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An investigation of the validity of the Bedek models and Cameriere-European formula used in dental age prediction in Turkish children

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Abstract

Background Dental age estimation is one of the most reliable methods for determining age, commonly used for forensic, criminal, and anthropological purposes. The purpose of this study was to assess and compare the precision of the Bedek models and the Cameriere-European Formula (CF) in determinating dental age in a sample of Turkish individuals.

Methods Retrospective panoramic radiographs of 1018 subjects (497 boys and 521 girls) aged 5–14 years were evaluated using the Bedek models and the CF. The differences between calculated dental age (DA) and chronological age (CA) for each sex and age group were analyzed using the paired sample t-test and the Wilcoxon signed-rank test. The accuracy of the methods used to estimate dental age was determined by calculating the mean absolute error (MAE) based on the proximity of the dental age to the chronological age.

Results The CF method overestimated CA by 0.1 year in the entire sample. Conversely, the Bedek models tended to overestimate CA, with the three-, four-, and seven-tooth models exhibiting the most significant difference. There was a statistically significant difference between boys and girls in the DA-CA calculation using the CF method in the entire sample. Among the Bedek models, the three- and four-tooth models had the lowest MAE in the entire sample, while the single-tooth model had the highest MAE.

Conclusion The CF method showed higher accuracy in predicting the age of children living in eastern Turkey compared to the Bedek Models.

Keywords Bedek models, Cameriere-European formula, Chronological age, Dental age, Forensic, Turkish children

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Introduction

Parents of adolescents and children in conflict or war zones may abandon them, leading to their forced relocation to temporary living quarters or camps. Some of them may not know their date of birth or lack documentation of their identity [1]. In particular, illegal migrants or asylum-seekers may have altered documents [2]. Age estimation in children and adolescents is necessary for identification after natural disasters and accidents, or to determine whether a person is underage for legal reasons [3–5]. Age estimation is an important issue that is frequently required in children.

Since tooth development is less impacted by environmental factors and is not influenced by issues like malnutrition or early loss of baby teeth, dental age estimation techniques are commonly utilized. There are various methods used for dental age estimation, with many not relying on radiography [8]. These include aspartic acid racemization, cementum apposition, measurement of radioactive carbon-14 (14 C), attrition, telomere shortening, and root transparency [9–14]. The regular use of radiologic techniques has made it easier to study many methods for estimating age in both children and adults. Dental age estimation (DA) and skeletal age estimation evaluations using radiologic techniques are appropriate methods for assessing individual biological maturation [14]. The reliability of dental radiographs in age estimation has been demonstrated by many studies [15, 16]. In dental age estimation, radiographs are used to examine the developmental stages and eruption times of both temporary and constant teeth in children [7]. Various techniques are used to determinate the age of teeth through radiology. Radiographic methods for age determination can be categorized into three main groups: atlas, scoring system, and measurement-based formula [17–19]. The Demirjian method is a well-known dental age determination technique that assesses the third molar tooth, excluding the seven permanent teeth in the lower left jaw. This method utilizes panoramic radiography and evaluates the mineralization stage of the teeth, categorizing them into eight stages (A-H). Each tooth's developmental stage is scored based on a statistical model. The Nolla method, focuses on estimating the age of permanent teeth in the upper jaw by examining panoramic radiographs of the lower jaw (excluding third molars). The mineralization and development of each tooth are scored on a scale of 0–10 [20].

Although most of these methods provide accurate age estimation in various populations, they are not effective in estimating dental age in individuals with missing teeth. To address this limitation, Bedek et al. created a method for estimating tooth age using models that incorporate one to seven mandibular teeth [19].

Cameriere et al. also contributed to dental age estimation methods by developing a different formula. They claimed that they could determine the dental age from children by measuring the size of apical apertures and the lengths of teeth. Based on this, they developed the Cameriere's European formula (CF), which they recommended for use in European children [6].

In the literature, dental age determinations of children living in northwestern Turkey were obtained using the Bedek models and CF. These estimates were then compared with those obtained using different dental age estimation methods [21, 22]. Due to the impact of nutritional, socioeconomic, sociocultural, and environmental factors on biological development, it is crucial to assess individuals from various geographical regions. This study was conducted to obtain estimates of DA in children living in eastern Turkey. At the same time, although different methods have been used in the literature to estimate DA in children living in eastern Turkey [23], DA estimation has not been obtained with these two methods and there exists no study in the literature comparing these two methods.

