suggesting no significant difference between right and left SCGA in each subject. Reliability of each group was tested using Cronbach's α test. Cronbach's alpha is a measure of internal consistency, that is, how closely related a set of items are as a group. It is considered to be a measure of scale reliability. CBCT group shows highest reliability followed by polyvinyl siloxane group and aluwax group. Aluwax group is shown to be least reliable.

Table 2: Pearson correlation test for comparison between different groups

Groups	Pearson Coefficient	'p value'	Significance
CBCT and polyvinyl siloxane	0.07535	0.0001	Significant
CBCT and aluwax	0.3880	0.0001	Significant
Polyvinyl siloxane and aluwax	0.2567	0.0001	Significant

Table 2 illustrates correlation between each group. All three groups show significant correlation with each other.

Table 3: Comparison of SCGA using Student's Unpaired 't' test between groups

Groups	SCGA Mean ± SD	Student's Unpaired 't' test value 'p' value and significance	
CBCT	46.36° ±8.28°	CBCT and polyvinyl siloxane t = 5.97	p= 0.0001, significant
POLYVINYL SILOXANE	34.87° ±6.51°	CBCT and aluwax t = 6.64	p= 0.0001, significant
ALUWAX	32.95° ±7.37°	Polyvinyl siloxane and aluwax t = 1.07	p=0.9254, not significant

Table 3 illustrates the significant difference between mean of right and left SCGA of CBCT group and polyvinyl siloxane group, significant difference between mean of right and left SCGA of CBCT group and aluwax group but no significant difference between polyvinyl group and aluwax group. This suggests that there is significant difference between radiograph and clinical methods but insignificant difference within clinical methods.

Fig 12: Correlation of SCGA between CBCT and polyvinyl siloxane bite registration material

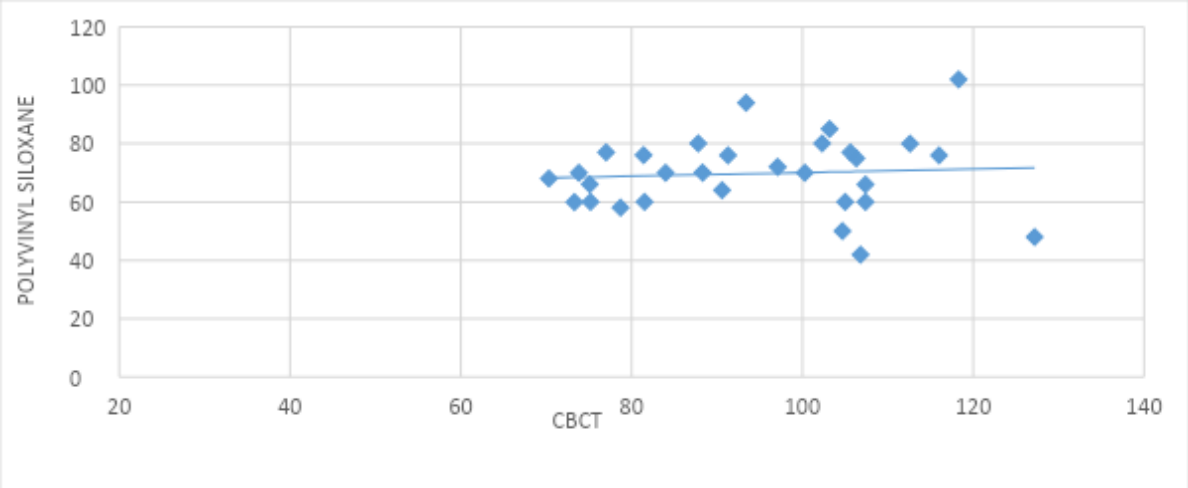

Figure 12 shows positive correlation of SCGA between CBCT group and polyvinyl siloxane group.

