ORIGINAL RESEARCH

Comparative Evaluation of the Horizontal Condylar Guidance Using Protrusive Interocclusal Records, OPG, and CBCT in Edentulous Patients: An *In Vivo* Study

Rashmi Gheedle[1], Peter John[2]

Abstract

Aims: A clinical study to compare the horizontal condylar guidance using protrusive interocclusal records, orthopantomography (OPG), and cone-beam computed tomography (CBCT) in edentulous patients.

Subjects and methods: Thirty-six edentulous subjects were selected as per predetermined criteria. Horizontal condylar guidance was recorded using protrusive interocclusal records (PIR), OPG, and CBCT for each patient. The PIR were obtained using extraoral Gothic arch tracers to program the Hanau articulator. The horizontal condylar guidance angles (HCGAs) were digitally constructed using appropriate software along the posterior slope of articular eminence for all radiographs. The collected data were recorded, tabulated, and statistically analyzed.

Results: The condylar guidance angle values were tested for significance to compare the different angles. The correlation of HCGA measurements on both sides between the three groups was analyzed. The PIR and OPG methods ($p = 0.001$), as well as the OPG and CBCT methods ($p = 0.001$), show substantial differences on both sides. On the contrary, the PIR and CBCT methods did not differ significantly ($p = 0.11$).

Conclusion: Cone-beam computed tomography is as reliable and accurate as the clinical method. A significant correlation exists between the clinical method and CBCT. It can be used as a dependable adjunct to the clinical method of HCGA measurement.

Clinical significance: Cone-beam computed tomography can overcome the shortcomings of the conventional clinical methods to determine the accurate horizontal condylar guidance angulation measurement. It is safer with minimum discomfort and wastage of time for the patients.

Keywords: Cone-beam computed tomography, Horizontal condylar guidance, Panoramic radiography, Protrusive interocclusal records.

The Journal of Contemporary Dental Practice (2023): 10.5005/jp-journals-10024-3517

Introduction

Artificial intelligence research is apace growing, and it creates a culmination of accomplishments in all acreage of evolution. Imaging within the dental specialty has greatly advanced over the last few years. Previously, we relied on static images for the maxillofacial investigation, but lately, everybody seems to be advancing toward three-dimensional (3D), digital, and interactive imagery. Due to its high spatial resolution and 3-D imaging capabilities, cone-beam computed tomography (CBCT), is becoming increasingly popular among physicians.[1]

CBCT developed by Aboudara et al. in 1984 provides varied benefits over traditional graphic methods.[2] CBCT might play a pivotal purpose in diminishing the load of overactive prosthodontics routine to the clinician and may essentially contribute to precise and efficacious treatment for the patient.[3]

The perfect replication of condylar guidance is an important factor in the success of complex prosthodontic treatments. The goal of mandibular movement registration is to recreate the participant's occlusion and mandibular range of motion as closely as an articulator.[4]

A documentary literature study in dentistry reveals that graphical tracings, intraoral or positional wax methods, and radiographic methods are among the techniques, philosophies, and materials that can be utilized to record condylar guidance.[5] The ubiquitous technique to set the condylar guidance in semi-adjustable articulators is by achieving centric, protrusive, and lateral interocclusal records after Gothic arch tracing. Nonetheless, the approaches are time-consuming and labor-intensive, and successive condylar guidance records, recording elements, and diverse types of articulators vary over time.

Radiographic methods such as lateral cephalograms, panoramic radiography, and computed tomography have recently been promoted to attain the same purpose. These procedures are more advantageous since they are based on stable bone references, which minimizes potential errors by user's incognizance and inadequate muscle coordination.[6]

An orthopantomography (OPG) provides less radiation but only bi-dimensional images, whereas a CT provides three-dimensional images at a higher radiation level. Cone-beam computed tomography evaluation of the condylar position eliminates projection inaccuracies and provides a precise 3D analysis of the

[1,2]Department of Prosthodontics, SRM Dental College, Chennai, Tamil Nadu, India

