ASDJ
AINSHAMS DENTAL
JOURNAL

Print ISSN 1110-7642
Online ISSN 2735-5039

AIN SHAMS DENTAL JOURNAL
Official Publication of Ain Shams Dental School
June 2025 • Vol. 38

Unraveling Changes in Horizontal Condylar Path Angles with Aging: A Six-Year Longitudinal Radiographic Comparison

Mostafa I Fayad[1], Mohamed Omar Elboraey[2], Abdel Naser M. Emam[3], Mohammed H. AbdElaziz[1], Ahmed A Laithy[4], Nahla Gamaleldin Elhelbawy[4], Mai Salah El-Din[5], Mohammed Mohsen Al Jearah[6], Ahmed A Almeshari[7], Rania Moussa[1]

Aim: This study aimed to evaluate changes in horizontal condylar path angles with age, recorded using two different radiographic techniques over a six-year period, and investigate potential differences between male and female participants.
Materials and methods: Initially, 50 participants aged 30-40 years were recruited for the study. However, 13 participants dropped out, resulting in 37 participants (20 males and 17 females) who completed the study. Horizontal condylar path angle (HCPA) measurements were recorded using orthopantomography and cone beam computed tomography (CBCT) methods at the start, after three years, and after six years for both the right and left condyles. Statistical analyses included repeated measures ANOVA to assess changes over time, independent samples t-tests to compare the male and female participants, and paired samples t-tests to compare the two methods at different intervals.
Results: This study revealed no significant differences between the orthopantomography and CBCT methods at different intervals ($p > 0.05$). The results show significant changes in HCPA over time for all methods, with a marked decrease in HCPA values consistent with aging. The gender comparison revealed that males generally had higher HCPA values than females at all time points, although the difference was not statistically significant.
Conclusion: The findings highlight the importance of considering age-related changes in condylar path angles in dental practice. Orthopantomography and cone beam CT methods are comparable in the short and long terms, suggesting that using an orthopantomogram to record HCPA is a simpler assessment tool.

Keywords: Condylar Path Angle ; Cone beam CT ; Oral Rehabilitation ; Orthopantomography

1. Department of Substitutive Dental Science, College of Dentistry, Taibah University, Madinah, Saudi Arabia.
2. Department of Preventive Dental Science, College of Dentistry, Taibah University, Saudi Arabia.
3. Prosthetic Dental Science Department, Faculty of Dentistry, Najran University, Najran, Saudi Arabia.
4. Restorative Dental Science Department, College of Dentistry, Taibah University, Saudi Arabia.
5. Fellow, Department of Prosthodontics, Alexandria University Main Hospital, Alexandria, Egypt.
6. Preventive Dental Science Department, Faculty of Dentistry, Najran University, Najran, Saudi Arabia.
7. Oral and Maxillofacial Surgery and Diagnostic Sciences Department, Faculty of Dentistry, Najran University, Saudi Arabia.

Corresponding author: Mostafa I Fayad, email: mifayad@taibahu.edu.sa

Introduction

The importance of accurately determining the horizontal condylar path angle (HCPA) lies in its critical role in the success of prosthodontic treatments, as it influences the morphology of occlusal surfaces and mandibular movements, thereby affecting occlusal harmony and reducing chairside adjustment time.[1] HCPA, which represents the angle formed by the path of the condyle during mandibular movements, plays a vital role in the diagnosis and treatment planning of these conditions. Despite advancements in measurement techniques, reliable and accurate methods to record HCPA remain in demand.[2]

Various methods have been explored to record this angle, including clinical, radiographic, and pantographic techniques, each with its own set of advantages and limitations.[3,4]

Clinical methods, such as the use of protrusive interocclusal records and semi-adjustable articulators, have been widely used due to their practicality and direct application in simulating mandibular movements.[5-7]

However, studies have shown that radiographic techniques, including cone beam computed tomography (CBCT) and panoramic radiographs, tend to yield higher HCGA values compared to clinical methods.[2,8]