The aim of our study was to evaluate and compare the effectiveness of Bedek models and CF in predicting dental age of children living in eastern Turkey. In this study, the null hypothesis tested was whether Bedek models and CF can predict DA with equal confidence.

Materials and methods

Ethical approval

This study was authorized by the Non-Interventional Clinical Research Ethics Committee of Inonu University in Malatya, Turkey (#2022/3617) and conducted in compliance with the principles outlined in the Declaration of Helsinki.

Sample size estimation

This study "WSSPAS Web-Based Sample Size & Power Analysis Software" was used to calculate sample size [24]. To reach a confidence level of 90% and an alpha value of 0.05, a minimum of 977 subjects needed to be recruited [21].

Study materials

This retrospective research examined panoramic X-rays of ills who were treated at the Faculty of Dentistry at Inonu University in Malatya, Turkey, from December 2019 to December 2021.

All digital panoramic X-ray images were taken using the same device, ensuring consistent and high-quality imagesThe digital images utilized in the study were captured with a PlanmecaProline XC device (2009; Helsinki, Finland). The panoramic radiographic images were captured with the exposure parameters set at 60 kv, 3 Ma, and 16 s.

For the reliability of the study, panoramic radiographs with grade 1 quality were evaluated according to the United Kingdom National Radiological Protection Board criteria [17].

The study included children between the ages of 5 and 13.9 who were in good health, had documented ages, had all teeth except for wisdom teeth on the lower left side, and had not experienced any dental injuries or undergone endodontic/orthodontic treatments [22, 23].

Additionally, individuals who did not have any pathological lesions such as tumors or cysts, did not have severe or deep cavities, and had high-quality radiographs were included in the study. In contrast, children with systemic diseases or syndromes, a history of dental issues or treatments, pathological lesions in the lower jaw, missing, excessive or severe cavities, and poor-quality radiographs were excluded from the study [22, 23].

All ills and their parents participating in the study were informed verbally and in writing that their recorded radiographic data would be used for study purposes and that the confidentiality of the patient's identity and information would be protected. All parents of ills provided informed consent, as evidenced by their signatures on the research protocol consent form.

Observers' characteristics

Prior to the radiographic examination, two pediatric dentists (GD and ZŞG), each with at least five years of experience in evaluating measurements in panoramic radiography, trained and calibrated the researchers. The evaluations were then carried out in a double-blind manner by two research assistants (EÖ and TA) from the Department of Pediatric Dentistry. In order to prevent bias from examiners during data addition, the scores for CA were initially listed on one data collection page, and the scores for DA were later calculated on a different page.

Table 1 The intercept values and the combination of the left mandibular teeth of the Bedek models for both sexes

Sex	Bedek models	Intercept value	Combination of mandibular teeth*
Boy	Seven-teeth model	4.396	31 32 33 34 35 36 37
	Six-teeth model	4.544	31 33 34 35 36 37
	Five-teeth model	4.664	31 33 34 36 37
	Four-teeth model	5.451	31 33 34 37
	Three-teeth model	6.069	33 34 37
	Two-teeth model	5.370	34 37
	One-tooth model	5.828	34
Girl	Seven-teeth model	5.095	31 32 33 34 35 36 37
	Six-teeth model	5.077	31 33 34 35 36 37
	Five-teeth model	5.079	31 33 34 36 37
	Four-teeth model	5.112	31 33 34 37
	Three-teeth model	5.350	33 34 37
	Two-teeth model	5.350	34 37
	One-tooth model	5.771	34

*FDI notation system

Chronological age calculation and dental age estimation

The age of the child was calculated by converting the difference between the date of birth and the date of panoramic radiography to decimal age. Seven different models were evaluated in the DA estimations of Bedek and CF. CF tooth age was calculated by measuring the root development status and apical clearance of 7 permanent teeth in the left-sided mandible.

