

# Forensic Age Estimation Using Mathew's Method via Bite-Wing Radiographs in A Group of Turkish Population: A Cross-sectional study

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Article Info	ABSTRACT
<b>Article History</b> <b>Received:</b> 19.11.2024 <b>Accepted:</b> 02.05.2025 <b>Published:</b> 30.12.2025  <b>Keywords:</b> Forensic dentistry, Bite-wing radiograph, Mathew method, Two dimensional radiography.	<b>Aim:</b> It is aimed to predict age within acceptable margins of error by the Mathew's Method in a sample of Turkish individuals based on bite-wing radiographs. <b>Material and Methods:</b> Measurements were recorded on the total of 302 bite-wing radiographic image based on Mathew's technique. Pearson's correlation coefficient assessed the relationship between estimated and chronological ages, while the intraclass correlation coefficient measured intra-observer reliability. A test set of 60 samples and a training set of 242 samples were created from the data set. A regression equation was developed from the 242 samples and tested for accuracy with the 60 samples. An Independent Samples t-test was applied to assess the significance of the difference between chronological and estimated ages. <b>Results:</b> There is a moderate negative the correlation among estimated and chronological age values obtained from the regression equation ( $r = -0.397$ ; $p \cong 0.000 < 0.05$ ). The intraclass reliability coefficient was found to be 0.992. The mean estimated and chronological age did not differ significantly ( $p=0.153$ ). 16.1% of the difference in the pulp chamber crown-root trunk height ratio was explained by chronological age. There was statistical significance in the regression equation ( $p < 0.05$ ). There was no statistically significant difference in the mean estimated ages based on gender. ( $p=0.259$ ). <b>Conclusion:</b> Mathew's method demonstrates a correlation between accurate and estimated ages in a sample of the Turkish population, suggesting the potential use of bite-wing radiographs for forensic age estimation.

## Türk Popülasyonundan Bir Grup Üzerinde Bite-Wing Radyograflar Kullanılarak Mathew Yöntemi ile Adli Yaş Tayini: Kesitsel Bir Çalışma

Makale Bilgisi	ÖZET
<b>Makale Geçmişi</b> <b>Geliş Tarihi:</b> 19.11.2024 <b>Kabul Tarihi:</b> 02.05.2025 <b>Yayın Tarihi:</b> 30.12.2025  <b>Anahtar Kelimeler:</b> Adli diş hekimliği, Bite-wing radyografi, Mathew yöntemi, İki boyutlu radyografi.	<b>Amaç:</b> Türk bireylerden oluşan bir örnekleme, bite-wing radyograflarına dayalı olarak Mathew's Yöntemi ile yaşın kabul edilebilir hata marjları içinde tahmin edilmesi amaçlanmıştır. <b>Gereç ve yöntemler:</b> Çalışmaya toplam 302 bite-wing radyografik görüntü dahil edilmiştir. Ölçümler Mathew's tekniğine göre görüntüler üzerinde kaydedilmiştir. Tahmini yaş ile kronolojik yaş arasındaki ilişki Pearson korelasyon katsayısı ile değerlendirilirken, gözlemci içi güvenilirlik intraclass korelasyon katsayısı ile ölçülmüştür. Verilerden 60 örnek içeren bir test seti ve 242 örnek içeren bir eğitim seti oluşturulmuştur. Eğitim setinden elde edilen regresyon denklemi, test seti ile doğruluk açısından test edilmiştir. Kronolojik yaş ile tahmini yaş arasındaki farkın anlamlılığı Bağımsız Örneklem t-testi ile değerlendirilmiştir. <b>Bulgular:</b> Regresyon denklemi ile elde edilen tahmini ve kronolojik yaş değerleri arasında orta düzeyde negatif bir korelasyon bulunmuştur ( $r = -0,397$ ; $p \cong 0,000 < 0,05$ ). Gözlemci içi güvenilirlik katsayısı 0,992 olarak saptanmıştır. Ortalama tahmini yaş ile ortalama kronolojik yaş arasında anlamlı bir fark bulunmamıştır ( $p=0,153$ ). Pulpa odası kron-kök gövde yüksekliği oranındaki farkın %16,1'i kronolojik yaş ile açıklanmıştır. Regresyon denkleminde istatistiksel anlamlılık gözlenmiştir ( $p < 0,05$ ). Cinsiyete bağlı olarak tahmini yaş ortalamaları arasında istatistiksel olarak anlamlı bir fark bulunmamıştır ( $p=0,259$ ). <b>Sonuç:</b> Mathew yöntemi, Türk popülasyonundan bir örnekleme doğru ve tahmini yaşlar arasında bir ilişki olduğunu göstermekte olup, bite-wing radyograflarının adli yaş tahmini için potansiyel bir kullanım alanı olabileceğini düşündürmektedir.