Panoramic radiography offers a comprehensive view of the maxillofacial structures, encompassing the dental arches, temporomandibular joints, and facial bones, all captured in one image.[9] In recent years, efforts have been made to develop three-dimensional imaging tools that can replace conventional CT scanners while reducing radiation exposure and decreasing costs. This endeavor has led to the introduction of Cone Beam CT (CBCT), which has revolutionized tomographic imaging and enabled volumetric image reconstruction.[10,11]

This discrepancy suggests that radiographic methods may offer a more detailed view of the condylar path, potentially leading to more precise prosthodontic outcomes. Many studies have considered panoramic radiography and CBCT to be valuable tools for the assessment of HCPA, with CBCT offering enhanced accuracy and detail. Both methods have strengths and limitations, and their accuracy over long-term periods has been debated.[12-15]

Moreover, the use of electronic devices, such as the Arcus Digma, for recording HCPA has been explored, showing promising reliability as an alternative to traditional methods.[16-19]

The reviewed literature underscores the importance of considering age-related changes in HCPA in prosthodontic practice. Studies have consistently indicated that HCPA decreases with age. Sreelal et al. found significant differences in HCPA values among various age groups, with a noticeable decrease from younger to older groups. This trend was observed using both articulator and cephalometric methods, which showed no significant differences in the values recorded. The flattening of the condyle and a decrease in the posterior slope of the articular eminence with advancing age contribute to the reduced HCPA .[20]

Similarly, other studies have reported a correlation between age and changes in the condylar guidance using panoramic radiography. They found that as age advances, there is a tendency for the condylar angle to decrease.[21,22]

Although previous studies have documented the effects of aging on the TMJ and its impact on HCPA, there is a lack of longitudinal studies that compare orthopantomography and CBCT over extended periods. Understanding how these methods perform over time is essential for improving diagnostic and treatment outcomes in dental practice.

This study seeks to answer the following questions: how do orthopantomography and cone beam CT methods compare in measuring HCPA over six years? What are the changes in HCPA over time, and how do these changes correlate with the aging process? Are there significant differences in HCPA measurements between males and females?

By comparing these methods over six years, the study contributes to the existing body of knowledge and can help practitioners make informed decisions when choosing measurement techniques. The findings also highlight the importance of considering age-related changes in condylar path angles, ultimately improving diagnostic accuracy and treatment planning for TMJ disorders and other related conditions.

Materials and Methods

Data collection

This longitudinal study was designed to evaluate changes in horizontal condylar path angles with age, recorded using two different radiographic techniques over a six-year period. HCPA was recorded at the start of the study, after three years, and after six years. Ethical approval was obtained from the institutional review board (IRB) of the Faculty of Dental Medicine, Al-Azhar University (Ethical Application Ref: AUAREC20180017-12), and informed consent was obtained from all participants before the commencement of the study.

Previous studies have established that a sample size of 36 cases is sufficient to achieve a statistical power of 0.80, a confidence interval of 0.95, and an alpha level of 0.05. Therefore, a higher sample size of 50 participants was chosen to account for potential withdrawals of edentulous participants due to illness, death, or difficulties with the research protocol.[2,13]

Participants selection

Fifty participants aged between 30 and 40 years were recruited for this study. However, 13 participants dropped out during the course of the study, resulting in a final sample size of 37 participants (20 males and 17 females).

The inclusion criteria were patients with complete natural dentition or fully functional prosthetic restoration with normal overjet and overbite and Angle's Class I relationship, no history of orthodontic treatment in the past five years, and no craniofacial abnormalities. Patients who had no history of temporomandibular joint (TMJ) disorders or significant dental anomalies were selected for the study.

Individuals with any signs of temporomandibular dysfunction or neurological or muscular diseases were excluded. Only those individuals without a history of bone diseases or fractures of the mandible or maxilla were selected.