Figure 13: Correlation of SCGA between CBCT and aluwax bite registration material

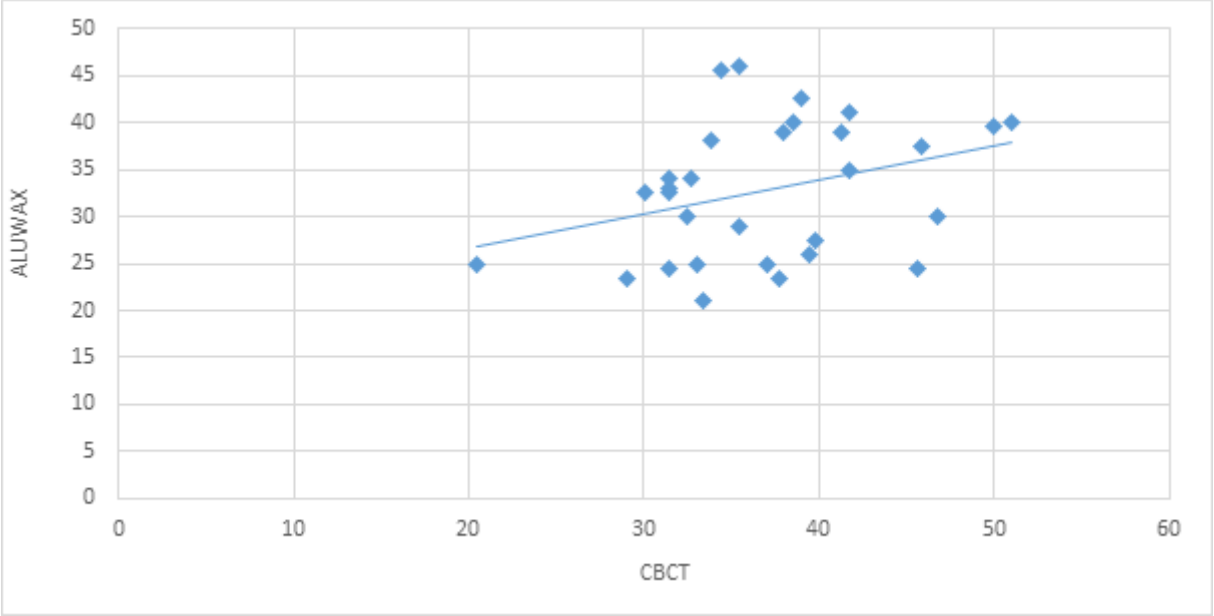

Figure 13 shows positive correlation of SCGA between CBCT group and aluwax group.

Figure 14: Correlation of SGCA between polyvinyl siloxane and aluwax bite registration materials

