Original Article

Comparative evaluation of condylar inclination in dentulous subjects as determined by two radiographic methods: Orthopantomograph and cone-beam computed tomography – An *in vivo* study

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Abstract

Aim: The aim of the study was to compare two radiographic techniques, orthopantomograph (OPG), and cone-beam computed tomography (CBCT) in determining the sagittal condylar guidance (SCG) and to find out if CBCT can serve as an alternative aid to program semi-adjustable and fully adjustable articulators.

Materials and Methods: Following the inclusion and exclusion criteria, 40 individuals (20 males and 20 females) aged between 20 and 40 years were selected. An OPG and a CBCT radiograph were obtained for each individual. Using appropriate software, the SCG was measured for both the sides, for both the radiographic methods. The values for each individual were obtained by two investigators for both the methods using the respective software and the average value was taken. After performing the Shapiro–Wilk test, paired *t*-test was used to compare the mean difference pairwise (for both right and left side) while *t*-test was used to compare the mean difference between two groups.

Results: Results showed that the right and left SCG values obtained from both, OPG and CBCT methods were comparable and there were no significant differences. Statistically significant difference was not found between the left and ride side condylar inclination values for both the sex obtained from both the methods. With increasing age, condylar inclination values obtained from both the radiographic methods tend to decrease. The values for SCG obtained from both the methods (CBCT and OPG) are thus comparable and correlated.

Conclusion: The values for SCG obtained from both the methods (CBCT and OPG) are comparable and correlated. Thus, CBCT being a better radiographic technique can be used for obtaining the condylar inclination for programming the semi-adjustable and fully adjustable dental articulators.

Keywords: Cone-beam computed tomography, dental articulators, panoramic radiography

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INTRODUCTION

Complex prosthodontic procedures demand an accurate simulation of the condylar path of the patient on an articulator to restore the dentition with a noninterfering occlusion.[1] According to The Glossary of Prosthodontic Terms 9, condylar guidance can be defined as mandibular guidance generated by the condyle and articular disc traversing the contour of the articular eminence (AE).[2] Inappropriate recording of the condylar guidance can lead to occlusal interferences, thus leading to an increase in valuable chairside denture adjust time. These consequences lead to inadequate patient satisfaction and a disharmonious occlusion.[3] Average values of condylar guidance ranging from 22° to 65° are relied on by many practitioners.[4] However, the average values can lead to inaccuracies depending on the steepness or flatness of the individual inclination of the AE.[5] For semi-adjustable articulators, the condylar guidance is set by protrusive or lateral interocclusal records.[6-9] Intraoral or positional wax method, graphic records, functional recordings, and cephalometrics are the methods that are used to record the centric and eccentric relations of the mandible.[10,11] In spite of accurately following the registration methods, errors may arise due to inhibition of smooth movements between the condylar components of the articulator due to friction.[12] Errors in laboratory procedures arise due to material instability and variation in their nature of polymerization.[13] On the other hand, pantographs are used to record tracings and aid in the programming of fully adjustable articulators.[14] Errors arising due to the inexperienced operator should also be taken into consideration as the clinical methods are technique sensitive.[14] Radiographic methods such as lateral cephalograms, oral pantographs, and tomograms are also used for recording the condylar guidance.[5,15,16] 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.[17,18] The main drawbacks of widespread usage of radiographic methods are expensive equipment, inconvenience, and radiation exposure to the patients. Above it, there is a scarcity of evidence in the literature to support the radiographic techniques over the conventional clinical methods.[18] Recently, cone-beam computed tomography (CBCT) has made them more accurate, noncumbersome, safer, and cheaper resulting in widespread application in prosthodontics.[18] Panoramic radiography provides a two-dimensional image of the temporomandibular joint (TMJ), but CBCT being a more advanced cutting-edge technology provide three-dimensional multiplanar sections without superimposition.[19] Hence, the sagittal condylar guidance (SCG) values obtained from the radiographic techniques can be directly used to program the semi-adjustable articulators, thus resulting in eliminating the technique sensitive clinical methods. There are very few studies in the prosthodontic literature comparing the sagittal condylar angle values obtained from radiographic methods such as orthopantomograph (OPG), lateral cephalograms, and other novel and advanced techniques such as conventional computed tomography and CBCT scans.