Intra-examiner and inter-examiner reliability were assessed for both methods. For intra-examiner reliability, the same examiner repeated the measurements on ten randomly selected participants after a one-week interval. For inter-examiner reliability, a second examiner independently measured HCPA for the same 10 participants. Intraclass correlation coefficients (ICCs) were calculated to evaluate the reliability.

A digital panoramic radiograph (Fig 1.a) of each patient was taken using a Sirona digital panoramic machine (Sirona Dental System GmbH, USA) with the parameters of 76 KV, 11 MA, and 12-sec exposure. To determine HCPA, the Frankfort plane was determined, and then a second line between the highest point of the glenoid fossa and the lowest point of articular eminence was drawn. The horizontal condylar guidance was formed between the two lines, and then HCPA was measured using Triana Software (Genoray Co. Ltd., Korea).[15,23]

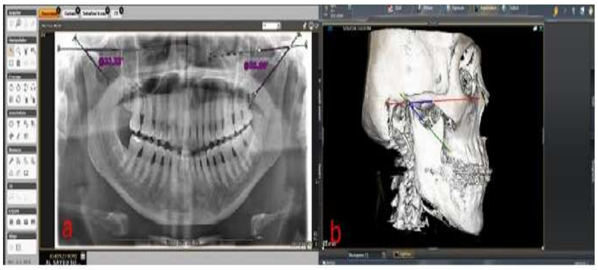

Figure 1. HCPA measurements on (a) Digital panoramic radiography and (b) CBCT.

CBCT scans were taken of each patient (Fig 1.b). The CBCT scans were taken using a Carestream CBCT machine (Carestream Health, Inc., Verona Street Rochester, NY, USA). The used exposure parameters were 180 VOXAL, 4 ma, 80 KV, and 8.01 sec. To record HCPA in a 3D view, two lines were determined. The Frankfort plane was established by determining the orbitale (the lowest point of the infraorbital margin) and the porion (the highest point of the bone margin of the auditory meatus) and then drawing a line between these two points. A second line was drawn along the posterior slope of the articular eminence. The two lines intersect, and the horizontal condylar angle is formed between them.[2] HCPA was measured using SIDEXIS 4 from Dentsply Sirona Imaging Software, Hong Kong.

The orthopantomogram and CBCT images were used to determine HCPA at the start of the study and at different time intervals to record the horizontal condylar path angle (HCPA) over six years, examining the changes in HCPA over time and investigating potential differences between the male and female participants.

Statistical analysis

The data obtained from both methods were analyzed using statistical software (SPSS version 25, IBM Corp., Armonk, NY). Descriptive statistics, including the mean and standard deviation, were calculated for the HCPAs recorded using both methods. The independent samples t-test was used to compare the mean HCPA values between males and females at each time point (start, three years, and six years) for each method. The paired samples t-test was used to compare the mean HCPA values obtained using the orthopantomogram and CBCT images at each time interval (start, three years, and six years). Repeated measures ANOVA was used to compare the means of HCPA recorded at different time intervals (start, three years, and six years) for each method. The level of significance was set at $p < 0.05$.

Results

Initially, 50 participants (26 males and 24 females) were enrolled in this study with a age range 31-40 years (mean 35.62) . However, 13 participants (26%) dropped out, resulting in a final sample size of 37 participants (20 males and 17 females) who completed the study. The reasons for dropout were not specified but may include personal reasons, relocation, or loss of follow-up.

The descriptive statistics for the HCPA measurements using the orthopantomography and cone beam CT methods at different time intervals (start, three years, and six years) are summarized in Table (1) .

Table 1: HCPA measurements using the orthopantomography and CBCT at different time intervals.

