ATATÜRK ÜNİVERSİTESİ YAYINLARI
ATATURK UNIVERSITY PUBLICATIONS

Research Article *Araştırma Makalesi* DOI: 10.17567/currresdentsci.1557614

Use of Tooth/Pulp Ratios in Dental Volumetric Tomography Sections for age Estimation in Forensic Dentistry

Adli Diş Hekimliğinde Yaş Tahmininde Diş Hacimsel Tomografi Kesitlerinde Diş/Pulpa Oranlarının Kullanımı

Fatma Nur YOZGAT İLBAŞ[1]
[1]Nimet Bayraktar Oral and Dental Health Hospital, Kayseri, Türkiye
Fatma ÇAĞLAYAN[2]
[2]Department of Oral Dental and Maxillofacial Radiology, Atatürk University, Faculty of Dentistry, Erzurum, Türkiye

ABSTRACT

Objective: The objective of the present study was to estimate age by measuring the pulp width and tooth width of subjects in Cone Beam Computed Tomography (CBCT) images.
Methods: The study was conducted between November 2020 and November 2021, and included a retrospective analysis of CBCT images obtained from patients who presented between 2008 and 2021. For age estimation, the pulp width/tooth width ratio of the mandibular first molar teeth of 175 patients was calculated in both horizontal and vertical planes..
Results: The findings of the study indicated that linear regression analysis was a viable method for age estimation, with the pulp width/tooth width ratio contributing to 17.8% of the variation in age estimation in the vertical plane and 3.6% in the horizontal plane. It was also determined that the change in age varies by 82.2-96.4%, respectively, depending on other factors.
Conclusion: The measurements used for age estimation using CBCT images alone were insufficient and a regression equation was not created.
Keywords: Forensic dentistry, CBCT, age assessment

ÖZ
Amaç: Çalışmanın amacı, Konik Işınlı Bilgisayarlı Tomografi (KIBT) görüntülerinde pulpa genişliği/diş genişliği kullanılarak yaş tahmini yapmaktır.
Yöntemler: Çalışma Kasım 2020-Kasım 2021 tarihleri arasında yürütülmüş olup, çalışma kapsamında 2008-2021 yılları arasında başvuran hastalardan elde edilen KIBT görüntüleri retrospektif olarak analiz edilmiştir. Yaş tahmini için 175 hastanın alt çene birinci molar dişlerinin pulpa genişliği/diş genişliği oranı hem yatay hem de dikey düzlemde hesaplandı.
Bulgular: Yaş tahmini için doğrusal regresyon analizi yapıldı. Dişlerin pulpa genişliği/diş genişliği oranı dikeyde %17,8, genişlikte ise %3,6 olup yaşı açıklayabilir. Yaştaki değişim diğer faktörlere bağlı olarak sırasıyla %82,2-96,4 arasında değişmektedir.
Sonuç: Sadece KIBT görüntüleri kullanılarak yaş tahmini için kullanılan ölçümlerin yetersiz olduğu ve bir regresyon denkleminin oluşturulmadığı görüldü.
Anahtar Kelimeler: Adli diş hekimliği, KIBT, yaş değerlendirmesi

Geliş Tarihi/Received 28.09.2024
Revizyon Talebi/Revision Requested 19.11.2024
Son Revizyon/Last Revision 16.08.2025
Kabul Tarihi/Accepted 26.08.2025
Yayın Tarihi/Publication Date 21.07.2026

Sorumlu Yazar/Corresponding author: Fatma Nur YOZGAT İLBAŞ
E-mail: fatmayozgat9466@gmail.com
Cite this article: Yozgat İlbaş FN, Çağlayan F. Use of Tooth/Pulp Ratios in Dental Volumetric Tomography Sections for age Estimation in Forensic Dentistry. *Curr Res Dent Sci.* 2026; 36(3):195-199. DOI: 10.17567/currresdentsci.1557614