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## INTRODUCTION

Dental age estimation is a reliable and non-invasive method used globally to determine the most likely chronological age in circumstances of missing documents or unexplained unidentified bodies. Various anatomical structures have been utilized for chronological age estimation in forensic and clinical settings.<sup>1</sup> Given its wide applicability, forensic age determination plays a crucial role in assessing the age of asylum applicants who lack identity documents and in identifying unknown deceased individuals.<sup>2,3</sup> Dental age estimation methods have been widely studied and validated across different populations. These methods rely on various dental parameters such as root formation, pulp chamber volume, and tooth mineralization to estimate chronological age with high accuracy.<sup>4</sup>

Following root completion, secondary dentine accumulates over the time of a person's lifetime, reducing the pulp chamber. It is commonly recognized that other environmental factors have the least impact on the pulp chamber's size, which decreases with increasing chronological age.<sup>5</sup> Non-invasive radiological methods have been made to analyze the pulp chamber's reduction in order to determine the quantity of secondary dentine deposited. Regression equations were formulated to predict age, utilizing the association between age and the reduction in pulp chamber volume.<sup>6,7</sup>

An essential tool for forensic science is radiology.<sup>8</sup> Orthopantomograms, bitewing radiographs, and intraoral periapical radiographs are some of the techniques used to achieve this goal. To be assessed using the chosen development standards, the forming teeth of interest must be visible in the radiography imaging.<sup>9</sup>

The pulp chamber size, as determined by radiographic inspection of the individuals' teeth, is a measure correlated with the victims' chronological age.<sup>10</sup> As a result the pulp chamber's capacity varies throughout life, the techniques that use the ratio of dental tissues

are employed to determine the pulp chamber volume in both panoramic and periapical radiographs.<sup>11</sup>

Bite-wing radiographs are frequently utilized for diagnostic purposes.<sup>12</sup> Higher-resolution intraoral imaging modalities include bite-wing, occlusal, and periapical radiography. The teeth and the surrounding structures can all be visualized using an intraoral procedure known as bite-wing radiography. Compared to periapical radiography, this makes more teeth viewable and evaluable on a single image. Using this approach, the beam is given an 8–10 degree vertical angle, which prevents the teeth from overlapping and allows the beam to pass through the contact point.<sup>13,14</sup>

Various dental age estimation methods focusing on dentin deposition have been extensively studied in the literature. Previous research has primarily utilized three-dimensional tomographic images and panoramic radiographs for age estimation.<sup>15,16</sup> By employing bitewing radiographs instead of panoramic or CBCT images, this approach offers a potential advantage in reducing patient radiation exposure while maintaining the reliability of age estimation. By using bitewing radiographs instead of panoramic imaging, the aim was to eliminate image distortion while also reducing radiation dose. Compared to CBCT, the radiation dose was significantly reduced. This study aims to evaluate the Mathew's<sup>17</sup> method using two-dimensional bitewing radiographs in a sample of Turkish individuals with acceptable error margins.

## MATERIAL AND METHODS

Bite-wing radiographs are selected from the archive of the Oral Diagnosis and Maxillofacial Radiology Department at Lokman Hekim University's Faculty of Dentistry. These radiographs were originally obtained for various diagnostic purposes, including the assessment of approximal caries, evaluation of alveolar bone defects, and examination of restorations.

The research was granted approval by the Lokman Hekim University Clinical Research Ethics Committee (2024/215), and the guiding terms of the Declaration of Helsinki were followed. A post hoc power analysis was conducted using G\*Power 3.1 (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany) with an alpha level of 0.05 and assuming a medium effect size (Cohen's  $d = 0.5$ ). The analysis indicated that our sample size of 300 provided a power exceeding 80%, suggesting that the study was sufficiently powered to evaluate the applicability of the age estimation method in the Turkish population.