	Orthopantomography				CBCT			
	Minimum	Maximum	Mean	SD	Minimum	Maximum	Mean	SD
0Rt	30.19	36.78	34.19	1.36	32.12	36.7	33.82	.876
0L	31.35	36.96	34.57	1.37	32.78	36.1	34.25	.761
3Rt	20.76	34.97	31.36	2.14	30.12	32.7	31.38	.529
3L	29.98	32.99	31.74	.780	30.59	32.9	31.83	.653
6Rt	28.67	34.89	30.23	1.22	29.78	31.2	30.54	.418
6L	29.12	32.89	31.18	.870	29.89	32.4	31.44	.534

0Rt—HCPA measurements for RT condyle at the start.
0L—HCPA measurements for left condyle at the start.
3Rt—HCPA measurements for RT condyle after three years.
3L—HCPA measurements for left condyle after three years.
6Rt—HCPA measurements for RT condyle after six years.
6L—HCPA measurements for left condyle after six years.

The independent t-tests (Table 2) showed non-significant differences in HCPA values between males and females at all time points for both methods. The gender-specific analysis shows that males generally had higher mean HCPA values compared to females at all time intervals.
The independent t-tests (Table 3) revealed no significant differences between the orthopantomography and cone beam CT methods at different intervals ($p > 0.05$)., indicating that both methods can be used for HCPA measurements.

Table 2: Mean difference comparison of HCPAs between male and female patients at different intervals.

Variable	OPG (Orthopantomogram)		Sig (p-value)	CBCT (Cone Beam CT)		Sig (p-value)
	Male Mean	Female Mean		Male Mean	Female Mean	
0Rt	34.42	33.92	0.276	33.86	33.78	.799
0L	34.77	34.34	0.360	34.16	34.35	.453
3Rt	31.99	30.62	0.053	31.37	31.41	.823
3L	31.94	31.50	0.090	31.75	31.91	.461
6Rt	30.33	30.10	0.584	30.54	30.54	.967
6L	31.42	30.90	0.071	31.37	31.53	.364

0Rt—HCPA measurements for RT condyle at the start.
0L—HCPA measurements for left condyle at the start.
3Rt—HCPA measurements for RT condyle after three years.
3L—HCPA measurements for left condyle after three years.
6Rt—HCPA measurements for RT condyle after six years.
6L—HCPA measurements for left condyle after six years.

Table 3: Mean difference comparison of HCPAs between the two methods at different intervals.

		Mean	Std. Deviation	Sig (2-tailed)
0Rt	OPG	34.19	1.36	.230
	CBCT	33.82	.87	
0L	OPG	34.57	1.37	.080
	CBCT	34.25	.76	
3Rt	OPG	31.36	2.14	.949
	CBCT	31.38	.52	
3L	OPG	31.74	.78	.600
	CBCT	31.83	.65	
6Rt	OPG	30.23	1.22	.147
	CBCT	30.54	.41	
6L	OPG	31.18	.87	.149
	CBCT	31.44	.53	

0Rt—HCPA measurements for RT condyle at the start.
0L—HCPA measurements for left condyle at the start.
3Rt—HCPA measurements for RT condyle after three years.
3L—HCPA measurements for left condyle after three years
6Rt—HCPA measurements for RT condyle after six years.
6L—HCPA measurements for left condyle after six years.

The repeated measures ANOVA for the HCPAs, as recorded using the orthopantomography (OPG) (Table 4) and CBCT (Table 5), indicated significant changes in the HCPAs over time ($P < 0.05$). The HCPA values decreased significantly from the start to three years and from three to six years. The mean HCPA values decreased over time, indicating the expected reduction in the condylar guidance angle with aging.

Table 4: HCPA repeated measures mean comparison using OPG at different intervals.