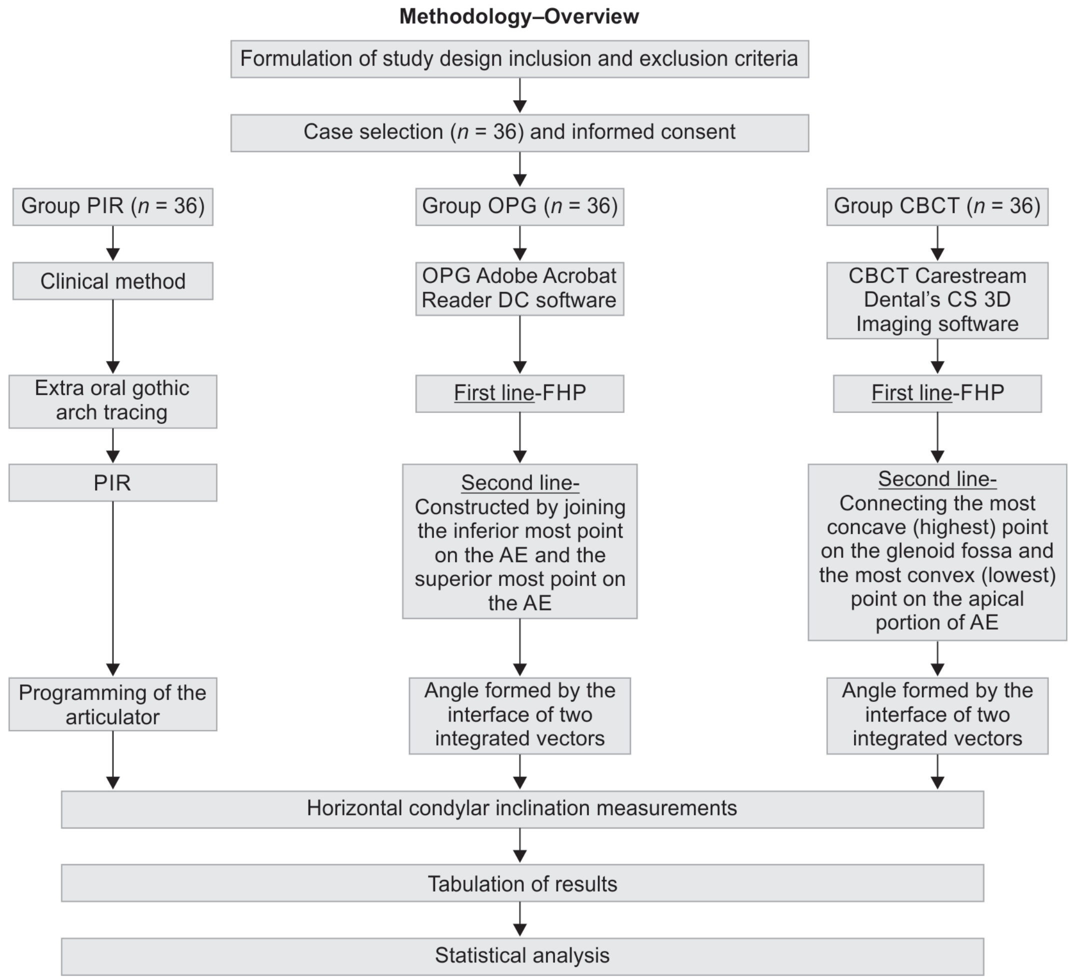
Corresponding Author: Rashmi Gheedle, Department of Prosthodontics, SRM Dental College, Chennai, Tamil Nadu, India, Phone: +91 9425557256, e-mail: rash.gheedle@gmail.com

How to cite this article: Gheedle R, John P. Comparative Evaluation of the Horizontal Condylar Guidance Using Protrusive Interocclusal Records, OPG, and CBCT in Edentulous Patients: An *In Vivo* Study. J Contemp Dental Pract 2023;24(6):403–408.

Source of support: Nil

Conflict of interest: None

Flowchart 1: Methodology



craniofacial structures with shorter exposure times than those used for a panoramic image. Moreover, the recorded volume can simulate multiple plain and tomographic projections.

