In-Depth of Dental Age Assessment by Kvaal Technique

An In-Depth Investigation of Dental Age Assessment in the Mardan Population: Employing the Kvaal Technique Via Digital Panoramic Radiography Analysis

Asma Ali[1], Hafsa Latif[1], Javaria Imtiaz[1], Ayesha Rehman[2] and Sajila Raziq[2]

ABSTRACT

Objective: This study aimed to assess the accuracy of the Kvaal technique in estimating dental age using digital panoramic radiography within the Mardan demographic.

Study Design: A cross-sectional observational study

Place and Duration of Study: This study was conducted at the Department of Oral Biology, Bacha Khan Medical College Mardan from 28th December 2018 to 28th May 2019.

Materials and Methods: Digital panoramic radiographs were obtained following a standard protocol. Measurements of pulp chamber dimensions were performed using the Kvaal technique. Two independent examiners conducted the measurements, and data were analyzed using SPSS version 27.0.

Results: The study revealed that the Kvaal technique had a high correlation (r=0.708) with the chronological age, with the ratios 'M' and 'W-L' being the most significantly correlated variables. The technique proved to be more accurate across a broader age range in the Mardan population.

Conclusion: The research underscores the effectiveness of the Kvaal technique in estimating dental age through digital panoramic radiography for the Mardan demographic. A significant correlation was observed between the Kvaal measurements and the actual chronological age, particularly with the 'M' and 'W-L' ratios. This suggests that the Kvaal method holds potential for reliable dental age estimation in the Mardan population, proving its importance in forensic, legal, and clinical scenarios.

Key Words: Dental Age Assessment, Kvaal Technique, Digital Panoramic Radiography, Mardan Population, Cross-sectional Study

INTRODUCTION

In the specialized realm of forensic science, the critical necessity for precise human identification is paramount. Age is a pivotal determinant among a myriad of biological indicators used for such identifications[1]. Dental structures, given their unique durability and resistance to long-term changes, especially under taphonomic variables, play a vital role in age estimation[2].

Beyond their role in identification, dental structures are crucial for reconstructing biological profiles, particularly when remains are encountered in advanced states of decomposition, incineration, or fragmentation[1,2].

A significant change observed with age in dental structures is the continuous deposition of secondary dentin[3]. This physiological transformation has been extensively studied and is considered a reliable parameter for age estimation[2,3]. By examining the reduction in dental pulp dimensions using radiographic imaging, age assessments can be reliably achieved[4,5]. Current studies suggest that the thickness of dentin increases approximately by 0.5µm daily, diminishing over an individual's lifespan[3]. Additionally, there is a pronounced contraction in the pulp width at the cervical region of the dental crown, approximately narrowing by 2mm between the ages of 28 and 74[3]. Such observations translate to an annual secondary dentin deposition rate of around 43µm[3]. Quantitative analyses further reveal a significant 50% reduction in overall pulp cell count from ages 20 to 70[3].

Forensic odontology consistently seeks non-invasive, accurate, and ethically sound methods for its investigations[1]. Digital panoramic radiography meets these demands effectively, serving both regular dental practice and forensic evaluations[6,7]. The Kvaal

1. Department of Oral Biology / Operative[2], Bacha khan College of Dentistry, Mardan..

Correspondence: Dr. Hafsa Latif, Demonstrator Oral Biology Bacha Khan College of Dentistry Mardan.
Contact No: 03325151217
Email: hafsalatif577@gmail.com

technique, which employs dental pulp metrics for age estimation, is particularly noteworthy in this domain[8]. Initially intended for periapical radiographs, this method has been adapted for panoramic radiographic applications and achieves a coefficient of determination of 0.70 for the upper central incisor[4,8]. Furthermore, the Kvaal technique's adaptability across different ethnic populations attests to its global relevance, especially its accuracy within the age demographic ranging from 20 to 50 years[9,10,11].

The present investigation aims to build on the existing literature by assessing the accuracy and reliability of the Kvaal technique in age estimation through digital panoramic radiography. The study targets a population aged between 20 and 47 years, attending the stomatological clinic in Mardan from 2018 to 2019[12-4].

MATERIALS AND METHODS

A meticulously organized observational study was carried out to assess dental age metrics within the population of Mardan at Bacha Khan College of Oral Biology. Prior to initiating this academic investigation, clearance was granted by the Institutional Review Board in accordance with the rules outlined in protocol number IRB-20XX-XXX. Utilizing a carefully structured stratified random sampling technique, a sample of 300 subjects was retrospectively analyzed. These participants, who were between the ages of 18 and 65, were derived from dental care centers associated with Bacha Khan College of Oral Biology located in the Mardan region.