INTRODUCTION

The process of identifying an individual and describing their distinctive characteristics that set them apart from others is termed identification. Instances in which identification studies have assumed significance include natural disasters and wars that have resulted in large-scale fatalities, the remains of mass graves, and corpses that have undergone such extensive decomposition that identification is no longer feasible.[1] The accurate performance of identification is of paramount importance for both the individual and society as a whole. The fundamental physical characteristics that serve as the foundation for medical identity are age, gender, bones, eye colour, and fingerprints.[2] The capacity to ascertain an individual's age is of paramount importance in a multitude of scenarios that are encountered with considerable frequency in contemporary society. These scenarios include, but are not limited to, the delineation of legal rights and obligations, marital eligibility, military enlistment, civil service eligibility, the age at which school entry is permitted, responses to sexual assault, infants with ambiguous identity, the distinction between mature and immature bodies, and individuals who are unaccounted for.[3] The identification of corpses resulting from holocausts, wars, crimes, vehicle accidents, and natural disasters has proven to be a significant challenge, given the increasing frequency of such events on a global scale. Furthermore, the identification of corpses following periods of prolonged mortality has also posed

substantial difficulties. In such cases, the only evidence that remains are skeletal remains and teeth.[4] Teeth and dental materials used for treatment are far more resistant to external factors and environmental conditions compared to other parts of the body, even if they undergo various lifelong changes.

The ideal age estimation method should yield results that are as close as possible to the chronological ages of individuals, while also being easily applicable. The extant literature attests to the reliability of age estimation from dental records and radiographs.[5,6] In the extant literature, the use of panoramic and periapical radiographs for age estimation has been predominant.[7] The merits of employing radiological techniques are manifold; they are expeditious and uncomplicated, innocuous to the material utilised, economical, and applicable to both living and deceased subjects.[7] However, plain radiographies are incapable of revealing the three-dimensional structure and volume of the pulp. However, recent advancements in cone-beam CT (CBCT) and micro-CT technology have facilitated reliable analysis of the pulp's three-dimensional structure.[8] Studies employing micro-CT and CBCT to compare the pulp and dental volume have recently been published.[9-14]

Accurate age estimation is possible until the apexes of teeth are closed; however, this becomes more challenging after apex closure. The objective of this study is to assess the efficacy of the shrinkage of the pulpal chamber in age estimation as the individual progresses through the life cycle. The objective of this study is to estimate age by measuring the ratio of pulp width to dental width using CBCT.

METHODS

Study Design

The study, conducted in the Oral and Maxillofacial Radiology Department of the Faculty of Dentistry at Atatürk University between November 6,2020 and November 10,2021, was approved by the ethical committee of the Faculty of Dentistry of Atatürk University on November 6, 2020 (decision number 2020/33). In this study, CBCT images taken for various reasons from patients who applied to our clinic between 2008 and 2021 were retrospectively analyzed. The study incorporated a sample of 175 teeth from 175 individuals to facilitate age estimation.

The following criteria were applied for the selection of subjects: Firstly, the mandible must be completely within the field of the tomography, and the image must be optimal. Secondly, the subject must be over the age of 16 years, and there must be no cavities, fragments, fillings or prosthetic restorations in the mandibular first molar teeth. Thirdly, the root apical must be free of any lesions, and there must be no internal or external resorption in the dental root. Finally, there must be no calcification in the pulp. In this study, the mandibular molar teeth were preferred because of the large pulp chamber, which can show the narrowing more clearly.

CBCT procedures

The images of all subjects included in the study were obtained with the New Tom 3G Dental Volumetric Tomography device equipped with a flat panel detector (New Tom FP, Quantitative Radiology, Verona, Italy) in the Oral and Maxillofacial Radiology Department of the Faculty of Dentistry. The gantry angle of the device is fixed and perpendicular to the ground. Standard images are 110 kVp, operating with a maximum 15 mA conic beam, and its voxel dimension is 0.16 mm. The acquisition of images is accomplished within a time frame of 36 seconds, while the exposure duration is 5.4 seconds. Subsequent to image acquisition, a reconstruction process was initiated, yielding volumetric data. The data for the study were obtained with the secondary reconstruction process based on the axial section thickness of 0.5 mm in parallel to occlusion and covering the whole mandible, through the volumetric data obtained after primary reconstruction process. It is noteworthy that all scans conducted within our hospital have been obtained with identical parameters.