Raw data obtained from CBCT is formatted into Digital Imaging and Communications in Medicine (DICOM) data. Data from DICOM can be viewed by importing them into a program that allows real-time manipulation of multiplanar slices and 3D volume renderings. It is a modern technology for accurate measurements and can be transferred onto an articulator.[2]

However, the accuracy of the clinical technique, OPG, and CBCT for measuring horizontal condylar guidance must be determined. Therefore, this study aims to evaluate assesses protrusive interocclusal records (PIR), CBCT images, and OPG measurements of horizontal condylar guidance angulation in edentulous subjects.

Subjects and Methods

The Institutional review board and the ethical committee provided an ethical clearance declaration for the study. Subjects of either sex, aged between 40 and 80 years, completely edentulous, were recruited for the study from the Prosthodontics Department at SRM Dental College, Ramapuram, Chennai from 2019 to 2021. Each participant signed consent before performing the clinical steps, including their treatment-related radiographic and clinical data in the study.

Participants who were entirely edentulous and classified as Class I American College of Prosthodontics (ACP) edentulous were eligible.[7] Those with temporomandibular disorders, impaired neuromuscular control, declining general health, any pathologic disease concerning the oral soft or hard tissues, prior craniofacial trauma or surgery, or extreme facial asymmetry were excluded. The sample size of 36 was computed using G Power One software with a 10% dropout rate, an 80% power level, and a 5% alpha error rate.

The horizontal condylar guidance was obtained by PIR, OPG, and CBCT in all the subjects. An overview of the methodology is shown in Flowchart 1.

Protrusive Interocclusal Records

Conventional steps in the fabrication of complete dentures with balanced occlusion were carried out. Waxed occlusal rims were fabricated. The Niswonger method was used to record the tentative vertical jaw relation, and the horizontal relation was obtained by Nick and Notch method using zinc oxide eugenol material. An arbitrary earpiece face bow (Hanau springbow, Hanau Wide–Vue, USA) were used to record the orientation of jaw relation. The cast was mounted to a semi-adjustable articulator (Hanau Wide–Vue, Whipmix, USA).[8]

An arbitrary earpiece face bow (Hanau springbow, Hanau Wide–Vue, USA) was used to record the orientation of jaw relation.

Fig. 1: Horizontal condylar guidance determined on Hanau articulator too blur

Face bow transfer was done, and the cast was mounted to a semi-adjustable articulator (Hanau Wide-Vue, Whipmix, USA).

The patient's horizontal jaw relation was recorded using extraoral Gothic arch tracers (Bio Tracer, Delta) connected to the occlusal rims. The patients were instructed to make protrusive inter-occlusal records by requesting the subject to push the jaw forward by 6 mm and interocclusal records were made with quick-setting dental plaster. The casts and centric recordings were fitted to the Hanau Semi-adjustable articulator.

The articulator's centric locks and horizontal condylar guide were released before programming. PIR was placed on the lower occlusal rim. The upper member of the articulator was oriented onto the indentation of the PIR. By moving the right and left condylar guidance back and forth simultaneously, the rims were correctly seated into the PIR. When the occlusal rims were properly placed without swaying, each thumb nut for horizontal inclination was tightened. The horizontal condylar guidance of the articulator was established. (Fig. 1). The right and left side condylar guiding angles of each subject were recorded. After the PIR were recorded, OPG and CBCT for each patient were taken.[9]

For Panoramic Radiograph (Orthopantomography)

Proper radioprotective procedures were followed. All radiographs were taken from the OPG machine by only one operator. The images were shot with the Frankfort horizontal plane (FHP) collateral to the ground at 74 kV and 10 Ma. Using Adobe Acrobat Reader DC software, the structural contours of both the articular eminence (AE) and glenoid fossae (GF) were identified. The FHP was built by linking both markers "orbitale" and "porion" along either side. A second line reflecting the mean condylar path was created by linking the uppermost site to the lowermost site on the articular tubercle. The angle formed by the interface of two integrated vectors was used to determine the horizontal condylar guidance angle (Fig. 2).