	Time	Mean	Std. Deviation	Sig.[b]
OPG0R	OPG0R	34.19	1.36	------
	OPG3R	31.36	2.14	.000
	OPG6R	30.23	1.22	.000
OPG3R	OPG0R	34.19	1.36	.000
	OPG3R	31.36	2.14	------
	OPG6R	30.23	1.22	.036
OPG0L	OPG0L	34.57	1.37	------
	OPG3L	31.74	.784	.000
	OPG6L	31.18	.870	.000
OPG3L	OPG0L	34.57	1.37	.000
	OPG3L	31.74	.784	-----
	OPG6L	31.18	.870	.001

Based on estimated marginal mean, the mean difference is significant at 0.05 level.*Adjustment for multiple comparisons: Bonferroni.[b]
OPG0R—HCPA using OPG for RT condyle at the start.
OPG0L—HCPA using OPG for left condyle at the start.
OPG3R—HCPA using OPG for RT condyle after three years.
OPG3L—HCPA using OPG for left condyle after three years.
OPG6R—HCPA using OPG for RT condyle after six years.
OPG6L—HCPA using OPG for left condyle after six years.

Table 2: HCPA repeated measures mean comparison using cone beam CT at different intervals.

	Time	Mean	Std. Deviation	Sig.[b]
CBCT0R	CBCT0R	33.82	.876	------
	CBCT3R	31.38	.529	.000
	CBCT6R	30.54	.418	.000
OPG6R	CBCT0R	33.82	.876	.000
	CBCT3R	31.38	.529	------
	CBCT6R	30.54	.418	.000
CBCT0L	CBCT0L	34.25	.761	------
	CBCT3L	31.83	.653	.000
	CBCT6L	31.44	.534	.000
CBCT6L	CBCT0L	34.25	.761	.000
	CBCT3L	31.83	.653	-----
	CBCT6L	31.44	.534	0.036

Based on estimated marginal mean, the mean difference is significant at 0.05 level.*Adjustment for multiple comparisons: Bonferroni.[b]
CBCT0R—HCPA using CBCT for RT condyle at the start.
CBCT0L—HCPA using CBCT for left condyle at the start.
CBCT3R—HCPA using CBCT for RT condyle after three years.
CBCT3L—HCPA using CBCT for left condyle after three years.
CBCT6R—HCPA using CBCT for RT condyle after six years.
CBCT6L—HCPA using CBCT for left condyle after six years.

Discussion

The accurate recording of the horizontal condylar path angle (HCPA) is essential for various dental procedures, including prosthodontics, orthodontics, and TMJ management.[24]

This study aimed to compare the horizontal condylar path angle (HCPA), recorded using orthopantomography and cone beam computed tomography (CBCT) methods over six years, focusing on changes in HCPA over time and potential differences between male and female participants.

This study found that males generally had higher HCPA values than females, although the difference was not statistically significant, reflecting a trend observed in some previous studies. Gender differences in condylar morphology and TMJ function have been noted in the literature, with males often exhibiting more pronounced condylar angles due to larger joint structures and greater muscle mass.[25,26] Additionally, male individuals tend to have larger mandibular dimensions, including the condylar head, than female individuals.[27]

However, the lack of statistically significant differences in the HCPA values between genders at all time points suggests that while there are inherent anatomical differences, the rate of change in HCPA due to aging may be similar across genders. This is supported by studies showing that males and females exhibit similar condylar positional changes and adaptation following mandibular reconstruction.[28]

Additionally, the lack of significant gender differences in this study may be attributed to the sample size and the natural variability in condylar morphology among individuals. This suggests that, while gender can influence HCPA values, individual anatomical and functional factors play a more critical role.

The study findings show that there were no significant differences between the orthopantomography and CBCT methods at different intervals. This aligns with the results of previous studies, such as those by Shreshta et al.[26], which reported comparable HCPA values across clinical and radiographic methods, although CT scans tended to show slightly higher values. This consistency suggests that both methods are reliable for longitudinal studies on HCPA, providing flexibility in clinical and research settings, depending on the availability of technology and specific patient needs.