A total of 302 digital bitewing radiographs were included in the study. Of these, 203 belonged to females and 99 to males, with ages ranging from 17 to 70 years. High resolution of the image and the presence of the lower first mandibular molar teeth were prerequisites for inclusion. The sample did not include digital bitewing radiographs with low image resolution, artifacts, dental developmental changes, missing or fractured teeth, teeth with orthodontic appliances or restorations of any kind, or images of people who had previously received orthodontic treatment. Bitewing radiographs were obtained at 65 kVp and 10 mA using a RXDC X-ray intraoral digital imaging device (NewTom, Imola, Italy) and scanned with a

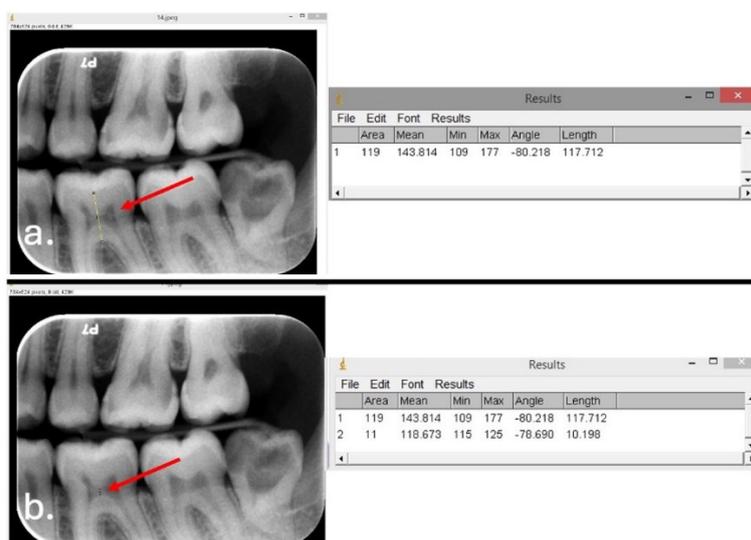
Carestream 7200 scanner (Carestream Dental, Atlanta).

The radiographic images were numbered randomly before analysis. Measurements were performed using the Fiji ImageJ open-source program (ImageJ, 1.34n; National Institute of Health, Bethesda, MD, USA).

Mathew et al.<sup>13</sup> described a method for estimating age based on measuring secondary dentin deposition. In the method, the distance from the central fossa of the molar tooth to the root furcation is measured on a panoramic radiograph. Additionally, the distance between the pulpal floor and ceiling along the same line is measured, and the two values are used to calculate a ratio. In this study, the same method was applied using bitewing radiographs instead of panoramic images.

A straight line was drawn between the central fossa and the uppermost point on the root furcation, and the length of this line was measured and recorded as the crown-root trunk height (CRTH) (Figure 1a). The distance between the pulp chamber's floor and roof along the same axis was measured and recorded as the pulp chamber height (PCH) (Figure 1b). These measurements were obtained for each mandibular first molar. The PCH/CRTH ratio was then calculated for each case.<sup>17,18,19</sup>

**Figure 1:** Measurement of the line between the central fossa and the uppermost point on the root furcation on mandibular first molar teeth **a.** The crown-root trunk height (CRTH) **b.** Pulp chamber height (PCH)



To assess intraobserver reliability, 75 randomly selected radiographs were re-evaluated after one month. All measurements were conducted by a radiologist with five years of experience. Additionally, data on the individual's gender and age at the time of radiographic exposure were recorded.

### Statistical Analyses

Two subsets of the subjects were generated. The regression formula for estimating age based on pulp chamber length was derived from the first group ( $n = 242$ ). The accuracy of this formula was then tested using the second group ( $n = 60$ ). In order to analyze the data, descriptive statistics were employed. The reliability of the measurements was evaluated using a 95% confidence interval. Intra-observer reliability was assessed using a one-way random effects model with consistency for intraclass correlation coefficient (ICC). The obtained ICC value was interpreted based on established guidelines.<sup>20</sup> The association between PCTHR (PCH/CRTH) levels and accurate age was evaluated by means of the Pearson correlation coefficient. A regression model was created in order to estimate age in Turkish adults through regression analysis.

To assess whether the differences in group means were statistically significant, an independent t-test was applied. Statistical significance was set at  $p < 0.05$ .