This novel study has been designed to compare the SCG obtained from OPG and a relatively newer and more accurate radiographic method, i.e., CBCT and to find out if CBCT can serve as an alternative aid to program semi-adjustable and fully adjustable dental articulators. The null hypothesis was that the values of SCG obtained from both the methods show a statistically significant difference and that CBCT cannot be used as an alternative aid to program semi-adjustable and fully adjustable dental articulators.

MATERIALS AND METHODS

A total of 40 individuals (20 males and 20 females) within the age group of 20–40 years, of either sex were selected following the inclusion and exclusion criteria. Individuals were chosen from among the patients who reported to the outpatient department of the Department of Prosthodontics, Crown, and Bridge including Implantology of MR Ambedkar Dental College and Hospital, Bengaluru, Karnataka, India, seeking some sort of prosthetic treatment. Radiographs were obtained from the patients only when it was indicated for treating their condition. A written consent was obtained from each of them before including their treatment-related radiographic information in this study. Proper radioprotective protocols were followed. An ethical clearance certificate was obtained from the Ethical Committee of the institution. Inclusion criteria included individuals having an almost full complement of natural teeth (at least three teeth in each posterior segment), Class I molar relationship and an overjet of 2–4 mm. Individuals with severe temporomandibular disorders (myofascial pain dysfunction syndrome, osteoarthritis, internal derangements, rheumatoid arthritis, ankylosis, tumors, trauma, and developmental disorders), faulty restorations, periodontal diseases, gross attrition, poor neuromuscular control, deteriorating general health, and pregnancy were excluded from the study.

For panoramic radiograph (orthopantomograph)

A panoramic radiographic image of each individual was obtained. The same operator made all the radiographs

in the same panoramic radiographic unit (Kodak 8000c digital panoramic and cephalometric unit, Kodak). Keeping the Frankfort horizontal plane (FHP) parallel to the floor, the images were acquired at 74 kV and 10 Ma. The head was aligned in the same position for all the individuals using a cephalostat. Using appropriate software (Masterview 4.5.1, Kodak), the anatomic outlines of the left and right AE and glenoid fossae were traced. On each side, the FHP was drawn by joining the two landmarks – "orbitale" and "porion." A second line representing the mean condylar path was constructed by joining the inferior most point on the articular tubercle and the superior-most point on the AE [Figure 1]. The angle of sagittal condylar inclination was obtained by measuring the angle formed between the intersection of the two constructed lines for both the right and left sides [Figure 2].