The lack of significant differences between the orthopantomography and CBCT methods at different intervals ($p > 0.05$) is consistent with earlier studies that have shown both methods to be reliable for measuring HCPA, albeit with some variations in precision. For instance, panoramic radiographs have been noted for their efficacy in measuring condylar guidance values (CGVs) compared to articulators, with arcon types recording slightly higher CGVs than non-arcon types due to better jaw movement simulation.[29] Although no significant difference was found, the literature highlights CBCT's superior resolution, three-dimensional imaging capabilities, and accuracy in providing multiplanar views of the temporomandibular joint (TMJ) without superposition, magnification, or distortion, which offer more detailed assessments of the condylar path and surrounding anatomical structures. Pamukcu et al.[30] emphasized the utility of CBCT in detecting osseous changes related to temporomandibular joint osteoarthritis (TMJ OA), which can impact HCPA measurements.

The results revealed significant changes in HCPA over time, with a marked decrease in HCPA values consistent with aging.

The observed decrease in HCPA values over time aligns with findings that suggest degenerative changes in the condylar surface, which are more prevalent with increasing age and can affect TMJ space dimensions.[31]

The significant changes in HCPA over time align with previous research into the effects of aging on TMJ. Pullinger and Seligman[32,33] and Pamukcu et al.[30] reported that degenerative changes in the TMJ, such as osteoarthritis and cartilage wear, can lead to alterations in condylar movements and, consequently, HCPA. Our findings support these observations, showing a significant decrease in HCPA over time.

The observed decrease in HCPA values over six years is consistent with the findings of Sreelal et al.[20], who documented a significant reduction in HCPA with advancing age. This age-related flattening of the condyle and decrease in the posterior slope of the articular eminence likely result from physiological remodeling and wear, highlighting the importance of considering age in prosthodontic planning.

The significant decrease in HCPA over time underscores the importance of considering age-related changes in condylar path angles when planning and executing dental treatments. For practitioners, understanding that HCPA reduces with age can aid in more accurate diagnosis and treatment planning for TMJ disorders, prosthodontic restorations, and orthodontic interventions. Our study also highlights the need for consistent measurement techniques.

This research adds to the existing body of knowledge by providing a longitudinal comparison of two prevalent methods for recording HCPA. It confirms the trends observed in previous studies regarding age-related changes in condylar path angles and introduces new insights into the long-term reliability of these methods.

One of the strengths of this study is its longitudinal design, which allowed us to observe changes over an extended period. The sample size of 37 participants is another strength, providing a robust data set for analysis.

However, there are limitations to consider. The study's sample was limited to individuals aged 31 to 40, which may not represent all age groups. Future studies should aim to include a broader age range and explore automated or digital enhancements to reduce potential biases.

Future Directions

Future research should focus on the development of simple methods that combine the precision and con-venience of digital imaging, which could offer a promising direction for future studies. Future research should focus on expanding the age range of participants to include older and younger populations, providing a more comprehensive understanding of HCPA changes throughout life.

Additionally, studies should investigate the integration of digital tools with traditional methods to enhance accuracy and consistency. Exploring the potential of three-dimensional imaging techniques and their application in routine clinical practice could also provide valuable insights. Lastly, longitudinal studies with larger sample sizes and diverse demographics will help validate the findings and support the development of standardized protocols for recording HCPA.

Conclusions

In conclusion, orthopantograms and CBCT are comparable for recording the horizontal condylar path angle. The choice between these methods should be guided by the specific clinical context, balancing the need for accuracy with practical considerations of ease of use and patient comfort. Our study confirms that the horizontal condylar path angle decreases significantly with age, a finding consistent with previous research. This research contributes valuable insights into the long-term reliability of these methods, suggesting areas for improvement and future investigation.

Ethics approval

The study was conducted in accordance with the Declaration of Helsinki, and approved by the institutional review board (IRB) of the Faculty of Dental Medicine, Al-Azhar University (Ethical Application Ref: AUAR-EC20180017-12), and informed consent was obtained from all participants before the commencement of the study.