### RESULTS

A total of 302 bitewing radiographs from individuals aged between 17 and 70 were incorporated into the research. Age groups were categorized into six classes.

Using the test-retest method with 75 subjects, the ICC was found to be 0.992 (95% CI: 0.987–0.995), indicating excellent reliability according to the classification proposed by Koo and Li.<sup>20</sup> The association between PCH/CRTH levels and age at diagnosis was evaluated using the Pearson correlation coefficient.

There was a significant statistical difference in terms of the correlation between accurate age and PCTHR (PCH/CRTH) values. A moderate negative correlation was observed between chronological age and PCTHR (PCH/CRTH) values ( $r = -0.397$ ;  $p \cong 0.000 < 0.05$ ). The complete dataset was divided into two sets such as training set and test set including 242 samples and 60 samples, respectively (Table 1).

**Table 1:** Distribution of age groups

	Training set			Test set			
		Gender		Total	Gender		Total
		Female (n)	Male (n)		Female (n)	Male (n)	
Age groups	17- 25	80	39	119	10	6	16
	26- 34	30	15	45	19	4	23
	35- 43	24	16	40	7	2	9
	44- 52	18	5	23	3	1	4
	53- 61	8	3	11	2	5	7
	62- 70	1	3	4	1	0	1
Total		161	81	242		42	18

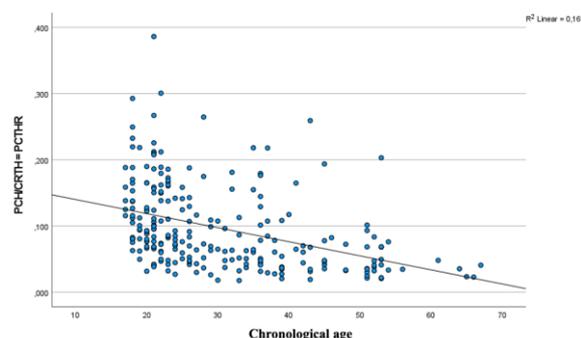
**Table 2:** The regression analysis

	Unstandardized Coefficients		Standardized Coefficients	t-value	p-value	95,0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
Constant	37.589	1.288		29.190	.000	35.052	40.125
PCTHR	-75.676	11.156	-.401	-6.784	.000	-97.651	-53.700

The regression equation was derived using the training set and validated with the test set. The regression equation was derived using 242 samples, and its accuracy was tested with 60 samples. A linear regression analysis was conducted to estimate chronological age based on PCTHR (PCH/CRTH). The regression equation was derived as: Estimated Age = 37.589 - 75.676 (PCTHR). The unstandardized coefficient (B) for PCTHR was -75.676 (SE = 11.156), with a t-value of -6.784 and  $p < 0.001$ . The 95% confidence interval for B ranged from -97.651 to -53.700. The model demonstrated a correlation coefficient (R) of 0.401 and an  $R^2$  value of 0.161, indicating that 16.1% of the variance in chronological age was explained by PCTHR. The overall model was statistically significant ( $F = 46.018$ ,  $p < 0.001$ ). (Table 2) The scatter plot shows that chronological age explained 16.1% of the

variation in PCTHR values. The regression equation is found significant ( $p < 0.05$ ) (Figure 2). The Independent Samples t-test was used to test the significance of the difference between chronological age and the estimated age (Table 3). Statistically, no difference was found between the means of chronological age and estimated age ( $p = 0.153 > 0.05$ ).

**Figure 2:** The scatter plot of distribution of the PCTHR



**Table 3:** Independent samples t-test

	N	Mean	Std. Deviation	Std. Error Mean
Chronological age	60	33.6833	12.44172	1.60622
Estimated age	60	31.2370	4.14215	.53475
				p=.153

**Table 4:** Descriptive statistics

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min.	Max.
						Lower Bound	Upper Bound		
Chronological age	Female	42	32.61	11.02	1.70	29.18	36.05	18.00	62.00
	Male	18	36.16	15.31	3.61	28.54	43.78	19.00	60.00
	Total	60	33.68	12.44	1.60	30.46	36.89	18.00	62.00
Estimated age	Female	42	31.63	3.57	.55	30.52	32.74	22.95	36.28
	Male	18	30.30	5.24	1.23	27.70	32.91	16.65	36.41
	Total	60	31.23	4.14	.53	30.16	32.30	16.65	36.41
The difference between estimated age and chronological age	Female	42	-.98	10.12	1.56	-4.13	2.16	-30.05	13.20
	Male	18	-5.85	14.37	3.38	-13.00	1.28	-34.15	15.04
	Total	60	-2.44	11.65	1.50	-5.45	.56	-34.15	15.04

Descriptive analysis was conducted for chronological age, estimated age, and the discrepancy between them (Table 4).