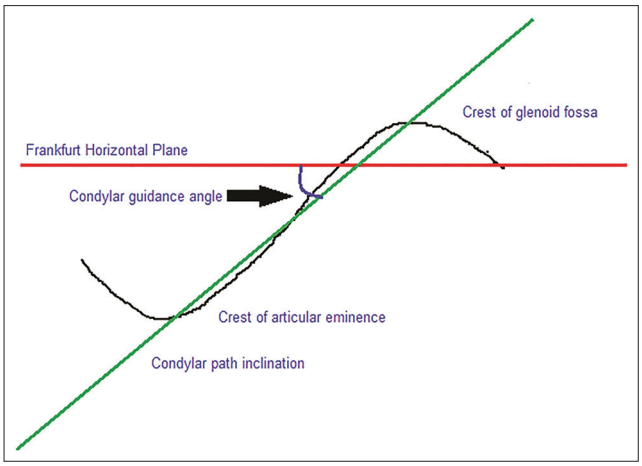

Figure 1: Line diagram showing the tracing of the condylar guidance angle

For cone-beam computed tomography

A CBCT image of the midfacial region of each individual was obtained by the same operator in the same unit (Carestream Kodak 9300C, Kodak). Using appropriate software (CS 3D-Imaging software, Carestream Dental), axial sections perpendicular to condylar long axis were made (width = 200 mm, thickness = 1 mm, and step = 2 mm) at the level of the head of the condyle and inferior border of the zygomatic arch. To determine the maximum depth of glenoid fossa, a perpendicular line connecting the deepest point of the glenoid fossa was drawn onto another line connecting the two sides of glenoid fossa on the central section and two sections before and after. The section which had the maximum length of the perpendicular line was selected. The FHP was constructed after identifying the "porion" and "orbitale" and another second line was constructed along the posterior slope of AE, connecting the most concave (highest) point on the glenoid fossa and the most convex (lowest) point on the apical portion of AE. The condylar inclination angle for both the sides [Figure 3] was obtained by measuring the angle between FHP and the second constructed line for each individual. The values for each individual were obtained by two investigators for both the methods using the respective software and the average value was taken. Finally, condylar inclination values obtained by both the radiographic methods were evaluated.

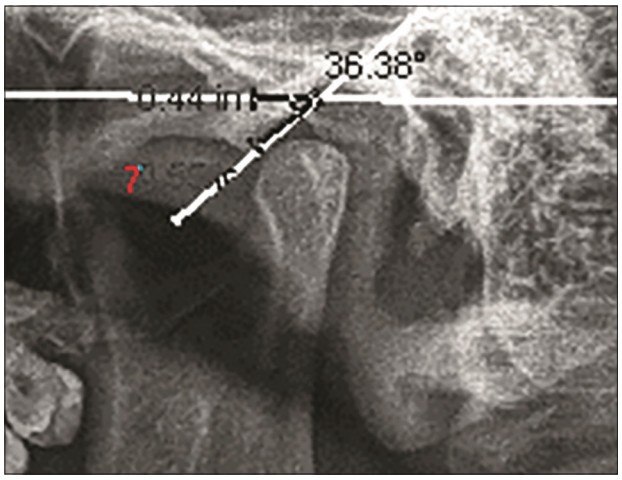

Figure 2: Orthopantomograph interpretation of a subject

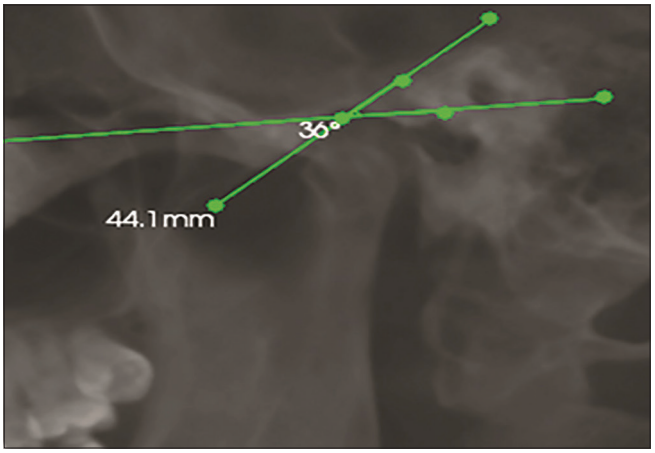

Figure 3: Cone-beam computed tomography interpretation of a subject

Statistical analysis

After the collection of data, the data were entered into Microsoft Office Excel 2007, Microsoft and analyzed with Statistical package for the social sciences software. The data with normal distribution (obtained by Shapiro-Wilk test) were further subjected to parametric tests. Paired *t*-test was used to compare the mean difference pairwise (for both right and left sides) while *t*-test was used to compare the mean difference between two groups. Pearson's r coefficient test was used when testing for correlations as appropriate. $P \leq 0.05$ was considered as statistically significant, and all tests were two-tailed.