Competing interest

The authors have no conflict of interest to declare publication

Data availability

Data availability Data can be shared upon reasonable request be directed to the corresponding author.

Funding:

This research received no external funding

References

1. Potdukhe SS, Iyer JM, Nadgere JB. A systematic review and meta-analysis of accuracy between protrusive interocclusal record and horizontal condylar guidance angle recording methods in dentulous patients. *J Indian Prosthodont Soc*. 2024;24:3-14.
2. 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 Dent Pract*. 2023;24:403-408.
3. Paul R, Das S, Bhattacharyya J, Ghosh S, Goel P, Dutta K. A study on the accuracy of horizontal condylar guidance values in edentulous patients using preprosthetic diagnostic radiographs. *J Indian Prosthodont Soc*. 2018;18:263-270.
4. Potdukhe SS, Iyer JM, Nadgere JB. Evaluation of accuracy between extraoral Gothic arch tracing and various other methods assessing horizontal condylar guidance angle in completely edentulous patients: A systematic review and meta-analysis. *J Indian Prosthodont Soc*. 2023;23:322-334.
5. Prajapati P, Sethuraman R, Naveen YG, Patel J. A clinical study of the variation in horizontal condylar guidance obtained by using three anterior points of reference and two different articulator systems. *Contemp Clin Dent*. 2013;4:162-169.
6. Naqash TA, Chaturvedi S, Yaqoob A, Saquib S, Addas MK, Alfarsi M. 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;23:550-554.
7. Galagali G, Kalekhan SM, Nidawani P, Naik J, Behera S. Comparative analysis of sagittal condylar guidance by protrusive interocclusal records with panoramic and lateral cephalogram radiographs in dentulous population: A clinico-radiographic study. *J Indian Prosthodont Soc*. 2016;16:148-153.
8. Kapse P, Kumar SM. Evaluation of the Horizontal Condylar Guidance Using Different Anterior Reference Points: A Clinicoradiographic Study. *J Int Clin Dent Res Organ*. 2023;15
9. Elfallal WI, Ashmawy MSED, Ali TM, abo fotouh mm. Validity of Panoramic Multilayer Imaging Program in the Diagnosis of Proximal Caries: An Ex-vivo Study. *Ain Shams Dental Journal*. 2025;37(1):51-60.
10. Elkhateeb SM, Abu el Sadat Ali SM. Validity of CBCT for Soft Tissue Examination in the Maxillofacial Area: A Review of the Current Literature. *Ain Shams Dental Journal*. 2024;35(3):134-148.
11. Najm AA, albahrani z, Akram h. Radiographic Assessment of Maxillary Sinus Pathologies Using Cone Beam Computed Tomography (CBCT): Prevalence and Distribution Analysis. *Ain Shams Dental Journal*. 2025;37(1):113-121.
12. Kwon OK, Yang SW, Kim JH. Correlation between sagittal condylar guidance angles obtained using radiographic and protrusive occlusal record methods. *J Adv Prosthodont*. 2017;9:302-307.
13. Mawani D, Muddugangadhar BC, Das A, Mukhopadhyay A. Comparative evaluation of condylar inclination in dentulous subjects as determined by two radiographic methods: Orthopantomograph and cone-beam computed tomography - An in vivo study. *J Indian Prosthodont Soc*. 2019;19:113-119.
14. Nahuincopa-Rios RJ, Nahuincopa-Lopez PM, Angeles-Lopez RG. Comparison of sagittal condylar guidance obtained from radiographic and clinical records in dentate patients. *Rev Cient Odontol (Lima)*. 2021;9:e060.
15. 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;18:19-23.
16. Mage K, Celic R, Cimic S, Dulcic N. Comparison of Parameters for Programming Adjustable Dental Articulators by Using Wax Eccentric Records and Arcus Digma Device. *Acta Stomatol Croat*. 2019;53:213-223.
17. Nigam AA, Lee JD, Lee SJ. A clinical comparison of sagittal condylar inclination and Bennett angle derived from a conventional electronic tracking device and an optical jaw tracking device. *J Prosthet Dent*. 2023;