The significance of the difference in estimated age between female and male was tested. There was no difference between the mean estimated ages of women and men ( $p = 0.259 > 0.05$ ) (Table 5).

**Table 5:** The difference in estimated age between gender

		N	Mean	Std. Deviation	Std. Error Mean
Estimated age	Female	42	31.63	3.57	.55
	Male	18	30.30	5.24	1.23

p=0.259>0.05

## DISCUSSION

Morphological, biochemical, and radiographic methods are among the various dental age estimation approach used for estimation the age of alive and deceased people. The most commonly utilized technique for determining a child or adolescent's dental age is radiological examination of developing teeth.<sup>9</sup> Secondary dentine deposition measurements have been used to construct a number of precise age estimation formulae. Dentin deposition causes the size of the tooth pulp chamber to decrease; volumetric reduction may be used as an age indicator.<sup>21,22</sup> Kvaal et al.<sup>23</sup> suggested a technique that measures pulp radiolucency on periapical radiographs to quantify secondary dentin deposition indirectly. Cameriere et al.<sup>24</sup> presented utilizing the ratio of pulp volume for age estimation based on Italian formulas. Along with these methods, Mathew et al.<sup>17</sup> established another method for estimating age using mandibular first molar radiographs. In the method described by Mathew et al.,<sup>17</sup> panoramic radiographs were used. Since distortion caused by the alignment of the teeth onto panoramic images, one tooth was chosen for the investigation to guarantee consistent distortion in every sample. In the present study, the secondary dentin measurement method used by Mathew et al.<sup>17</sup> was applied. While the measurement technique remained the same, the imaging method was changed. The extraoral imaging technique was replaced with an intraoral imaging method, and bitewing radiography was used to prevent potential distortions.

The tooth's limited exposure to external factors makes it a dependable body part for forensic age estimation. Disaster victim identification heavily relies on dental characteristics and morphology.<sup>25,26</sup> The capacity to estimate age becomes critical when a large number of people are involved, and skeletal and dental developing patterns are vital markers for estimating age.<sup>27,28</sup>

Nonuniform magnification and geometric distortion throughout the image are additional issues with panoramic radiography. The panoramic image inherently distorts the object's size and shape, rendering it extremely unreliable for linear or angular measurements.<sup>29</sup>

The least amount of distortion achievable should be present on radiographs. The majority of distortion is not brought on by the curvature of the structures, but rather by incorrect x-ray beam angulation. The beam is precisely positioned parallel to the occlusal plane and between the teeth. The opposing cusps' overlapping into the occlusal surface is reduced in this position.<sup>30</sup>

Therefore, unlike the method of estimating age described by Mathew et al.,<sup>17</sup> in the current study an intraoral imaging technique with reduced image distortion was preferred. Using a film holder for bitewing radiographs ensures that the patient receives a lower radiation dose compared to panoramic films and permits the teeth and sensor to be at a straight angle to the center X-ray beam.<sup>31</sup> On the other hand, the use of bitewing radiographs with a film holder is also widespread in routine radiological examinations from childhood to adulthood.

Mathew et al.<sup>17</sup> in his new method for measuring age in South Indians, he discovered a negative association between ratio and age ( $r = -0.56$ ,  $p = 0.000$ ). Similar to this outcome, the current study found a moderately negative relationship between PCTHR (PCH/CRTH) stages and accurate age. ( $r = -0.397$ ;  $p \cong 0.000 < 0.05$ ).

There are studies in the literature that use the Mathew method. Jain et al.<sup>32</sup> compared reliability of two different dental age estimation techniques for adulthood by using digital orthopantomographs to assess the pulp/tooth ratio and tooth coronal index (TCI). Similar to this study, the results demonstrated revealed there was a negative relationship between both methods and age, and that PCTHR in first mandibular molar teeth was an effective way to estimate age. PCTHR outperformed TCI as a technique for estimating age and displayed a little greater negative correlation. Additionally, unlike to this study Jain et al.<sup>32</sup> observed a statistically significant difference between calculated and accurate age ( $p = 0.153$ ).