For Cone-beam Computed Tomography

All patients were required to have a craniofacial CBCT taken by only one operator using a single unit. Axial slices perpendicular to the center of longitudinal plane at the level of the vertex of the condyle were created using Carestream Dental's CS 3D Imaging software. The FHP was established by combining the two landmarks "porion" and "orbitale." An additional line was drawn along the incline of AE, uniting the highest point on the GF to the lowest portion on AE. On both sides, the calculated angle degree between FHP and the second generated line was utilized to estimate the condylar guidance angle (HCGA). Results for each individual's HCGA were obtained using software, and the average was derived for both sides (Fig. 3).

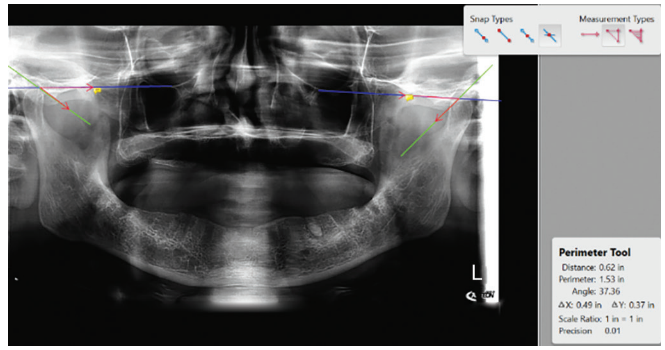


Fig. 2: HCGA measurement – OPG using Adobe Acrobat Reader DC cropped too much on left side

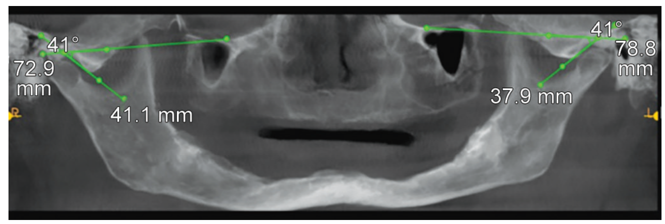


Fig. 3: HCI measurement – CBCT using CS 3D imaging software, Carestream Dental

The information gathered was collated, and statistical studies were performed on it. The significance of the measurements was determined using the ONE-WAY ANOVA test ($p < 0.01$) When one-way ANOVA gave a significant result. Tukey *post hoc* test was used to compare the mean in two groups. The correlation of HCGA measurements on both sides, between the three groups was analyzed using the Pearson's correlation test ($p < 0.01$).

Results

The mean value of HCGA on each participant's left and right sides was estimated independently using the three approaches have been presented in Table 1.

For the clinical protrusive interocclusal record (PIR) approach, the mean value of left HCGA obtained from 36 patients is 32.86, with a range of 30–35. In the OPG technique, the average left HCGA is 38.77, with a span of 30.31–46.33. In the CBCT technique, the left HCGA is 34.44, with a spectrum of 29–40 (Table 1).

In the clinical PIR approach, the mean value of the right HCGA acquired from 36 participants is 32.22, with a range of 30–35.0. In the OPG technique, the mean value of the right HCGA is 35.32, with a range of 28.48–45.27. In the CBCT technique, the mean value of the right HCGA is 34.03, with a range of 20–44 (Table 1).

A bar diagram depicted the comparisons between right and left HCGA for three groups (Fig. 4).

As depicted in Table 2, the significance of the measurements was determined using the ONE-WAY ANOVA test ($p < 0.01$). The statistical test ($p = 0.000$) on the left side of the HCGA demonstrated a significant difference between groups ($p < 0.001$). Whereas no

Table 1: Mean values of HCGA measurements by PIR, OPG, and CBCT

	N	*Mean*	*SD*	*SE*	*95% CI*	*Min–Max*
Left						
PIR	36	32.86	2.13	0.36	32.15–33.57	30–35
OPG	36	38.77	4.17	0.7	37.4–40.14	30.31–46.33
CBCT	36	34.44	2.92	0.49	33.48–35.4	29–40
Total	108	35.36	4.03	0.39	34.6–36.12	29–40
Right						
PIR	36	32.22	2.29	0.38	31.48–32.96	30–35
OPG	36	35.32	3.87	0.65	34.05–36.59	28.48–45.27
CBCT	36	34.03	6.21	1.04	31.99–36.07	20–44
Total	108	33.86	4.57	0.44	33–34.72	20–44