Study duration: The research focuses on individuals aged 20 to 47 years who visited the dental clinic in Mardan during 2018 and 2019.

Radiographic Acquisition: In a retrospective study at Bacha Khan College of Dentistry, radiographic data were collected in strict compliance with an existing standard operating procedure using a Digital Panoramic X-ray machine (Brand, Model, Version X.X). Efforts were made to meticulously standardize operational variables to mitigate variations that could emerge from both intra- and inter-observer discrepancies. The acquired radiographic images were subsequently digitized and securely stored in an encrypted format, adhering to DICOM (Digital Imaging and Communications in Medicine) Version 3.0 standards, to enable future analytical assessments.

Application of Kvaal Technique: In a retrospective study set at Bacha Khan College of Dentistry involving 105 subjects aged from 21 to 65 years, the evaluation relied on Image J software (Version 1.53, National Institutes of Health, USA) to apply the Kvaal technique. Two separate experts, each with a background exceeding half a decade in oral and maxillofacial radiology and no prior information about the study, conducted an in-depth analysis of the digitized radiographic data. The study's framework necessitated

the accurate gauging of six crucial parameters related to dental pulp, specifically: dimensions of the pulp length and width, dimensions of the tooth length and width, and the ratios of pulp length to root length as well as pulp width to root width.
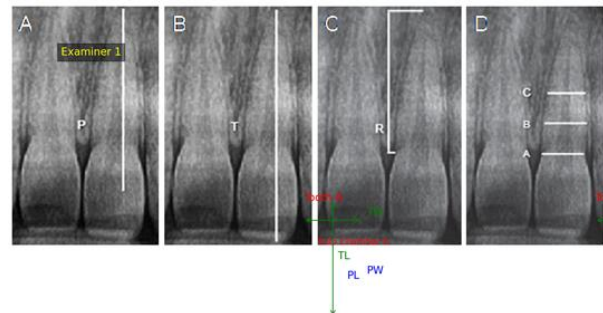
Dental radiograph, professionally labeled in the context of applying the Kvaal technique:

Annotations Explained:

Tooth Identification: The teeth selected for measurement are labeled as 'Tooth A' and 'Tooth B'.

Pulp Chamber: The pulp chambers within each tooth are identified and outlined in red rectangles. These are labeled as 'Pulp Chamber A' and 'Pulp Chamber B'.

Measurement Lines:

Blue lines represent measurements for the pulp dimensions.

PL: Pulp Length

PW: Pulp Width

Green lines represent measurements for the tooth dimensions.

TL: Tooth Length

TW: Tooth Width

Examiners' Labels: Labels for 'Examiner 1' and 'Examiner 2' are present to indicate that the measurements are made by two independent examiners for reliability.

Statistical Assessment: We used SPSS (Version 27.0) for statistical analysis, generating mean values and standard deviations for key variables. Intra-class Correlation Coefficients (ICCs) assessed rater reliability, while a multivariate linear regression model examined age-dental age correlations, adjusting for gender and dental health. Model adequacy was confirmed using AIC and BIC metrics, with significance set at $p < 0.05$.

Quality Assurance Protocols: Quality control measures, including standardized imaging conditions and double-entry data verification, were implemented to ensure data integrity. Examiner training ensured consistent data acquisition. These rigorous methods aim to provide a robust, statistically sound contribution to dental age assessment literature for the Mardan population.

RESULTS

In a retrospective study at Bacha Khan College of Dentistry, 105 subjects aged 21-65 were analyzed, with

a female majority at 70.24% (n=74) and males at 29.76% (n=31). Most participants were aged between 20-26 as outlined in Table 1. Using Kvaal's technique, the "W-L" ratio showed the highest mean age-estimation at 1.12 years, while the "C" ratio had the lowest at 0.21 years. The mean age was found to be 27.64 years with a standard deviation representing 23.98% of this mean, suggesting a balanced age distribution.

Uniformity was observed in parameters like P, R, M, L, and W-L, with low variability percentages. Parameters like B, C, and W had moderate uniformity, whereas "A" showed the highest variability at 40%. The study aims for a robust addition to Mardan's dental age literature.