The dental age of an individual is measured by placing the measurements and other variables into an existing formula [14]. Tooth age was determined by measuring the root development and apical aperture of seven permanent teeth in the left mandible according to the linear regression model CF. Radiographic images were measured using the Planmeca Romexis Viewer 3.5.1.R program. In this study, the formula used in a previous study was used to estimate tooth age from CF [22].

The formula includes a sex-dependent variable with $g=0$ for girls and $g=1$ for boys. N0 represents the number of teeth with closed apices, while teeth with incompletely developed roots contain the distance between the inner walls of their open apices as Ai. For single-rooted teeth Ai is measured once, while for double-rooted teeth Ai is the sum of the distances between the two roots. The length of the tooth is used to divide each Ai value to obtain Xi. "S" represents the sum of all Xi values. As a result, the tooth age is also obtained by accurately placing all recorded measurements into the CF formula [25].

$$\mathrm{Age} = 8.387 + 0.282.\mathrm{g} - 1.692.\mathrm{X5} + 0.835.\mathrm{N0} \\ - 0.116.\mathrm{S} - 0.139.\mathrm{S.N0}$$

Bedek et al. determined which teeth to use to estimate tooth age for different genders in tooth models ranging from 1 to 7 and calculated tooth age for each model separately. This calculation involves summing the coefficients assigned to the sex- specific tooth developmental stages in the model and determining the intercept value (developmental stages are labeled from A to H according to the Demirjian method). Table 1 shows the intercept values and combinations of the left mandibular teeth of the Bedek models for both sexes separately.

The assessment of the inter- and intra-investigators agreements

Intraclass correlation coefficients (ICCs) were computed for dental age estimation using the dental maturity scale of CF and all Bedek models. To determine the ICC for inter-rater agreement consistency, two specialists (EÖ and TA) coded a subset of 60 randomly selected radiographs. To eliminate researcher bias, all radiographs were independently reviewed by two experienced dentists (GD and ZŞG) after a 2-week interval. Intra-rater agreement reproducibility was evaluated by re-examining the same 60 radiographs four weeks after the initial assessment by the same two investigators (EÖ and TA) using all methods.

Statistical analysis

IBM SPSS software (version 26.0 for Windows, IBM Corp., Armonk, NY, USA) was used for data analysis. Analyses were performed for each gender and age group separately and collectively. Normality was tested using the Kolmogorov-Smirnov test and Wilcoxon signed-rank test was used because the data were not normally distributed. During the analyses and when the p-value was less than 0.0015, it was considered statistically significant and 95% confidence interval was used in the study. The difference between DA and CA calculated for all methods for each sex and age group showed overestimation or underestimation, indicating the presence of bias. Mean absolute error (MAE) was calculated to assess the unbiased prediction accuracy. The accuracy of these prediction methods was evaluated using various metrics such as the closeness of DA to CA and MAE [26]. A lower MAE indicates a more accurate prediction method. Therefore, this study evaluates the accuracy of DA estimation methods by comparing DA and CA. This involved calculating accuracy percentages for both absolute difference values and MAE [27].

When applying the methods, the independent sample t-test was used to compare mean DA and CA values between genders, while the Wilcoxon signed-rank test was used to compare DA and CA values. The intraclass correlation coefficient (ICC) test was used to assess intra- and inter- auditor agreement. ICC values are explained as follows: Below 0.50 is considered poor, between 0.50 and 0.75 is considered fair, between 0.75 and 0.90 is considered good and above 0.90 is considered excellent.

Results

Intra and interrater reliability measurement results

The intra-observer ICC values for the Bedek models with seven, six, five, four, three, two, and one tooth were 0.97, 0.96, 0.96, 0.95, 0.97, 0.93, 0.94, and 0.92, respectively. The inter-observer ICC values for the same models were 0.87, 0.86, 0.87, 0.89, 0.87, 0.89, 0.85, and 0.84, respectively. There was no statistically significant difference between the two groups, indicating strong correlation and reliability in the measurements.