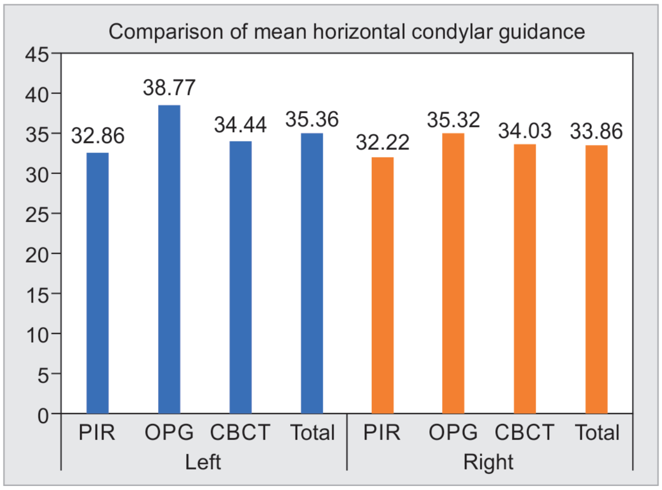


Fig. 4: Comparisons of right and left HCGA of PIR, OPG, and CBCT

Table 2: Intergroup comparison using one-way ANOVA

	SS	*DF*	*MSS*	*F value*	*p-value*
Left					
Between groups	673.51	2	336.75	33.21	<0.001* HS
Within groups	1,064.69	105	10.14		
Total	1,738.21	107			
Right					
Between groups	173.90	2	86.95	4.44	
Within groups	2,056.94	105	19.58		0.014
Total	2,230.84	107			

significant difference ($p = 0.014$) was seen between groups on the right side HCGA (Table 2).

As depicted in Table 3, a *post hoc* intergroup comparison test was performed ($p < 0.05$) for the left side HCGA. There was a substantial difference between the PIR and OPG methods ($p = 0.001$), as well as the OPG and CBCT methods ($p = 0.001$), but not between the PIR and CBCT methods ($p = 0.10$) (Table 3).

As depicted in Table 4, for the right side HCGA, a *post hoc* intergroup comparison test revealed a statistically significant difference between the PIR and OPG methods ($p = 0.001$), as well as the OPG and CBCT methods ($p = 0.001$), but not between the PIR and CBCT methods ($p = 0.19$) (Table 4).

Table 3: *Post hoc* comparison of PIR, OPG, and CBCT on the left side

Treatments pair	*Tukey HSD Q-statistic*	*Tukey HSD p-value*	*Tukey HSD inference*
Left			
PIR *vs* OPG	11.13	0.001	HS
PIR *vs* CBCT	2.98	0.10	NS
OPG *vs* CBCT	8.15	0.001	HS

Table 4: *Post hoc* comparison of PIR, OPG, and CBCT on the right side

Treatments pair	*Tukey HSD Q-statistic*	*Tukey HSD p-value*	*Tukey HSD inference*
Right			
PIR *vs* OPG	4.19	0.01	HS
PIR *vs* CBCT	2.45	0.19	NS
OPG *vs* CBCT	1.7320	0.44	HS

Table 5: Pearson correlation test of PIR, OPG, and CBCT on the left side

	PIR	*OPG*	*CBCT*
PIR			
Pearson correlation "*r*"	1.00	0.85	0.943
Significance (two-tailed)		<0.01	<0.01
N	36	36	36
OPG			
Pearson correlation "*r*"	0.85	1.00	0.946
Significance (two-tailed)	<0.01		<0.01
N	36	36	36
CBCT			
Pearson correlation "*r*"	0.943	0.946	1.00
Significance (two-tailed)	<0.001	<0.01	
N	36	36	36

As depicted in Table 5, the Pearson correlation test ($p < 0.01$) was used to examine the correlation of HCGA values on the left side among the three groups. The Pearson correlation test found a substantial correlation ($p = 0.000$) (Table 5).