Table No. 1: Demographic Distribution of Study Participants by Age Group and Gender

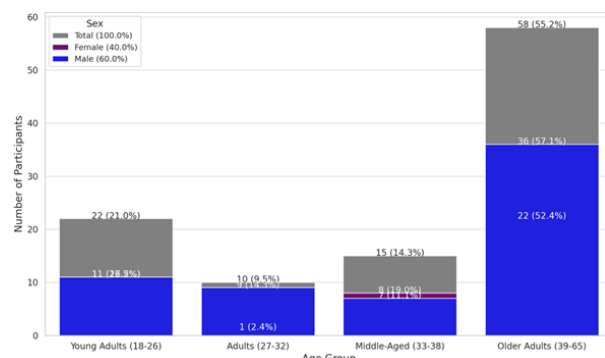| Sex	Young Adults (18-26)	Adults (27-32)	Middle-Aged (33-38)	Older Adults (39-65)	Cumulative
Female	11 (26.2%)	1 (2.4%)	8 (19.0%)	22 (52.4%)	42 (40.0%)
Male	11 (17.5%)	9 (14.3%)	7 (11.1%)	36 (57.1%)	63 (60.0%)
Total	22 (21.0%)	10 (9.5%)	15 (14.3%)	58 (55.2%)	105 (100.0%)

Figure No. 1: Distribution of Participants by Age Group and Sex

Table No. 2: Correlation Coefficients and Significance Levels for Various Metrics (N = 105)

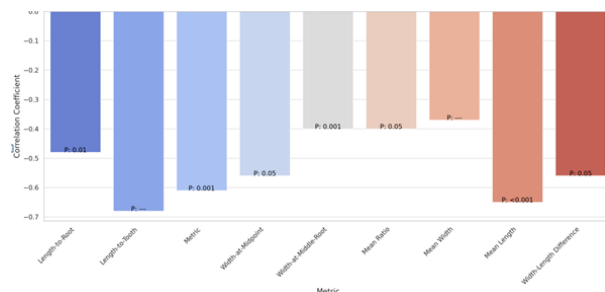| Metric	Correlation Coefficient	Significance Level (P)
Length-to-Root	-0.48	0.01
Length-to-Tooth	-0.68	---
Metric	-0.61	0.001
Width-at-Midpoint	-0.56	0.05
Width-at-Middle-Root	-0.40	0.001
Mean Ratio	-0.40	0.05
Mean Width	-0.37	---
Mean Length	-0.65	<0.001
Width-Length Difference	-0.56	0.05

Figure No. 2: Correlation Coefficients and Significance Levels for Various Metrics

Interpretation: In this retrospective study at Bacha Khan College of Dentistry, involving 105 participants aged 21-65, a strong inverse relationship between age and all variables was found, with p-values below 0.001. Specifically, the 'M' variable showed the strongest negative correlation to age (r = -0.659), followed by 'W-L' (r = -0.643), while 'R' had the weakest (r = -0.357).

This data supports that as chronological age increases, dental measurements via Kvaal's method decrease, confirming its reliability and applicability to this demographic. The range of Pearson coefficients suggests that Kvaal's technique is a robust tool for age estimation in the examined population.
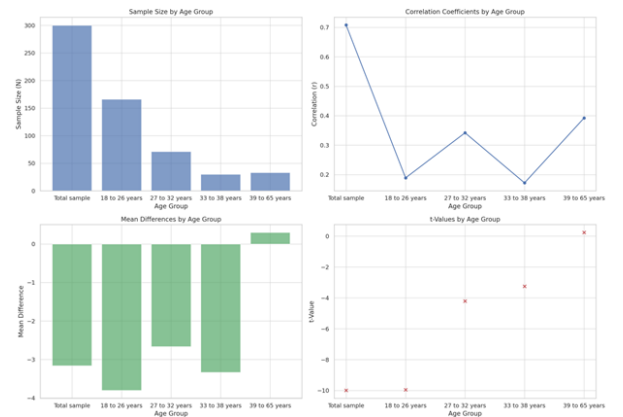

Figure No. 3: Visualizations for the dental age assessment using the Kvaal Method.

DISCUSSION

In our investigation titled "An In-depth Investigation into Dental Age Assessment in the Mardan Population: Employing the Kvaal Technique via Digital Panoramic Radiography Analysis," we focused on a non-invasive approach to estimate dental age in adults. Utilizing digital panoramic radiography, the study comprised 300 individuals between the ages of 18-65.

Our findings suggest that the measurements most significantly correlated with chronological age are M (-0.659) and W-L (-0.643). This result aligns with Sharma R. et al[10], but contrasts with other studies like Marroquin et al. [11] and Patil et al. [15], who found other measurements to be better indicators. This inconsistency may be attributed to diverse factors affecting secondary dentin deposition, including but not limited to ethnicity, diet, and lifestyle [9].

When juxtaposed with previous investigations, our study displayed a high Pearson correlation coefficient (=0.708 r =0.708) between estimated dental and chronological ages. This is notably higher than earlier studies, such as those by Singal, K.et al. [14], Sharma R. et al. [10], and others. Consequently, the present study implies a greater accuracy when employing the Kvaal technique within the Mardan population.