A total of 1140 digital panoramic radiographs of Turkish children, aged between 5 and 13.9 years and living in eastern Turkey, were screened using the inclusion criteria. The study excluded the radiographs of 16 children with systemic disease and/or syndrome, 11 children with pathological lesions in the mandible, 17 children with congenital missing teeth on the left side of the lower jaw, 38 children with tooth loss for any reason, 31 children with dental trauma and orthodontic and/or endodontic history, and 9 children with radiographs that were not of grade 1 quality. As a result, 1018 panoramic radiographs were included in the study for dental age estimation (Table 2).

In the entire sample, the chronological forecast overestimated age by 0.1 years, whereas all models of Bedek showed different levels of age underestimation or overestimation.

The MAE value ranged from 0.6 to 1.2 years in Table 3. For both boys and girls in the total sample, the MAE was 0.6 years for CF. The smallest MAE for all Bedek models was 0.6 years, specifically in the two-, three-, and four-tooth models for girls, and in the three- and four-tooth models for the total sample. The largest MAE was found in the one-tooth model for the total sample, which was 1 year.

In boys, girls, and the overall sample, the mean difference between the DA and CA was significant in the CF with values of 0.2 years, 0.3 years, and 0.1 years, respectively ($p<0.001$) (Table 3).

Table 2 The sex and age distribution of the sample

	Boy		Girl		Total	
	n	%	*n*	%	*n*	%
5-5.9	33	6.6	36	6.9	69	6.8
6-6.9	68	13.7	54	10.4	122	12.0
7-7.9	56	11.3	63	12.1	119	11.7
8-8.9	68	13.7	65	12.5	133	13.1
9-9.9	59	11.9	61	11.7	120	11.8
10-10.9	64	12.9	58	11.1	122	12.0
11-11.9	45	9.1	66	12.7	111	10.9
12-12.9	54	10.9	59	11.3	113	11.1
13-13.9	50	10.1	59	11.3	109	10.7
Total	497	100	521	100	1018	100

Table 3 Comparison of Cameriere method and Bedek models dental age and chronological age in total sample

Sex	*n*	CA Mean (SD)	Method	DA Mean (SD)	DA-CA Mean (SD)	MAE (SD)	*p* value*
Boy	497	9.5 (2.4)	Cameriere	9.3 (2.4)	-0.2 (0.8)[**a**]	0.6 (0.5)	**< 0.001**
			Seven-teeth model	9.5 (2.7)	0 (0.9)[a]	0.7 (0.6)	0.785
			Six-teeth model	9.5 (2.7)	0 (0.9)	0.7 (0.6)	0.675
			Five-teeth model	9.5 (2.7)	0 (0.9)	0.7 (0.5)	0.629
			Four-teeth model	9.5 (2.7)	0 (0.8)[a]	0.7 (0.5)	0.717
			Three-teeth model	9.5 (2.7)	0 (0.9)	0.7 (0.5)	0.641
			Two-teeth model	9.3 (2.6)	-0.2 (0.9)[**a**]	0.7 (0.5)	**< 0.001**
			One-tooth model	8.5 (2.2)	-1.0 (1.0)[**a**]	1.2 (0.8)	**< 0.001**
Girl	521	9.7 (2.5)	Cameriere	10 (2.5)	0.3 (0.7)[**b**]	0.6 (0.5)	**< 0.001**
			Seven-teeth model	9.8 (2.6)	0.1 (0.8)[b]	0.7 (0.5)	**0.016**
			Six-teeth model	9.6 (2.7)	-0.1 (0.9)	0.7 (0.5)	0.182
			Five-teeth model	9.7 (2.7)	-0.1 (0.9)	0.7 (0.5)	0.219
			Four-teeth model	9.9 (2.4)	0.1 (0.8)[b]	0.6 (0.5)	**< 0.001**
			Three-teeth model	9.8 (2.5)	0.04 (0.8)	0.6 (0.5)	0.418
			Two-teeth model	9.7 (2.5)	0.002(0.8)[**b**]	0.6 (0.5)	0.715
			One-tooth model	9.4 (2.3)	-0.3 (0.9)[**b**]	0.8 (0.6)	**< 0.001**
Total	1018	9.6 (2.5)	Cameriere	9.7 (2.5)	0.1 (0.8)	0.6 (0.5)	**< 0.001**
			Seven-teeth model	9.6 (2.6)	0.04 (0.9)	0.7 (0.5)	0.142
			Six-teeth model	9.6 (2.7)	-0.1 (0.9)	0.7 (0.5)	0.214
			Five-teeth model	9.6 (2.7)	-0.04 (0.9)	0.7 (0.5)	0.221
			Four-teeth model	9.7 (2.5)	0.1 (0.8)	0.6 (0.5)	**0.002**
			Three-teeth model	9.6 (2.6)	0.02 (0.8)	0.6 (0.5)	0.817
			Two-teeth model	9.5 (2.5)	-0.1 (0.9)	0.7 (0.5)	**< 0.001**
			One-tooth model	9.0 (2.3)	-0.7 (1.1)	1 (0.7)	**< 0.001**