As depicted in Table 6, the Pearson correlation test ($p < 0.01$) was used to examine the correlation of HCGA values on the right side between the three groups. The Pearson correlation test found a substantial correlation ($p = 0.000$) (Table 6).

Hence, a significant difference exists between PIR and OPG method ($p = 0.001$) and also between the OPG and CBCT method ($p = 0.001$), whereas no significant difference was seen between PIR and CBCT method ($p = 0.10$) on both the sides. The Pearson correlation test suggests a significant correlation between clinical and CBCT methods.

According to *post hoc* intergroup comparison test, there was no significant difference between clinical and CBCT methods. As a result, compared with panoramic radiographs, the CBCT method is as efficient as the clinical method. There was a notable discrepancy between the clinical and OPG methods.

Table 6: Pearson correlation test of PIR, OPG, and CBCT on the right side

	PIR	*OPG*	*CBCT*
PIR			
Pearson correlation "*r*"	1.00	0.785	0.892
Significance (two-tailed)		<0.01	<0.01
N	36	36	36
OPG			
Pearson correlation "*r*"	0.785	1.00	0.930
Significance (two-tailed)	<0.01		<0.01
N	36	36	36
CBCT			
Pearson correlation "*r*"	0.892	0.930	1.00
Significance (two-tailed)	<0.001	$p < 0.01$	
N	36	36	36

Discussion

The predominate goal of prosthetic dentistry is to restore the missing tooth morphology together with optimum occlusion following the patient's stomatognathic system. According to Hanau's five factors for determining articulation, the condylar guidance is the most significant and fundamental component for ensuring balanced articulation.[10] Gilis, Gysi, and Kohler were the first to identify the need of determining the horizontal course of condyles.[11] The patient's condylar path should be accurately reproduced with an articulator in order to restore the occlusal form, developing accurate restorations.[12]

The face bow transfer, with centric, lateral, and PIR, together replicate the lower arch movements on the articulator. The HCGA is configured with the protrusive interocclusal record. This angle, which is synced to the angle of the temporomandibular joint's eminence, is a relative quantity rather than a fixed value.[13] According to Dos Santos et al. and Olsson and Posselt, the Hanua articulator was designed to deliver an accurate replica of the patients' condylar path.[14]

To overcome the limitations of clinical approaches, Corbett et al., Ingervall, Christensen and Slabbert popularized the radiographic method for acquiring horizontal condylar guidance in the 1970s.[15–17] Magnetic resonance imaging was previously used to determine the form and inclination of the articular eminence.[18] According to Davis and Mackay, CBCT and interactive computer processing are beneficial with high-quality pictures, rapidity of application, direct analysis, and high precision.[19]

A similar study by Kumari et al.[9] for radiographic evaluation of sagittal condylar guidance aforementioned that the OPG to set the condylar guidance on semi-adjustable articulator for complete denture therapy is questionable. Similarly, in the current study, a notable discrepancy between clinical and OPG method was presented. Although according to Shetty S, protrusive condylar guidance angles obtained by OPG are probably used for programming semi-adjustable articulators.[20]

In the present study, the CBCT method is as efficient as the clinical method to determine the horizontal condylar guiding angle in completely edentulous patients. Gheriani, Winstanley, and Zamacona showed similar results, as they used radiographical techniques to determine HCGA, but in patients with temporomandibular joint problems.[13,14]

As Gilboa I et al. mentioned, differentiation of the inferior most location on the AE is difficult since it overlaps the zygomatic arch's inferior aspect. The merging of the three structures, such as a mandibular notch, coronoid process, and zygomatic arch around the TMJ in an OPG causes inconsistencies. Digital panoramic imaging, as per Davis and Mackay, should be employed to overcome this gap.[13]

Using the Carestream Dental's CS 3D Imaging software, the mid-sagittal plane crossing through the center of the condyle was chosen for the current study. According to Sümbüllü MA, the slice is chosen for HCI measurement because it provides the steepest region of the eminence and reliable measurement of HCI.[21]

The software can be used to change the density to distinguish the inferior position on the AE from the lower portion of the zygomatic arc compared with traditional radiographic films. Digital imaging provides high-definition images, the convenience of analysis, reduced time, and reduced radiation exposure.[22] Furthermore, employing software to measure HCGA abolished the likelihood of human mistakes, reduced incorrect measurements by the tracing technique and eliminated the risk of difficulties from manual film processing errors.