RESULTS

Condylar guidance angle obtained for both the right and left sides using both the radiographic techniques: OPG and CBCT for all the samples have been presented in Table 1. Paired *t*-test was used to compare the mean difference pairwise (for both right and left sides). As depicted in Table 2, for CBCT modality, the $P = 0.44$ showing no significant difference between the condylar inclination obtained for both the sides. For OPG modality, the $P = 0.31$, showing no significant difference between the condylar inclination obtained for both the sides. The correlation between condylar inclination angle values obtained using CBCT and OPG on the right and left sides are depicted in Figures 4 and 5, respectively. As depicted in Tables 3 and 4, the mean condylar guidance values obtained by CBCT and OPG method, respectively, showed no significant difference between both the genders. As depicted in Tables 5 and 6, there was a decrease in the condylar guidance values with age on both the sides for both CBCT and OPG method respectively, and the *P* values suggest that there is a significant difference among the various age groups for both the methods. Pearson's coefficient test was used when testing for correlations as appropriate. There was a positive correlation between the condylar inclination values obtained from the right and left sides for both the modalities [Table 7].

DISCUSSION

After evaluating the results, we can state that the null hypothesis stands defeated. The condylar guidance values obtained from both the radiographic methods for right and left sides did not show any statistically significant difference. Shreshta *et al*. also reported that measurements obtained from clinical and radiographic methods for both the sides were statistically insignificant.[18] However, El-Gheriani and Winstanley have reported significant variation between the left and right condylar guidance values.[20] Similar results were obtained in Zamacona study.[1] The difference with Zamacona's results can

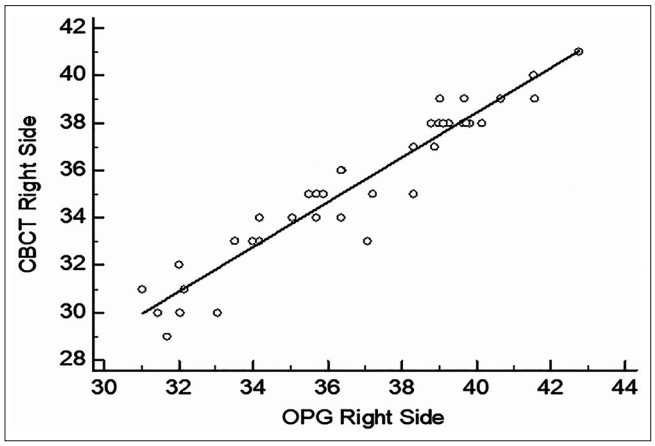

Figure 4: Graph showing correlation between condylar angle values obtained using cone-beam computed tomography and orthopantomograph on the right side ($r = 0.95$, $P < 0.001$)

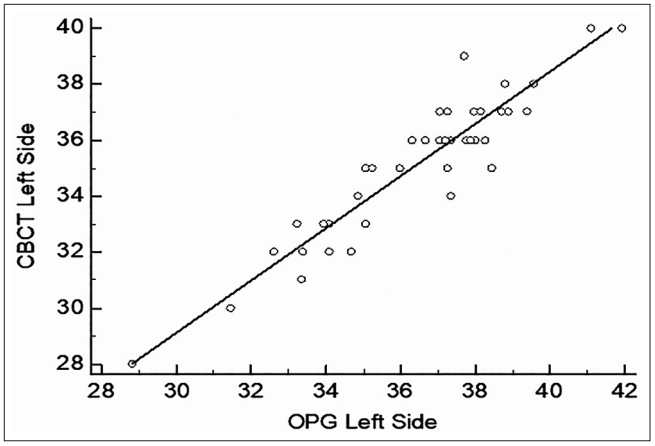

Figure 5: Graph showing correlation between condylar angle values obtained using cone-beam computed tomography and orthopantomograph on the left side ($r = 0.93$, $P < 0.001$)