Measurements

Following the acquisition of the relevant study data, oblique sagittal sections measuring 0.5 mm in thickness were obtained from mandibular first molar teeth for the purpose of analysis. The pulp width/dental width ratio was then calculated on the section where the pulp appeared to be at its widest (Figure 1a). For the purpose of vertical measurements, once more in the section where the pulp is at its widest, the ratio of the vertical length of the pulp to the vertical length of the distance between the top of the pulp and the furcation area was calculated (Figure 1b). The objective of this study was to examine whether the pulp had undergone age-induced narrowing, both vertically and mesodistally. The measurements were conducted and checked with a radiologist with 15 years of experience.

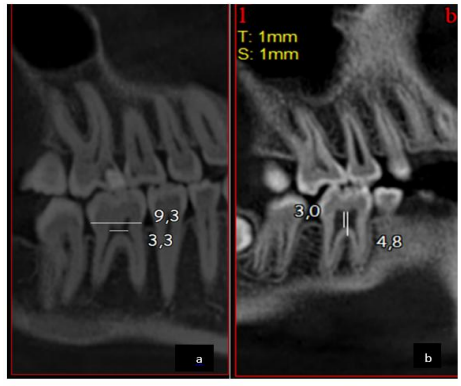

Figure 1. a) Measurement of the pulp and dental width; b) Dental vertical dimension

Statistical Analysis

The data obtained from the study were assessed in a computer environment using the Statistical Package for Social Sciences (SPSS) for Windows. The minimum sample size for the study was calculated with the Power Analysis & Sample Size (PASS) program. The calculation of the sample size for age estimation was performed using the following formula: n=105 at a power level of α=0.05 and 1-β=0.95. In the event that the correlation coefficient between age and the pulp width-tooth width ratio is R=0.70 (0.60-0.80), the predictor power is R2=0.49. The data obtained (n=175) was then assessed for age determination by means of t-test, Pearson correlation and linear regression (LR) analyses in independent groups. In order to estimate age, age (expressed in years) was taken as the dependent variable, while the pulp width/dental width ratio and the pulp vertical/dental vertical ratio were used as independent variables. These were analysed by means of LR.

The measurements were repeated on two occasions by the same observer and were subsequently checked by the radiologist, who had two years of experience in this field. The measurement's internal consistency was appraised using the Crobach alpha value, while the test-repeat analyses were assessed through the utilisation of interclass correlation analysis.

RESULTS

The number of subjects included in the study to determine age is 175. Of these, 49.7% are female, with a mean age of 37.4 years (±17.38), a median age of 31 years, and an age range of 16–80 years. The

distribution of the research group according to age groups and gender is presented in Table 1.

It has been observed that the mean of pulp width of the teeth number 46 and 36 of the study group is 3.42 (95% CI, 3.34-3.51) while the mean of dental width is 8.95 (95% CI, 8.85-9.05), the ratio of the pulp width to dental diameter is 0.38 (95% CI, 0.37-0.39), and that as age increases, these parameters become smaller (Table 2).

The mean vertical pulp volume of teeth numbered 46 and 36 in the study group was 1.34 (95% CI, 1.26-1.42), the mean dental vertical was 3.80 (95% CI, 3.67-3.93), and the ratio of pulp width to dental diameter was 0.35 (95% CI, 0.34-0.37). As the age of the subjects increases, these parameters tend to decrease (Table 3).

A weak negative relationship has been identified between the age and the vertical ratio (r = -0.421) and width ratio (r = -0.190) of the teeth numbered 46 and 36. However, the relationship between age and dental vertical has not been found to be statistically significant (Table 4).

When the effects of the width and vertical ratios of the teeth numbered 46 and 36 on age change are analysed with linear regression, it is evident that the width ratio can account for 3.6% (R2=0.036) of the change in age, while the vertical ratio can account for 17.8% (R2=0.178) (Table 5). Consequently, it can be deduced that 82.2-96.4% of the observed variation in age is attributable to factors other than the width and vertical ratios of teeth 46 and 36.

It is evident that the impact of the width ratio and the vertical ratio on age change is negligible. Consequently, the development of a formula through regression analysis has not been successful.