Shah et al.<sup>33</sup> evaluated the precision of the pulp/tooth ratio technique for forensic age determination in the first and second molars in the mandible. Similar to this study, it was found that the age of individuals was strongly correlated with the PCTHR of both the first ( $r = -0.609$ ) and second ( $r = -0.422$ ) mandibular molars. Consistent with this study, no statistically significant difference was found between the measured and actual ages of either mandibular molar ( $p = 1.000$ ).

Jeon et al.<sup>34</sup> compared the accuracy of two imaging methods, intraoral periapical film and panoramic imaging, in estimating age based on the Mathew<sup>17</sup> method, using a new approach they developed based on this method. They analyzed the relation between age and pulp size on dental imaging, new regression models were recommended to estimation of Korean people using first molars in the mandible. Secondary dentin deposition served as the foundation for the

technique they outlined, and the pulp chamber's floor and ceiling, the top point on the furcation of root and the beginning of the lingual groove were all considered reference points. The measurements on mandibular first molars were completed using both extraoral and intraoral imaging techniques and the correlation was compared between the two methods. The pulp chamber roof height ratio has been reported to be slightly negatively associated with age, despite the current study showing a moderately negative relation ( $r = -0.397$ ) ( $r = -0.150$  to  $-0.127$ ). In accordance with the perspective supported in this study, the findings revealed that measurement ratios derived from intraoral radiographic imaging methods of mandibular first molars offer more trustworthy information than those obtained from panoramic radiographs.

Ilayaraja et al.<sup>35</sup> compared two different dental age estimation methods in the same individual by measuring canine teeth and mandibular first molar. Similar to this study, in the study where they evaluated using the Mathew method,<sup>17</sup> no significant differences were observed between the mean chronological age and the mean estimated age ( $p = 0.153 > 0.05$ ). Additionally, ratios estimated in first molars showed a statistically significant negative correlation with chronological age ( $R = -0.594$ ;  $P < 0.001$ ).

Tantanapornkul et al.<sup>36</sup> conducted a study using the Mathew method to estimate age and also investigate the effects of aging on intraoral conditions and morphometric parameters through panoramic radiographs. Their findings similarly revealed a negative correlation between chronological age and estimated age.

Although the sample size of the study was statistically sufficient, the distribution of individuals across age groups was not balanced in terms of the number of participants. One of the inclusion criteria of the study required the presence of the first molar tooth and the absence of any

restorations in the first molar. This led to a limitation, particularly in older age groups, where suitable radiographs that met the inclusion criteria were not available. This represents the most significant limitation of the study. It is recommended that future studies be conducted with a larger sample size for each age group.

Since that the current study is a retrospective radiologic research, errors may arise from variations in radiographic measurement. The primary cause of measurement mistakes appeared to be challenges identifying the line to be measured and identifying the radiographs' reference points when they were displayed on the monitorization. Although inclusion and exclusion criteria were defined, a limitation of the retrospective radiological examination is the inability to assess clinical conditions, such as bruxism, which could influence secondary dentin deposition.

The representativeness of the study group for the Turkish population may be compromised due to the small sample size and the scarcity of clinically intact molars among adults, potentially affecting the applicability of these models. To enhancement of dental age estimation's precision, future research should focus on larger sample sizes and include teeth other than the mandibular first molars.

## CONCLUSION

In this study, bitewing radiographs, an imaging technique that reduces distortion and magnification while also lowering the patient's radiation dose, were used instead of commonly employed imaging techniques for dental age determination. This technique was applied to a population of Turkish nationality to assess its applicability. The results demonstrated that bitewing radiography correlates well with chronological age. Therefore, this method appears to be a viable alternative to panoramic radiography for a subset of the Turkish population.

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### Ethical Approval

The ethical approval for this study was obtained from the Lokman Hekim University Clinical Research Ethics Committee (2024/215).

### Financial Support

The authors declare that this study received no financial support.

### Conflict of Interest

The authors deny any conflicts of interest related to this study.

### Author Contributions

Design: SC, Data collection or access: SC, Analysis and comments: SC, Literature search: SC, Writing: SC.

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