18. Lassmann L, Nowak Z, Orthlieb JD, Zoltowska A. Complicated Relationships between Anterior and Condylar Guidance and Their Clinical Implications-Comparison by Cone Beam Computed Tomography and Electronic Axiography-An Observational Cohort Cross-Sectional Study. *Life (Basel)*. 2023;13
19. Hue O. Condylar paths during protrusion in edentulous patients: analysis with electronic axiography. *J Prosthodont*. 2011;20:294-298.
20. Sreelal T, Janardanan K, Nair AS. Age changes in horizontal condylar angle: a clinical and cephalometric study. *J Indian Prosthodont Soc*. 2013;13:108-112.
21. Cai W, Hao F, Mengke G, Xing L. Correlation between protrusive interocclusal record and panoramic radiographic image: a pilot study. *J Prosthodont*. 2012;21:588.
22. Tannamala PK, Pulagam M, Pottem SR, Swapna B. Condylar guidance: correlation between protrusive interocclusal record and panoramic radiographic image: a pilot study. *J Prosthodont*. 2012;21:181-184.
23. Gilboa I, Cardash HS, Kaffe I, Gross MD. Condylar guidance: correlation between articular morphology and panoramic radiographic images in dry human skulls. *J Prosthet Dent*. 2008;99:477-482.
24. Celar AG, Tamaki K. Accuracy of recording horizontal condylar inclination and Bennett angle with the Cadiax compact. *J Oral Rehabil*. 2002;29:1076-1081.
25. Ma L, Liu F, Mei J, Chao J, Wang Z, Shen J. A comparative study to measure the sagittal condylar inclination using mechanical articulator, virtual articulator and jaw tracking device. *J Adv Prosthodont*. 2023;15:11-21.
26. Shreshta P, Jain V, Bhalla A, Pruthi G. A comparative study to measure the condylar guidance by the radiographic and clinical methods. *J Adv Prosthodont*. 2012;4:153-157.
27. Miranda-Viana M, Moreira GM, de Souza LM, Nejaim Y, Haiter-Neto F, Freitas DQ. Tridimensional assessment of the mandibular angle in patients with different skeletal patterns by cone-beam computed tomography scans: a retrospective study. *BMC Oral Health*. 2023;23:361.
28. Polasek A, Plisko M, Profozic A, Plazibat A, Cimic S. Study of the Difference Between Centric Occlusion and Retruded Contact Position. *The Journal of Dentists*. 2022;10:39-44.
29. Aljohani AO, Sghaireen MG, Abbas M. Comparative Evaluation of Condylar Guidance Angles Measured Using Arcon and Non-Arcon Articulators and Panoramic Radiographs-A Systematic Review and Meta-Analysis. *Life (Basel)*. 2023;13
30. Pamukcu U, Tetik H, Peker I, Altunkaynak B, Zafersoy Akarslan Z. Does the horizontal condylar angle have a relationship to temporomandibular joint osteoarthritis and condylar position? A cone-beam computed tomography study. *Folia Morphol (Warsz)*. 2022;81:723-731.
31. Görürgöz C, İçen M, Kurt MH. Degenerative changes of the mandibular condyle in relation to the temporomandibular joint space, gender and age: A multicenter CBCT study. *Dent Med Probl*. 2023;60:127-135.
32. Pullinger AG, Seligman DA. Quantification and validation of predictive values of occlusal variables in temporomandibular disorders using a multifactorial analysis. *J Prosthet Dent*. 2000;83:66-74.
33. Seligman DA, Pullinger AG. Analysis of occlusal variables, dental attrition, and age for distinguishing healthy controls from female patients with intracapsular temporomandibular disorders. *J Prosthet Dent*. 2000;83:76-82.