Table 1. The distribution, by gender and age, of those included in the study of age estimation

	Gender					
	Female		Male		Total	
Age group	Number	%	Number	%	Number	%
16-19	9	60.0	6	40.0	15	8.6
20-24	18	45.0	22	55.0	40	22.9
25-29	10	38.5	16	61.5	26	14.9
30-34	8	50.0	8	50.0	16	9.1
35-39	6	85.7	1	14.3	7	4.0
40-44	9	52.9	8	47.1	17	9.7
45-49	6	100.0	0	0.0	6	3.4
50-54	2	14.3	12	85.7	14	8.0
60-64	13	81.3	3	18.8	16	9.1
65-69	2	25.0	6	75.0	8	4.6
70-74	3	50.0	3	50.0	6	3.4
75-80	1	25.0	3	75.0	4	2.3
Total	**87**	**49.7**	**88**	**50.3**	**175**	**100.0**

Table 2. The distribution, by age groups, of the pulp width, dental width, and pulpal width/dental width ratio, respectively

	Pulp width			Thread diameter			Width ratio		
		95.0 % C.I.			95.0 % C.I			95.0 % C.I	
Age groups	$\bar{X}$	Lower Limit	Upper Limit	$\bar{X}$	Lower Limit	Upper Limit	$\bar{X}$	Lower Limit	Upper Limit
16-19	3.6600	3.4116	3.9084	9.0067	8.5488	9.4645	0.4063	0.3884	0.4242
20-24	3.5250	3.3126	3.7374	9.1625	8.9185	9.4065	0.3830	0.3651	0.4009
25-29	3.4462	3.2136	3.6787	8.9385	8.6602	9.2167	0.3840	0.3662	0.4017
30-34	3.9313	3.6428	4.2197	9.2125	8.8858	9.5392	0.4267	0.3993	0.4540
35-39	3.2000	2.7376	3.6624	8.7143	8.0998	9.3288	0.3685	0.3128	0.4241
40-44	3.1294	2.8643	3.3946	8.9000	8.6423	9.1577	0.3516	0.3233	0.3799
45-49	3.2833	2.7303	3.8363	8.5833	8.2054	8.9612	0.3815	0.3282	0.4348
50-54	3.2214	2.9742	3.4687	8.6357	8.3523	8.9191	0.3730	0.3469	0.3992
60-64	3.2063	2.9815	3.4310	8.9188	8.6287	9.2088	0.3606	0.3334	0.3877
65-69	3.2250	2.8386	3.6114	8.6125	8.1852	9.0398	0.3742	0.3352	0.4132
70-74	3.1500	2.5917	3.7083	8.6167	8.1501	9.0832	0.3650	0.3099	0.4202
75-80	3.2000	2.6968	3.7032	8.4500	7.8337	9.0663	0.3791	0.3156	0.4427
Total	**3.4240**	**3.3353**	**3.5126**	**8.9479**	**8.8463**	**9.0495**	**0.3818**	**0.3738**	**0.3899**

$\bar{X}$: Arithmetic Means, C.I.: Confidence Interval

Table 3. The distribution, by age groups, of the pulp vertical, dental vertical and pulp/dental vertical ratios, respectively

	Pulp vertical			Dent vertical			Ratio vertical		
		95.0 %C.I..			95.0 % C.I.			95.0 % C.I.	
Age groups	$\bar{X}$	Lower Limit	Upper Limit	$\bar{X}$	Lower Limit	Upper Limit	$\bar{X}$	Lower Limit	Upper Limit
16-19	1.7400	1.5025	1.9775	3.8333	3.4223	4.2444	0.4571	0.4095	0.5046
20-24	1.5950	1.4683	1.7217	4.1400	3.6803	4.5997	0.4009	0.3705	0.4313
25-29	1.3769	1.1731	1.5807	3.6692	3.3963	3.9422	0.3713	0.3295	0.4132
30-34	1.1938	0.9732	1.4143	3.6188	3.3248	3.9127	0.3375	0.2654	0.4096
35-39	1.5000	0.9102	2.0898	3.6571	3.0145	4.2998	0.3979	0.2878	0.5081
40-44	1.1706	0.9344	1.4067	3.7706	3.5784	3.9628	0.3073	0.2549	0.3598
45-49	0.9000	0.6429	1.1571	3.4667	3.1507	3.7827	0.2562	0.2058	0.3067
50-54	0.9357	0.7715	1.1000	3.6286	3.3811	3.8761	0.2566	0.2166	0.2967
60-64	1.1750	0.8954	1.4546	3.8125	3.4761	4.1489	0.3020	0.2438	0.3602
65-69	1.1125	0.6140	1.6110	3.6625	2.9229	4.4021	0.2943	0.2122	0.3764
70-74	1.4833	1.0028	1.9639	3.7667	3.2540	4.2794	0.3879	0.3000	0.4757
75-80	0.5500	0.4581	0.6419	3.3250	2.7104	3.9396	0.1664	0.1379	0.1948
Total	**1.3389**	**1.2616**	**1.4163**	**3.8000**	**3.6660**	**3.9340**	**0.3528**	**0.3350**	**0.3705**