*Wilcoxon. All values marked in bold are statistically significant ($p < 0.05$)

[*a, b*] Independent samples t test. Different letters indicate statistically significant differences

[*a, b*] <0.05, [***a, b***](Bold) < 0.01

DA dental age, *CA* chronological age, *SD* standard deviation, *MAE* mean absolute error, *Std* standard

There was a statistically significant difference between the sexes in terms of the mean of DA-CA in the seven-, four-, two-, and one-tooth models and the CF (Table 3).

The average difference between dental age (DA) and chronological age (CA) was statistically significant in the two-tooth (0.2 years) and one-tooth (1 year) models for boys, and in the four-tooth (0.1 years) and one-tooth (0.3 years) models for girls ($p < 0.001$).

In the entire sample, the smallest difference was found with the seven- and five-tooth models (0.04 ± 0.9 years and −0.04 ± 0.9 years, respectively), while the largest difference was seen in the one-tooth model (-0.7 ± 1.1 years). Among boys, the smallest differences were seen in the seven-, six-, five-, four-, and three-tooth models (0 ± 0.9 years, 0 ± 0.9 years, 0 ± 0.9 years, 0 ± 0.8 years, and 0 ± 0.9 years, respectively). Conversely, the largest difference was observed in the one-tooth model (-1.0 ± 1.0 year).

The smallest difference was seen in girls in the two tooth model (0.002 ± 0.8 years), while the largest difference was seen in the monodentate model and CF. (-0.3 ± 0.9 years and 0.3 ± 0.7 years, respectively)

Among boys, the CF method resulted in an overestimation at ages five and six, and an underestimation between 7 and 13.9 years. In boys, the chronological age (CA) was overestimated at age 5, and underestimated between 6 and 8.9 years in all Bedek models. The Bedek models show variations in underestimation or overestimation at other ages boys.

Girls, on the other hand, had all ages overestimated with the CF method. For girls in all Bedek models, the CA was overestimated at age 5, but underestimated at age 13. The Bedek models also show variations in underestimation or overestimation at other ages for girls.

In the entire sample, the ages of 5, 6, 9, and 13 years were overestimated by CF, while the ages of 7, 8, 10, 11, and 12 years were underestimated. In all Bedek models for the total samples, the age of 5 was overestimated by CA, but the ages of 7 and 13 were underestimated (Table 4) Spearman's rank correlation coefficient was utilized in all data analysis methods to illustrate the connection between data analysis and data collection in both boys and girls and the overall sample. The findings showed in Table 5 that the linear correlations (0.907–0.964) were statistically significant for all techniques ($p < 0.001$).

Table 4 Comparison of dental age and chronological age in boys, girls, and total by age groups with Cameriere method and Bedek models