Table 1: Condylar guidance angle using both methods

Method	Side	Number of individuals (*n*)	Minimum (°)	Maximum (°)	Mean±SD
CBCT	Right	40	29	41	35.43±3.13
	Left	40	28	40	35.18±2.62
OPG	Right	40	31.05	42.77	36.81±3.17
	Left	40	28.83	41.94	36.48±2.62

SD: Standard deviation, CBCT: Cone-beam computed tomography, OPG: Orthopantomograph

Table 2: Comparison of condylar guidance angle for both methods

Method	Side	Number of individuals (*n*)	Mean±SD	Δ	95% CI	*t* (df)	*P*
CBCT	Right	40	35.43±3.13	0.25	−0.41–0.91	0.77 (39)	0.44
	Left	40	35.18±2.62				
OPG	Right	40	36.81±3.17	0.33	−0.32–0.99	1.03 (39)	0.31
	Left	40	36.48±2.62				

Data were given as mean±SD and the significant difference between the groups was assessed by using paired *t*-test. Δ: Mean difference, df: Degree of freedom, SD: Standard deviation, CBCT: Cone-beam computed tomography, OPG: Orthopantomograph, CI: Confidence interval

Table 3: Gender wise comparison of condylar guidance angle for cone-beam computed tomography method

Side	Gender	Number of individuals (*n*)	Mean±SD	Δ	95% CI	*t* (df)	*P*
Right	Male	20	35.95±3.19	1.05	−0.95–3.05	1.06 (38)	0.29
	Female	20	34.90±3.06				
Left	Male	20	35.95±2.46	1.55	−0.07–3.17	1.93 (38)	0.06
	Female	20	34.40±2.60				

Data were given as mean±SD and the significant difference between the groups was assessed by using *t*-test. df: Degree of freedom, SD: Standard deviation, CI: Confidence interval

Table 4: Gender-wise comparison of condylar guidance angle for orthopantomograph method

Side	Gender	Number of individuals (*n*)	Mean±SD	Δ	95% CI	*t* (df)	*P*
Right	Male	20	37.31±3.17	0.99	−1.04–3.02	0.99 (38)	0.33
	Female	20	36.31±3.17				
Left	Male	20	37.07±2.48	1.17	−0.48–2.82	1.43 (38)	0.16
	Female	20	35.89±2.68				

Data were given as mean±SD and the significant difference between the groups was assessed by using *t*-test. Δ: Mean difference, df: Degree of freedom, SD: Standard deviation, CI: Confidence interval

Table 5: Age-wise comparison of condylar guidance angle for cone-beam computed tomography method

Side	Age (years)	Number of individuals (*n*)	Mean±SD	95% CI	*F* (df)	*P*
Right	25–30	17	37.41±2.93	36.23–38.59	17.05 (2/37)	<0.001**
	31-35	12	35.58±1.88	34.39–36.78		
	36-40	11	32.18±2.75	30.33–34.03		
Left	25-30	17	36.59±2.12	35.50–37.68	9.44 (2/37)	<0.001**
	31-35	12	35.25±1.91	34.03–36.47		
	36-40	11	32.91±2.55	31.20–34.62		

Data were given as mean±SD and the significant difference among the groups was assessed by using one-way ANOVA; $P<0.001$ showing the highly significant difference. df: Degree of freedom, SD: Standard deviation, CI: Confidence interval

Table 6: Age-wise comparison of condylar guidance angle for orthopantomograph method

Side	Age (years)	Number of individuals (*n*)	Mean ± SD	95% CI	*F* (df)	*P*
Right	25-30	17	39.01 ± 2.19	37.89–40.14	17.49 (2/37)	<0.001**
	31-35	12	36.57 ± 2.05	35.26–37.87		
	36-40	11	33.69 ± 2.79	31.81–35.57		
Left	25-30	17	37.89 ± 2.12	36.80–38.98	10.16 (2/37)	<0.001**
	31-35	12	36.63 ± 1.64	35.58–37.67		
	36-40	11	34.14 ± 2.66	32.35–35.92		