$\bar{X}$: Arithmetic Means, C.I.: Confidence Interval

Table 4. The correlation coefficient between the width and pulp widths of the teeth numbered 46 and 36 and the ratio of these to each other.

	Age (year)	Pulp width	Dental diameter	Ratio width	Pulp vertical	Dental vertical	Ratio vertical
Pulp width	**-0.270****	1					
Dental width	**-0.245****	0.607**	1				
Ratio width	**-0.190***	0.901**	0.207**	1			
Pulp vertical	**-0.387****	0.056	0.189*	-0.040	1		
Dental vertical	-0.119	0.053	0.230**	-0.056	0.506**	1	
ratio vertical	**-0.421****	0.054	0.068	0.020	0.845**	0.005	1

***Level of significance P<.01, *Level of significance P <.05*

Table 5. Summary table of the linear regression analysis of the effect of width and vertical ratios on age change

Variables	R	R^2	Adjusted R^2	F	*P*
Ratio width	0.190[a]	**0.036**	0.030	6.445	.012
Ratio vertical	0.421[a]	**0.178**	0.173	37.353	<.001

Predictors: (fixed): ratio width (Pulp width /dental width) and ratio vertical (Pulp vertical/dental vertical).: Age, dependent variable df: degree of freedom

DISCUSSION

Teeth have recently been frequently resorted to tissues. Determination of age is possible through consideration of various changes that accompany ageing in the permanent and milk dentition stages, closure degree of root apex, and the changes in permanent teeth. In individuals who have not yet reached adulthood, age estimation is facilitated by the study of teething and calcification degrees.[15] However, in adults, this process becomes more challenging due to the completion of eruption and calcification. Teeth are a pivotal component in age assessment. While these methods yield more reliable results in individuals who are not adults, various problems arise in adult individuals. The concept of estimating age through the analysis of structural changes in adult teeth was initially proposed by Gustafson, who utilised a set of six parameters.[16] Gustafson's study demonstrated that, while root transparency remains the most widely accepted parameter, the accumulation of secondary dentin could be used as a second alternative for estimating age. Research has been conducted that demonstrates an increase in secondary dentin accumulation with advancing age, which can be detected using various radiological techniques.[7,17,18] The objective of this study was to investigate the

relationship between age and the narrowing induced by secondary dentin accumulation in the pulp room using sectional measurements on CBCT. Dental radiography is the preferred modality in most studies due to its practicality and the fact that it does not cause damage to the dental structure. Kvaal et al.[7] have conducted a series of measurements using a stereo microscope on six distinct sections of teeth obtained from Norwegians using periapical films, and have developed a regression formula. It has been highlighted that the methodology devised is applicable to a range of ethnicities and open to further development. Conversely, Drusini et al.[17] employed premolar and molar teeth, in conjunction with radiography, in their study of an Italian population, thereby identifying standard errors in dental age estimation of 8.89 and 9.46 years, respectively. Cameriere et al.[18] have furthermore studied maxilla-canine teeth, again on an Italian society, on panoramic radiography. Their study investigated the relationship between the narrowing of the pulp chamber, resulting from secondary dentine accumulation, and found that the standard error between the actual age and the estimated age was less than four years.

A significant number of researchers have attempted to replicate the method developed by Kvaal et al. in a variety of societies, employing different techniques and teeth. Willems et al.,[19] have studied the original method on Belgian individuals, Bosmans et al.,[20] on panoramic radiography, and Paewinsky et al.,[21] on digital panoramic radiography, and all have found results similar to those of Kvaal et al. Contrary to these findings, Landa et al.[22] have tried this method with panoramic radiography and pointed out that the estimated ages they have obtained have been much different from the real ones, and hence, should not be used in estimating age. Meinl et al.[23] have also reported that this method is not applicable.