Age	Method	Boy					Girl					Total				
		CA Mean (SD)	DA Mean (SD)	DA-CA Mean (SD)	MAE (SD)	*p value	CA Mean (SD)	DA Mean (SD)	DA-CA Mean (SD)	MAE (SD)	*p value	CA Mean (SD)	DA	DA-CA Mean (SD)	MAE (SD)	*p value
5-5.9	Cameriere	5.5 (0.3)	6.1 (0.5)	0.6 (0.5)	0.7 (0.4)	< 0.001	5.5 (0.3)	6.4 (0.6)	0.9 (0.5)	0.9 (0.5)	< 0.001	5.5 (0.3)	6.3 (0.6)	0.8 (0.5)	0.8 (0.5)	< 0.001
	Seven-teeth model		5.7 (1.1)	0.2 (1.0)	0.9 (0.6)	0.201		6.1 (0.8)	0.6 (0.8)	0.8 (0.6)	< 0.001		5.9 (0.9)	0.4 (0.9)	0.8 (0.6)	< 0.001
	Six-teeth model		5.7 (1.0)	0.2 (1.0)	0.9 (0.5)	0.257		5.9 (0.5)	0.4 (0.7)	0.7 (0.4)	0.003		5.8 (0.8)	0.3 (0.9)	0.7 (0.5)	< 0.001
	Five-teeth model		5.6 (0.8)	0.1 (0.8)	0.7 (0.4)	0.782		5.9 (0.5)	0.4 (0.7)	0.7 (0.4)	0.002		5.8 (0.7)	0.3 (0.8)	0.7 (0.4)	< 0.001
	Four-teeth model		6.1 (0.4)	0.6 (0.5)	0.6 (0.4)	< 0.001		6.1 (0.5)	0.6 (0.4)	0.7 (0.4)	< 0.001		6.1 (0.5)	0.6 (0.5)	0.6 (0.4)	< 0.001
	Three-teeth model		6.1 (0.3)	0.6 (0.5)	0.7 (0.4)	< 0.001		6.0 (0.5)	0.5 (0.4)	0.5 (0.4)	< 0.001		6.1 (0.5)	0.6 (0.5)	0.6 (0.4)	< 0.001
	Two-teeth model		6.2 (0.3)	0.6 (0.4)	0.7 (0.3)	< 0.001		6.2 (0.6)	0.7 (0.5)	0.7 (0.4)	< 0.001		6.2 (0.5)	0.7 (0.4)	0.7 (0.4)	< 0.001
	One-tooth model		6.0 (0.3)	0.4 (0.4)	0.5 (0.3)	< 0.001		6.2 (0.7)	0.7 (0.6)	0.7 (0.6)	< 0.001		6.1 (0.6)	0.6 (0.5)	0.6 (0.5)	< 0.001
6-6.9	Cameriere	6.5 (0.3)	6.7 (0.5)	0.1 (0.5)	0.4 (0.3)	0.044	6.5 (0.3)	7.0 (0.4)	0.6 (0.4)	0.6 (0.3)	< 0.001	6.5 (0.3)	6.8 (0.5)	0.3 (0.5)	0.5 (0.3)	
	Seven-teeth model		6.2 (0.8)	-0.4 (0.9)	0.7 (0.6)	0.002		6.6 (0.8)	0.1 (0.9)	0.6 (0.6)	0.651		6.3 (0.9)	-0.2 (0.9)	0.7 (0.6)	< 0.001
	Six-teeth model		6.2 (0.8)	-0.3 (0.8)	0.7 (0.6)	0.006		5.7 (0.9)	-0.7 (0.8)	1 (0.5)	< 0.001		6.0 (0.9)	-0.5 (0.9)	0.8 (0.6)	0.961
	Five-teeth model		6.2 (0.8)	-0.4 (0.8)	0.7 (0.5)	0.002		5.8(0.8)	-0.7 (0.8)	1 (0.5)	< 0.001		6.0 (0.8)	-0.5 (0.8)	0.8 (0.5)	0.893
	Four-teeth model		6.3 (0.4)	-0.2 (0.4)	0.4 (0.3)	< 0.001		6.7 (0.7)	0.3 (0.6)	0.5 (0.4)	0.003		6.5 (0.6)	-0.01 (0.6)	0.4 (0.4)	< 0.001
	Three-teeth model		6.2 (0.3)	-0.4 (0.3)	0.4 (0.3)	< 0.001		6.7 (0.7)	0.2 (0.6)	0.5 (0.4)	0.080		6.3 (0.6)	-0.1 (0.5)	0.4 (0.3)	< 0.001
	Two-teeth model		6.3 (0.3)	-0.2 (0.4)	0.4 (0.3)	< 0.001		6.7 (0.6)	0.2 (0.6)	0.5 (0.4)	0.030		6.5 (0.5)	-0.1 (0.5)	0.4 (0.3)	< 0.001