Data were given as mean±SD and the significant difference among the groups was assessed by using one-way ANOVA; $P<0.001$ showing the highly significant difference. df: Degree of freedom, SD: Standard deviation, CI: Confidence interval

Table 7: Correlation between condylar guidance angles for both methods

Variables	CBCT		OPG	
	Right side	Left side	Right side	Left side
CBCT right side	1			
CBCT left side	0.76**	1		
OPG right side	0.95**	0.74**	1	
OPG left side	0.78**	0.93**	0.77**	1

Pearson's "*r*" coefficient correlation test. **$P<0.001$ highly significant. CBCT: Cone-beam computed tomography, OPG: Orthopantomograph

be attributed to the heterogeneity of the sample a mix of partially edentulous and completely edentulous individuals who were referred for treatment for TMJ disorders. Whereas in this study, individuals were chosen from within a homogeneous group consisting of only partially edentulous individuals or patients having a full complement of teeth. The mean sagittal condylar values obtained from OPG are slightly higher than that obtained from CBCT for both the sides. For both the techniques, in male samples, mean SCG obtained for left and right sides were slightly higher than the female samples. However, the "*P*" values for the right side and left side suggest that the differences were statistically insignificant [Tables 3 and 4]. Alshali *et al.* conducted a study to measure sagittal condylar inclination in male and female participants.[21] Results showed that there was no statistically significant difference in sagittal condylar inclination values between the right and left sides, or between the male and female groups. The results of this study are in accordance with the present study. The sagittal condylar inclination obtained from CBCT and OPG among various age groups was also compared. It was seen that that with increasing age the angle decreases on both the right and left sides, and the change in values are statistically significant for both the methods. Sreelal *et al.* compared the effect of age changes in horizontal condylar inclination using articulator method and a

radiographic method.[22] Horizontal condylar values showed a decreasing trend with increasing age, i.e., as age advances, there is a flattening of condylar head. The results of this study are also in accordance with the present study. Although OPG provides an overall view of the entire maxillomandibular region and related areas on a single film, its accuracy is limited due to image magnification and distortion. A panoramic radiographic image in the temporal region shows the outer radio-opaque line depicting the AE and inner radiopaque line depicting the inferior border of the zygomatic arch. These lines often intersect and can be confusing due to significant limitations of panoramic radiographs imputable to distortions inherent in the panoramic system and errors in patient positioning.[23] Parallax errors may arise with positioning errors of the head to the exposure path.[24] In the present study, the panoramic machine comes with a light source and cephalostat that helps in accurate positioning of the patients, and the same machine was used to obtain all radiographs. Furthermore, in panoramic imaging, the bony details are obliterated by the superimposition of the skull based on AE and the zygomatic arch. However, CBCT provides a three-dimensional image for both the sides without superimpositions, and so the glenoid fossa and the AE can be clearly delineated. On the other hand, with the advent of CBCT, tomography scans have become safer involving lower radiation exposure and more accurate resulting in their widespread application in dentistry.[25] In present-day scenarios, the only limitation of using CBCT is the high expense of the equipment. However, in future, with increased demand and usage of CBCT in various fields of dentistry, these scans are bound to become more economical and widely accepted.

CONCLUSION

Within the limitations of the study, it can be concluded that the right and left SCG obtained from OPG method were comparable, and there was no significant difference. The right and left SCG obtained from CBCT method were comparable, and there was no significant difference. The right and left side condylar guidance values for both the genders obtained from both the methods showed no significant difference. With increasing age, condylar inclination values obtained from both the radiographic methods tend to decrease. The values for SCG obtained from both the methods (CBCT and OPG) are comparable and correlated and CBCT being a better radiographic technique, it can be used as a valuable aid in determining SCG to program semi and fully adjustable articulators.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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