Secondary dentin accumulates equally in every direction of the pulp volume.[24] Therefore, two-dimensional graphs do not demonstrate equal narrowing of the pulp in every direction. In recent years, with the development of technology, three-dimensional devices such as micro-CT and CBCT have been produced and began to be used in many fields of dentistry. Aboshi et al. sought to estimate age by means of micro-CT and by proportioning pulp volume to the whole tooth. Mandibular first and second premolar teeth have been selected for this purpose. For the first and premolar, R2 has been calculated as 0.635 and 0.703, respectively. The authors have reported that the ratio of pulp volume to total tooth volume varies depending on age and that this variation provides a medium-to-high level of accuracy in age estimation.[25] Someda et al.[11] have conducted a study of 155 mandibular central incisor teeth using micro-CT. The crown of the tooth has been analysed, and the pulp volume has been proportioned to the entire tooth volume, with the exception of tooth enamel. The results obtained have shown that R2=0.67 and R2=0.76 have been found in females and males, respectively. The study concluded with the demonstration that medium-high level of accuracy in age estimation has been obtained.[11] In his 2017 study, Bayraktar reported the measurement of the proportion of the pulp room volume of maxillary central incisor and canine teeth to dental hard tissue volume using CBCT, with the results obtained from this study being meaningful for central teeth. It is important to note that volume measurements alone may be subject to variation due to environmental and genetic factors. Consequently, they cannot be used as a standalone method for age estimation. Nevertheless, he has emphasised that the volume ratio method has yielded a high degree of accuracy and that CBCT is a swift and reliable tool for age estimation.[26] In their 2020 study, Molina et al.[27] calculated the pulp/dental volume ratio of maxillary incisors in Spain and found the revelation coefficient to be R2=0.366. Asif et al.[28] studied the relationship between the pulp/dental volume ratio for maxillary incisors and right and left canines with age in 2019 in Malaysia. The result obtained for canine teeth has been found to be statistically insignificant. However, the correlation between the ratio calculated for the right maxillary incisor and age has been determined to be statistically significant, with a revelation coefficient of R2=0.70, thereby indicating a proven meaningful relationship. Sue et al.[29], in Japan, have utilised CBCT to investigate the correlation between the narrowing of the pulp chambers of maxillary and mandibular first molar teeth, resulting from secondary dentine formation, and age. While the revelation coefficient found for maxillary molar teeth is R2=0.586, it is R2=0.609 for mandibular molar teeth. Jagannathan et al.[30] have sought to estimate age with CBCT by measuring the volume of mandibular canine teeth. However, upon application of the formula developed for the Belgian population to the Indian population, no significant results were obtained. Consequently, the suggestion has been put forward that a formula peculiar to every society be developed. In another study, the formula obtained by Cameriere et al.[31] through the proportioning of pulp area to the entirety of the tooth on periapical films was applied to the Indian society. However, this resulted in a low correlation. In the same study, the formula produced for the Italian society was applied to the Indian society, and a comparison was made between the two societies.[32] Analogous outcomes were achieved. In order to estimate age with precision and to minimise errors, it appears that the development of regression formulas specific to every society is necessary.

In this study, the pulpal chambers have been found to shrink in response to the accumulation of secondary dentin. However, the revelation coefficients, as determined by the measurements obtained from CBCT sections (R2=0.036 for horizontal measurements and R2=0.178 for CBCT vertical measurements), have been found to be low. This observation indicates that CBCT is not a reliable method for age estimation. The study's limitations are evident in the analysis of mandibular first molar teeth, which exhibit rapid decay due to their early eruption. The presence of a healthy first molar tooth is an uncommon occurrence. As dental loss increases with age, it has not been possible to include an equal number of teeth from each age group in the study. The measurements were obtained using CBCT from a single slice. It is acknowledged that volume measurement will provide more reliable results for age determination. The gold standard is represented by micro-CT in 3D. However, its use is limited by its long scanning time, high cost, and high radiation content.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Atatürk University (Date: November 6, 2020, No: 2020/33).