Moreover, our study revealed that the estimated dental age averaged around 30.80 years, with a standard deviation of ± 7.33. These metrics were consistent with earlier studies like that of Chandan et al. [16], which substantiates the general applicability and accuracy of the Kvaal technique. However, it is worth noting that certain studies like those by Li Mj et al. [9] indicated overestimations or inaccuracies, suggesting that geographical and ethnic variations might affect the outcomes.

The correlation coefficients were notably higher when considering the entire sample, suggesting that the Kvaal technique provides better accuracy when applied to a broader age range within the Mardan population.

While the current study reports a high correlation and a low standard error, it is crucial to consider multiple variables that could influence these results. These could include the precision of the methodology, the sample size, and the age distribution of the sample[5].

Our study adds valuable data but also poses questions concerning the influence of factors like ethnicity and secondary dentin deposition on dental age estimation. As the first of its kind in the Mardan population, this research sets a precedent for further studies, especially considering the rich ethnic diversity within this region.

CONCLUSION

In conclusion, our findings indicate that the Kvaal method, when applied through digital panoramic radiography within the Mardan population, provides a reliable and accurate estimate of dental age across a range of adult ages. Future studies could potentially refine this technique further by accommodating various influencing factors, including race, diet, and lifestyle.

Author's Contribution:
Concept & Design of Study: Asma Ali
Drafting: Hafsa Latif, Javaria Imtiaz
Data Analysis: Ayesha Rehman, Sajila Raziq
Revisiting Critically: Asma Ali, Hafsa Latif
Final Approval of version: Asma Ali

Conflict of Interest: The study has no conflict of interest to declare by any author.

REFERENCES

1. Verma M, Verma N, Sharma R, Sharma A. Dental age estimation methods in adult dentitions: An overview. J Forensic Dent Sci 2019;11:57-63.
2. Du C, Zhu Y, Hong L. Age-related changes in pulp cavity of incisors as a determinant for forensic age identification. J Forensic Sci 2011;56:S72-S76.
3. Murray PE, Stanley HR, Matthews JB, Sloan AJ, Smith AJ. Age-related odontometric changes of human teeth. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2002;93(4):474-482.
4. Mittal S, Nagendrareddy SG, Sharma ML, Agnihotri P, Chaudhary S, Dhillon M. Age estimation based on Kvaal's technique using digital panoramic radiographs. J Forensic Dent Sci 2016;8:115-115.
5. Limdiwala PG, Shah JS. Age estimation by using dental radiographs. J Forensic Dent Sci 2013;5: 118-122.
6. Landa MI, Garamendi PM, Botella MC, Alemán I. Application of the method of Kvaal, et al. to digital orthopantomograms. Int J Legal Med 2009;123(2): 123-128.
7. Stramotas S, Geenty JP, Darendeliler MA, Byloff F, Berger J, Petocz P. The reliability of crown-root ratio, linear and angular measurements on panoramic radiographs. Clin Orthod Res 2000;3(4): 182-191.
8. Karkhanis S, Mack P, Franklin D. Age estimation standards for a Western Australian population using the dental age estimation technique developed by Kvaal et al. Forensic Sci Int 2014;235:104.e1-104.e6.
9. Li MJ, Chu G, Han MQ, Chen T, Zhou H, Guo YC. Application of the Kvaal method for age estimation using digital panoramic radiography of Chinese individuals. Forensic Sci Int 2019;301: 76-81.
10. Sharma R, Srivastava A. Radiographic evaluation of dental age of adults using Kvaal's method. J Forensic Dent Sci 2010;2(1):22-26.
11. Marroquin TY, Karkhanis S, Kvaal SI, Vasudavan S, Kruger E, Tennant M. Age estimation in adults by dental imaging assessment systematic review. Forensic Sci Int 2017;275:203-211.
12. Rajpal PS, Krishnamurthy V, Pagare SS, Sachdev GD. Age estimation using intraoral periapical radiographs. J Forensic Dent Sci 2016;8(1):56-57.

13. Jain S, Nagi R, Daga M, Shandilya A, Shukla A, Parakh A, et al. Tooth coronal index and pulp/tooth ratio in dental age estimation on digital panoramic radiographs—A comparative study. Forensic Sci Int 2017;277:115-121.

14. Singal K, Sharma N, Kumar V, Singh P. Coronal pulp cavity index as noble modality for age estimation: a digital image analysis. Egypt J Forensic Sci 2019;9(1):42.

15. Patil SK, Mohankumar KP, Donoghue M. Estimation of age by Kvaal's technique in sample Indian population to establish the need for local Indian-based formulae. J Forensic Dent Sci 2014;6:166-170.

16. Chandan PK, Arora KS, Das M, Kaur P, Mohaptra S, Pareek S. Assessment of validity and reliability of Kvaal's method for age estimation among a population sample—A retrospective study. Ind J Dent Res 2020;31:186-190.