The inaccuracies in the clinical procedure can be related to flaws in the registration methodology used and articulator errors. The main source of inaccuracy could be attributed to the articulator's intrinsic limitations. Constant intercondylar lengths and flat condylar paths limit the ability of the jaws and TMJs, resulting in inaccuracies, especially in the frontal and horizontal planes.[23,24]

The present study was studied over a short period with a small sample of edentulous patients without temporomandibular disorders, impaired neuromuscular control, pathologic disease of oral tissues, and prior craniofacial trauma or surgery. Although a significant correlation between the clinical and CBCT methods, unveiled that CBCT may be used to set the HCGA values on the semi-adjustable articulator. More research is necessary to provide more trustworthy and informative insights with a wider sample size than the one used in the current study.

Conclusion

There is a significant relationship between clinical and CBCT results. Therefore, CBCT can be an effective alternative to the clinical HCGA measuring procedure. Cursor-driven evaluation provides an interactive power of legitimate dimensional assessment to the physician. Measurements on the screen provided dimensions that are free of aberration and magnification.[9] Specifically, the existence of these parameters' aids in the precise estimation of condylar guidance angle in prosthodontic treatment.

However, within the study's limits, it can be stated that the condylar guidance angles determined by the radiological method and the extraoral Gothic arch tracing method have an affiliation. Therefore, CBCT could be a viable technique for obtaining condylar guide angle for semi-adjustable articulators in circumstances when extraoral Gothic arch tracing is difficult to achieve.

Orcid

Rashmi Gheedle https://orcid.org/000000028706698X

References

1. Zheng Z, Yan H, Setzer FC, et al. Anatomically constrained deep learning for automating dental CBCT segmentation and lesion