Informed Consent: Due to the retrospective design of the study, informed consent was not taken.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept- F.Ç.; Design- F.Ç.; Supervision- F.Ç.; Materials- F.N.Y.İ.; Data collection or processing- F.N.Y.İ.; Literature search- F.N.Y.İ.; Writing- F.N.Y.İ.; Critical Review- F.Ç.

Conflict of Interest: One of the authors, Fatma Çağlayan, serves as an Associate Editor of the journal. However, a Guest Editor was assigned to handle this manuscript, and the Associate Editor's identity was not disclosed to the Guest Editor or the reviewers. The evaluation process was conducted entirely independently and in accordance with the journal's ethical policies.

Financial Disclosure: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.
Use of Artificial Intelligence: No artificial intelligence tools were used in this study.

Etik Komite Onayı: Bu çalışma için etik komite onayı Atatürk Üniversitesi'nden (Tarih: 06.11.2020, No: 2020/33) alınmıştır.
Hasta Onamı: Çalışmanın retrospektif tasarımından dolayı hasta onamı alınamamıştır.
Hakem Değerlendirmesi: Dış bağımsız.
Yazar Katkıları: Fikir- F.Ç.; Tasarım- F.Ç.; Denetim- F.Ç.; Malzemeler- F.N.Y.İ.; Veri toplama veya işleme- F.N.Y.İ.; Literatür taraması- F.N.Y.İ.; Yazım- F.N.Y.İ.; Eleştirel inceleme- F.Ç.
Çıkar Çatışması: Yazarlardan Fatma Çağlayan derginin yardımcı editörüdür. Ancak yazı için konuk editör atanmış ve yardımcı editörün bilgisi konuk editör ve hakemlerle paylaşılmamıştır. Yazının değerlendirmesi tamamen bağımsız şekilde yürütülmüştür.
Finansal Destek: Bu araştırma, kamu, ticari veya kar amacı gütmeyen sektörlerdeki fon kuruluşlarından herhangi bir özel hibe almamıştır.
Yapay Zeka Kullanımı: Bu çalışmada herhangi bir yapay zeka aracı kullanılmamıştır.