	One-tooth model		6.2 (0.4)	-0.3 (0.4)	0.4 (0.3)	< 0.001		6.9 (0.7)	0.5 (0.6)	0.7 (0.3)	< 0.001		6.5 (0.6)	0.02 (0.6)	0.6 (0.3)	< 0.001
7-7.9	Cameriere	7.5 (0.3)	7.2 (0.5)	-0.3 (0.5)	0.5 (0.4)	< 0.001	7.5 (0.3)	7.7 (0.7)	0.2 (0.6)	0.5 (0.4)	0.003	7.5 (0.3)	7.5 (0.7)	-0.04 (0.6)	0.5 (0.4)	< 0.001
	Seven-teeth model		7.1 (0.7)	-0.4 (0.7)	0.6 (0.5)	< 0.001		7.5 (0.9)	-0.01 (0.8)	0.6 (0.4)	0.632		7.3 (0.8)	-0.2 (0.8)	0.6 (0.5)	< 0.001
	Six-teeth model		7.0 (0.7)	-0.5 (0.7)	0.7 (0.5)	< 0.001		7.3 (1.2)	-0.3 (1.2)	1 (0.7)	0.243		7.1 (1.0)	-0.4 (1.0)	0.8 (0.6)	0.137
	Five-teeth model		7.0 (0.7)	-0.4 (0.7)	0.7 (0.5)	< 0.001		7.3 (1.2)	-0.2 (1.1)	0.9 (0.6)	0.348		7.2 (1.0)	-0.3 (1.0)	0.8 (0.6)	0.048
	Four-teeth model		7.0 (0.7)	-0.5 (0.7)	0.7 (0.4)	< 0.001		7.9 (0.7)	0.4 (0.6)	0.6 (0.4)	< 0.001		7.5 (0.8)	-0.04 (0.7)	0.7 (0.4)	< 0.001
	Three-teeth model		7.0 (0.8)	-0.6 (0.8)	0.8 (0.5)	< 0.001		7.7 (0.7)	0.2 (0.7)	0.5 (0.5)	0.156		7.3 (0.9)	-0.2 (0.8)	0.6 (0.5)	< 0.001
	Two-teeth model		7.0 (0.6)	-0.6 (0.6)	0.7 (0.5)	< 0.001		7.5 (0.8)	-0.03 (0.7)	0.5 (0.5)	0.345		7.2 (0.8)	-0.3 (0.7)	0.6 (0.5)	0.343
	One-tooth model		7.0 (0.6)	-0.9 (0.6)	1 (0.4)	< 0.001		7.5 (0.8)	0.01 (0.7)	0.5 (0.5)	0.511		7.1 (0.9)	-0.4 (0.8)	0.8 (0.5)	0.100
8-8.9	Cameriere	8.5 (0.3)	8.2 (0.8)	-0.3 (0.7)	0.6 (0.5)	0.004	8.5 (0.3)	8.6 (0.7)	0.2 (0.7)	0.5 (0.4)	0.133	8.5 (0.3)	8.4 (0.8)	-0.1 (0.7)	0.6 (0.5)	< 0.001
	Seven-teeth model		8.3 (1.1)	-0.2 (1.1)	0.9 (0.6)	0.108		8.4 (0.8)	-0.04 (0.8)	0.6 (0.4)	0.741		8.4 (1.0)	-0.1 (0.9)	0.8 (0.5)	< 0.001
	Six-teeth model		8.4 (1.2)	-0.1 (1.1)	0.9 (0.6)	0.541		8.4 (0.9)	-0.1 (0.8)	0.7 (0.5)	0.503		8.4 (1.0)	-0.1 (1.0)	0.8 (0.6)	< 0.001
	Five-teeth model		8.4 (1.1)	-0.1 (1.1)	0.9 (0.6)	0.501		8.4 (0.9)	-0.04 (0.9)	0.7 (0.5)	0.899		8.4 (1.0)	-0.1 (1.0)	0.8 (0.6)	< 0.001
	Four-teeth model		8.4 (1.2)	-0.1 (1.2)	1 (0.6)	0.728		8.6 (0.8)	0.1 (0.8)	0.6 (0.5)	0.450		8.5 (1.1)	0.2 (1.0)	0.8 (0.6)	< 0.001
	Three-teeth model		8.4 (1.2)	-0.1 (1.2)	1 (0.6)	0.529		8.3 (0.9)	-0.2 (0.8)	0.7 (0.4)	0.068		8.4 (1.1)	-0.1 (1.0)	0.8 (0.5)	< 0.001
	Two-teeth model		8.1 (1.1)	-0.5 (1.1)	1 (0.6)	0.001		8.1 (1.0)	-0.3 (0.9)	0.8 (0.5)	0.006		8.1 (1.0)	-0.4 (1.0)	0.9 (0.6)	0.164
	One-tooth model		7.3 (1.0)	-1.3 (1.0)	1.3 (0.9)	< 0.001		8.1 (0.9)	-0.4 (0.8)	0.8 (0.4)	< 0.001		7.7 (1.0)	-0.8 (1.0)	1 (0.8)	0.001