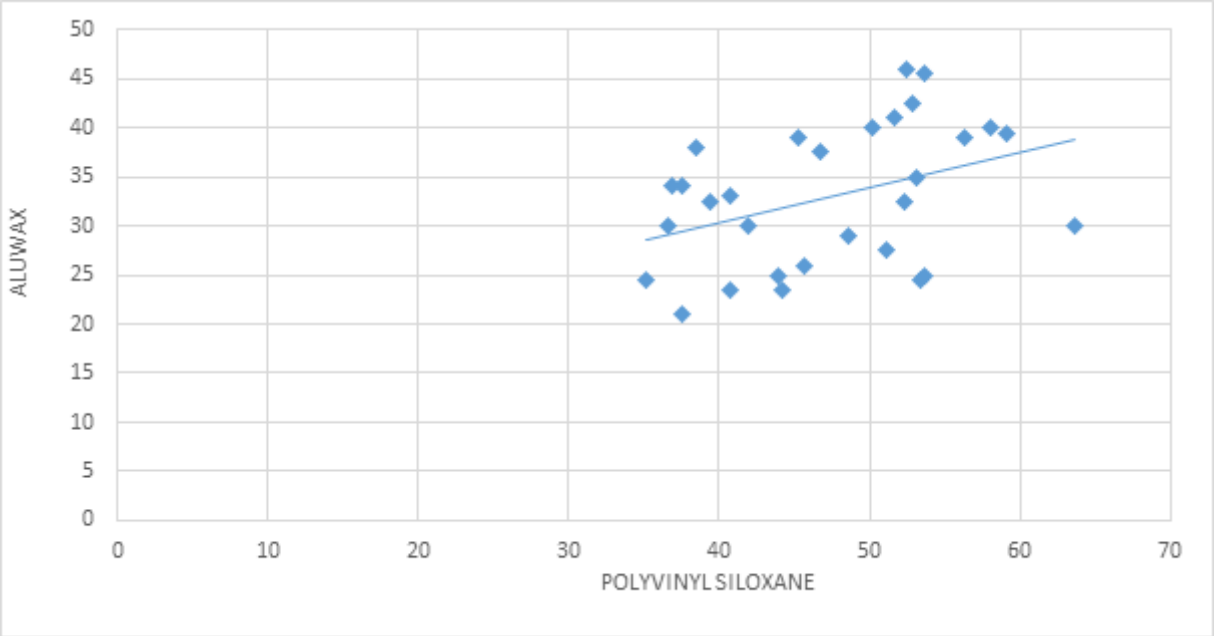

Figure 14 shows positive correlation of SCGA between polyvinyl siloxane group and aluwax group.

5. DISCUSSION

Evaluation and improvement of the accuracy of the materials and imaging techniques lead to progress in the quality of treatment. Due to introduction of different interocclusal recording materials, dentists encounter difficulties in the selection of appropriate material for the registration and transfer of occlusal records to the articulator.[19] Waxes are the most commonly used interocclusal recording materials because of their ease of manipulation and cost-effectiveness. Aluwax consists of low-viscosity wax with impregnated aluminum particles to evenly disperse the heat and to avoid excessive cooling contraction. There is general agreement that waxes, in any of the forms available (Baseplate, beauty hard wax, metallized, or metallized with an aluminum laminate) are the least accurate materials. Waxes have low ability to reproduce the occlusal surfaces accurately. They can be distorted upon removal and change dimensionally by release of internal stresses. Furthermore, wax records may cause mandibular deflection and resistance to closure. Currently, polyvinyl siloxane bite recording material is increasing in popularity due to its handling characteristics, accuracy, and dimensional stability. Polyvinyl siloxane bite registration material is characterized by short working time, setting time, high stiffness, low-percent strain in compression, and low flow. Using radiographic images to measure the SCGA has many advantages, especially in cases where there are difficulties measuring this angle using the protrusive occlusal record. Radiographic methods are more accurate than any other clinical methods as they involve stable bony landmarks and does not rely on the operator or patient's neuromuscular control.[12,13] With the advent of CBCT, tomography scans have involved lower radiation exposure and greater accuracy, resulting in their widespread application in dentistry[34]; however, limitations include the high cost of the equipment. 3D multiplanar sections obtained from a CBCT scan provide an improved anatomic overview of the condyle and its pathway without the superimpositions inherent in 2D radiographic images.[21] Few studies[12,18,20,21] have considered CBCT as an alternative method for obtaining SCGAs to program semi-adjustable and fully adjustable articulators. This study was conducted to compare the condylar guidance angle obtained from two mostly widely used interocclusal bite registration materials, polyvinyl siloxane and aluwax; with the advanced technology using CBCT. Condylar guidance on an articulator is adjusted utilizing either the patient's protrusive or lateral interocclusal registrations. The HANAU™ Wide Vue Articulator with fixed intercondylar distance can be set using the protrusive interocclusal registration.[25] Following the protrusive interocclusal registration condylar guidance is measured in degrees relative to a plane of reference.[32] Condylar inclination when obtained by different planes of reference cannot be compared. The present study utilized HANAU™ Spring Bow which relies on the Frankfurt's horizontal plane to transfer the patient's relation to the articulator. The same plane is readily demonstrable on CBCT by joining the porion and the orbitale landmarks. According to the most accepted definition of centric relation, condyles articulate in the anterior-superior position against the posterior slopes of the articular eminences[1], therefore the section with superior most and anterior most point on the posterior slope of articular eminence was chosen. The evidence that the horizontal axis runs through the medial poles of the condyles is found in the triangular fossae on the posterior slope of the articular eminence with the apex related to the medial pole[22], which suggests that true hinge axis passes through this point, hence section with medial most point in the coronal view was chosen. The problem with recording SCGA intraorally using various materials is that SCGA values changes with degree of protrusion.[23,25] The average functional range of protrusion rarely exceeds 4mm; while the 6 mm protrusive record holds the articulator mechanism more securely.[26] If a natural incising relation involving a protrusion of 2 or 3 mm is recorded, then the condyle paths on the articulator gets adjusted with a wide range of error. Alternatively, if a protrusion of 6 mm or more is recorded the operator can set the controls with greater accuracy[27], hence intraoral protrusive record was made at 6mm of protrusion for each individual. No significant difference was observed between