REFERENCES

1. Koçak A, Aktaş EÖ. *Diş Hekimleri ve Diş Hekimliği Öğrencileri İçin Adli Tıp*. Okullar Yayınevi; 2011:1-90.
2. Afşin H. *Adli Diş Hekimliği*. Adli Tıp Kurumu Yayınları; 2004.
3. Harorli A. *Adli Diş Hekimliği*. Atatürk Üniversitesi Yayınları; 2006:12-68.
4. Akay G, Güngör K. Dental kayıtlar ve kimliklendirmede önemi. In: *Adli Diş Hekimliğinde Radyolojik Yaklaşımlar*. 1st ed. Türkiye Klinikleri; 2020.
5. Haavikko K. Tooth formation age estimated on a few selected teeth. A simple method for clinical use. *Proc Finn Dent Soc*. 1974;70(1):15-19.
6. Maber M, Liversidge H, Hector M. Accuracy of age estimation of radiographic methods using developing teeth. *Forensic Sci Int*. 2006;159:S68-S73.
7. Kvaal SI, Kolltveit KM, Thomsen IO, Solheim T. Age estimation of adults from dental radiographs. *Forensic Sci Int*. 1995;74(3):175-185.
8. Kolltveit KM, Solheim T, Kvaal SI. Methods of measuring morphological parameters in dental radiographs: comparison between image analysis and manual measurements. *Forensic Sci Int*. 1998;94(1-2):87-95.
9. Ge ZP, Yang P, Li G, et al. Age estimation based on pulp chamber volume of first molars from cone-beam computed tomography images. *Forensic Sci Int*. 2015;253:133.e1-133.e7.
10. Sakuma A, Saitoh H, Suzuki Y, et al. Age estimation based on pulp cavity to tooth volume ratio using postmortem computed tomography images. *J Forensic Sci*. 2013;58(6):1531-1535.
11. Someda H, Saka H, Matsunaga S, et al. Age estimation based on three-dimensional measurement of mandibular central incisors in Japanese. *Forensic Sci Int*. 2009;185(1-3):110.e1-110.e4.
12. Yang F, Jacobs R, Willems G. Dental age estimation through volume matching of teeth imaged by cone-beam CT. *Forensic Sci Int*. 2006;159:S78-S83.
13. Tardivo D, Sastre J, Ruquet M, et al. Three-dimensional modeling of the various volumes of canines to determine age and sex: a preliminary study. *J Forensic Sci*. 2011;56(3):766-770.
14. Demirel S. *Mandibular Kanin Dişlerden Cinsiyet Tayini*. Master's thesis. Ankara Üniversitesi Sağlık Bilimleri Enstitüsü; 2020.
15. Demirjian A, Goldstein H. New systems for dental maturity based on seven and four teeth. *Ann Hum Biol*. 1976;3(5):411-421.
16. Gustafson G. Age determinations on teeth. *J Am Dent Assoc*. 1950;41:45-54.
17. Drusini AG, Toso O, Ranzato C. The coronal pulp cavity index: a biomarker for age determination in human adults. *Am J Phys Anthropol*. 1997;103(3):353-363.
18. Cameriere R, Ferrante L, Cingolani M. Variations in pulp/tooth area ratio as an indicator of age: a preliminary study. *J Forensic Sci*. 2004;49(2):317-319.
19. Willems G, Moulin-Romsee C, Solheim T. Non-destructive dental-age calculation methods in adults: intra- and interobserver effects. *Forensic Sci Int*. 2002;126(3):221-226.
20. Bosmans N, Ann P, Aly M, et al. The application of Kvaal's dental age calculation technique on panoramic dental radiographs. *Forensic Sci Int*. 2005;153(2-3):208-212.
21. Paewinsky E, Pfeiffer H, Brinkmann B. Quantification of secondary dentine formation from orthopantomograms: a contribution to forensic age estimation methods in adults. *Int J Legal Med*. 2005;119(1):27-30.
22. Landa MI, Garamendi PM, Botella MC, et al. Application of the method of Kvaal et al to digital orthopantomograms. *Int J Legal Med*. 2009;123(2):123-128.
23. Meinl A, Tangl S, Huber CD, et al. On the applicability of secondary dentin formation to radiological age estimation in young adults. *J Forensic Sci*. 2007;52(2):438-441.
24. Morse DR. Age-related changes of the dental pulp complex and their relationship to systemic aging. *Oral Surg Oral Med Oral Pathol*. 1991;72(6):721-745.
25. Aboshi H, Takahashi T, Komuro T. Age estimation using microfocus X-ray computed tomography of lower premolars. *Forensic Sci Int*. 2010;200(1-3):35-40.
26. Bayraktar E. *Adli Yaş Tayininin Üç Boyutlu Cone Beam Bilgisayarlı Tomografide Diş Pulpa Kavitesi ile Değerlendirilmesi*. Medical specialty thesis. Uludağ Üniversitesi Tıp Fakültesi; 2017.
27. Molina A, Bravo M, Fonseca GM, et al. Dental age estimation based on pulp chamber/crown volume ratio measured on CBCT images in a Spanish population. *Int J Legal Med*. 2021;135(1):359-364.
28. Asif MK, Nambiar P, Mani SA, et al. Dental age estimation in Malaysian adults based on volumetric analysis of pulp/tooth ratio using CBCT data. *Leg Med (Tokyo)*. 2019;36:50-58.
29. Sue M, Oda M, Sasaki Y, et al. Age-related changes in the pulp chamber of maxillary and mandibular molars on cone-beam computed tomography images. *Oral Radiol*. 2018;34(3):219-223.
30. Jagannathan N, Neelakantan P, Thiruvengadam C, et al. Age estimation in an Indian population using pulp/tooth volume ratio of mandibular canines obtained from cone beam computed tomography. *J Forensic Odontostomatol*. 2011;29(1):1-6.
31. Cameriere R, Cunha E, Sassaroli E, et al. Age estimation by pulp/tooth ratio in canines by periapical X-rays. *J Forensic Sci*. 2007;52(1):166-170.
32. Babshet M, Acharya AB, Naikmasur VG. Age estimation in Indians from pulp/tooth area ratio of mandibular canines. *Forensic Sci Int*. 2010;197(1-3):125.e1-125.e4.