detection. IEEE Trans Automat Sci Eng 2020;18(2):603–614. DOI: 10.1109/TASE.2020.3025871.
2. Singh A, Sandhu H. Cone-beam computerized tomography in prosthodontics Int J Contemp Dent Med Rev 2019;7(12):19–22. DOI: 10.15713/ins.ijcdmr.142.
3. Shah N, Bansal N, Logani A. Recent advances in imaging technologies in dentistry. World JRadiol 2014;6(10):794–807. DOI: 10.4329/wjr.v6.i10.794.
4. Das A, Muddugangadhar BC, Mawani DP, et al. Comparative evaluation of sagittal condylar guidance obtained from a clinical method and with cone beam computed tomography in dentate individuals. JProsthet Dent 2021;125(5):753–757. DOI: 10.1016/j.prosdent.2020.02.033.
5. Shetty M, Shetty G. Comparative evaluation of various techniques to record centric relation – a literature review. J Evolution Med Dent Sci 2020;9(01):53–59. DOI: 10.14260/jemds/2020/12.
6. Naqash TA, Chaturvedi S, Yaqoob A, et al. Evaluation of sagittal condylar guidance angles using computerized pantographic tracings, protrusive interocclusal records, and 3D-CBCT imaging techniques for oral rehabilitation. Niger J Clin Pract 2020;23(4):550–554. DOI: 10.4103/njcp.njcp_544_19.
7. McGarry TJ, Nimmo A, Skiba JF, et al. Classification system for complete edentulism. J Prosthodont 1999;8(1):27–39. DOI: 10.1111/j.1532-849x.1999.tb00005.x.
8. Jain AR, Dhanraj M. A clinical review of spacer design for conventional complete denture. Biol Med 2016;8(5):1. DOI: 10.4172/0974-8369.1000307.
9. Kumari VV, Anehosur GV, Meshramkar R, et al. An *in vivo* study to compare and correlate sagittal condylar guidance obtained by radiographic and extraoral gothic arch tracing method in edentulous patients. European Journal of Prosthodontics 2016;4(1):12. DOI: 10.4103/2347-4610.182961.
10. Singh S, Thombare R. Evaluating the validity of interocclusal plaster records made while recording protrusive jaw relation using extraoral tracing device. Int J Contemp Dent 2008;2(3). Corpus ID: 74222678.
11. Zamacona, JM, Otaduy E, Aranda E. Study of the sagittal condylar path in edentulous patients. J Prosthet Dent 1992;68(2):314–317. DOI: 10.1016/0022-3913(92)90336-9.
12. Donegan SJ, Christensen LV. Sagittal condylar guidance as determined by protrusion records and wear facets of teeth. Int J Prosthodont 1991; 4(5):469–472. PMID: 1811642.
13. Gonzalez JB, Kingery RH. Evaluation of planes of reference for orienting maxillary casts on articulators. The Journal of the American Dental Association 1968;76(2):329–336. DOI: 10.14219/jada.archive.1968.0052.
14. Santos JD, J. Nelson S, Nummikoski P. Geometric analysis of occlusal plane orientation using simulated ear-rod facebow transfer. J Prosthodont 1996;5(3):172–181. DOI: 10.1111/j.1532-849x.1996.tb00293.x.
15. Corbett NE, Devincenzo JP, Huffer RA, et al. The relation of the condylar path to the articular eminence in mandibular protrusion. The Angle Orthodontist. 1971 Oct;41(4):286-292. DOI: 10.1043/0003-3219(1971)041<0286:TROTCP>2.0.CO;2.
16. Ingervall B. Relation between height of the articular tubercle of the temporomandibular joint and facial morphology. Angle Orthod 1974; 44(1):15–24. DOI: 10.1043/0003-3219(1974)044<0015:RBHOTA>2.0.CO;2.
17. Christensen LV, Slabbert JC. The concept of the sagittal condylar guidance: biological fact or fallacy? J Oral Rehabil 1978;5(1):1–7. DOI: 10.1111/j.1365-2842.1978.tb00384.x.
18. Gilboa I, Cardash HS, Kaffe I, et al. Condylar guidance: correlation between articular morphology and panoramic radiographic images in dry human skulls. J Prosthet Dent 2008;99(6):477–482. DOI: 10.1016/S0022-3913(08)60112-2.
19. Davis DN, Mackay F. Reliability of cephalometric analysis using manual and interactive computer methods. Br J Orthodont 1991;18(2):105–109. DOI: 10.1179/bjo.18.2.105.
20. Shetty S, Kunta M, Shenoy K. A clinico-radiographic study to compare and co-relate sagittal condylar guidance determined by intraoral gothic arch tracing method and panoramic radiograph in completely edentulous patients. J Indian Prosthodont Soc 2018;18(1):19–23. DOI: 10.4103/jips.jips_207_17.
21. Sümbüllü MA, Çağlayan F, Akgül HM, et al. Radiological examination of the articular eminence morphology using cone beam CT. Dentomaxillofac Radiol 2012;41(3):234–240. DOI: 10.1259/dmfr/24780643.
22. Scarfe WC, Farman AG, Sukovic P. Clinical applications of cone-beam computed tomography in dental practice. Journal-Canadian Dental Association 2006;72(1):75–80. PMID: 16480609.
23. Prasad KD, Shah N, Hegde C. A clinico-radiographic analysis of sagittal condylar guidance determined by protrusive interocclusal registration and panoramic radiographic images in humans. Contemporary Clinical Dentistry 2012;3(4):383–387. DOI: 10.4103/0976-237X.107419.
24. Larheim TA, Abrahamsson AK, Kristensen ML, et al. Temporomandibular joint diagnostics using CBCT. Dentomaxillofac Radiol 2015;44(1):20140235. DOI: 10.1259/dmfr.20140235.