right and left SCGA within each group. This can be because of good neuromuscular control of the subjects. Previous studies[29,30] found that intraoral methods of SCGA measurement have lower levels of reproducibility, which is attributable to variations between the instruments and operators.[31] The error in protrusive occlusal record measurements can be large due to various factors.[25,27] According to Seirawan MK[19], polyvinyl siloxane was found to be the most accurate among the four tested materials (zinc oxide eugenol paste, polyvinyl siloxane, Aluwax, and Baseplate wax). It showed the least mean value of vertical separation and lateral displacement. This may be attributed to its high stiffness and low permanent deformation at the time of removal. Cronbach's α that measures reliability, was highest for CBCT, indicating a high internal consistency. Whereas for both the clinical methods it was slightly lower than CBCT and was least for aluwax, this is comparable to studies[16,29,33] proving wax as the most variable and least reliable of all interocclusal recording materials. Strong correlations were found between CBCT and clinical methods in the studies[12,18,20,21] that used CBCT for measuring condylar guidance. Results of this study also revealed positive correlation between each group using Pearson correlation test. However, there was significant difference between the values of SCGA obtained from CBCT and clinical methods, except for one study[21], that found no significant difference between the two methods. Radiographic values were 10-12 degrees higher than clinical methods, which is similar to the results obtained in other studies.[12,18,28] Brewka[35] in 1981 stated that radiographic methods and clinical methods are in disagreement. Christensen and Slabbert[28] in a 1978 review has stated that "no radiographically determined sagittal condylar guidance angle coincided with that obtained with the use of intra-oral records. Radiographically determined angle showed a greater mean value than that determined by intra-oral records". Shreshta P et al[12] in their study have attributed inconsistency of intra oral methods due to change of condylar angle with each degree of protrusion. Standard 6mm of protrusion was used in this study to avoid error with different degrees of protrusion. SCGA recorded using various clinical methods have been reported to show wide variations between each other. Results from previous studies[31,36] have also reported significant differences between instruments and methods and also between consecutive registrations for the same patients. Semi-adjustable articulator was used in the study for receiving the records and calculating SCGA from the clinical methods. Semi-adjustable articulators are limited in their capabilities to accurately simulate the TMJs, the jaws and their movements because of the fixed inter condylar distances and the straight condylar pathways, which are reported to cause errors especially in the horizontal and frontal plane[17] and arbitrary hinge axis is being used to transfer the facebow record to the articulator. This might be the reason for variance between the CBCT and clinical methods. Christensen's phenomenon[17] might also result in variations between radiographic and clinical methods. It could be inferred from this study that clinical methods were not found to be comparable to CBCT in giving SCGA. Given the superior precision and standardization of CBCT, these must be introduced in the clinical work flow for measuring condylar determinants. It may be beneficial to employ CBCT scans for condylar measurements especially for complex oral rehabilitations. However, clinical methods are more practical, economical and are consistent with each other. Hence, further studies with larger sample sizes are required to confirm the results of the present study. Future studies should investigate the effect of TMJ disorders on clinical methods. Reliability of obtaining condylar guidance from CBCT and using it with newer technologies like virtual articulators should be evaluated.

6. CONCLUSION

Determination of condylar inclination by using polyvinyl siloxane and aluwax with the help of semi-adjustable articulator showed less inclination in degrees than the values determined from CBCT. Thus, CBCT should be a method used for correctly determining the condylar guidance inclination as the values are determined from three dimensional surface. Virtual articulators should be used in combination with condylar guidance values determined from CBCT.Condylar inclination seem to be similar on right and left side of each dentulous subject with good neuromuscular co-ordination.Further studies should be carried out by printing the model and calculating the condylar guidance.

7. AUTHORS CONTRIBUTION STATEMENT

Sneha Bahadursingh Ailsinghani, Deepak Vikhe, Umesh Palekar, Veena Saraf contributed to the design and implementation of the research and analysed the data. Neha Hajira and Pallavi Madanshetty provided valuable inputs towards designing of the manuscript. All authors read and approved the final version of the manuscript.

8. CONFLICT OF INTEREST

Conflict of interest declared none.

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