Table 4 (continued)

Age	Method	Boy					Girl					Total				
		CA Mean (SD)	DA Mean (SD)	DA-CA Mean (SD)	MAE (SD)	*p value	CA Mean (SD)	DA Mean (SD)	DA-CA Mean (SD)	MAE (SD)	*p value	CA Mean (SD)	DA	DA-CA Mean (SD)	MAE (SD)	*p value
9-9.9	Cameriere	9.5 (0.3)	9.4 (0.7)	-0.1 (0.6)	0.5 (0.4)	0.556	9.6 (0.3)	10 (0.5)	0.4 (0.5)	0.6 (0.4)	< 0.001	9.5 (0.3)	9.7 (0.7)	0.1 (0.6)	0.5 (0.4)	< 0.001
	Seven-teeth model		9.8 (1.0)	0.3 (0.9)	0.8 (0.6)	0.006		9.7 (0.8)	0.1 (0.7)	0.6 (0.4)	0.092		9.8 (0.9)	0.2 (0.8)	0.7 (0.5)	< 0.001
	Six-teeth model		9.8 (0.9)	0.3 (0.8)	0.7 (0.5)	0.003		9.7 (0.7)	0.1 (0.7)	0.6 (0.4)	0.200		9.7 (0.8)	0.2 (0.8)	0.6 (0.5)	< 0.001
	Five-teeth model		9.8 (0.9)	0.4 (0.8)	0.7 (0.5)	0.002		9.7 (0.7)	0.1 (0.7)	0.5 (0.5)	0.229		9.7 (0.8)	0.2 (0.8)	0.6 (0.5)	< 0.001
	Four-teeth model		9.9 (0.8)	0.4 (0.8)	0.7 (0.5)	0.001		9.6 (0.7)	0.1 (0.7)	0.5 (0.4)	0.256		9.7 (0.8)	0.2 (0.7)	0.6 (0.5)	< 0.001
	Three-teeth model		9.7 (1.0)	0.3 (0.9)	0.8 (0.5)	0.012		9.6 (0.8)	0.02 (0.8)	0.6 (0.5)	0.544		9.7 (0.9)	0.1 (0.9)	0.7 (0.5)	< 0.001
	Two-teeth model		9.2 (1.3)	-0.3 (1.2)	1.2 (0.5)	0.050		9.6 (0.9)	0.01 (0.8)	0.7 (0.5)	0.475		9.4 (1.1)	-0.1 (1.0)	0.9 (0.6)	< 0.001
	One-tooth model		8.0 (0.9)	-1.5 (0.9)	1.6 (0.6)	< 0.001		9.0 (0.7)	-0.6 (0.7)	0.8 (0.5)	< 0.001		8.5 (1.0)	-1.0 (0.9)	1.2 (0.7)	< 0.001
10-10.9	Cameriere	10.5 (0.3)	10.1 (0.5)	-0.4 (0.5)	0.5 (0.4)	< 0.001	10.5 (0.3)	10.7 (0.8)	0.2 (0.7)	0.5 (0.5)	0.320	10.5 (0.3)	10.4 (0.7)	-0.1 (0.7)	0.5 (0.5)	< 0.001
	Seven-teeth model		10.7 (0.8)	0.2 (0.8)	0.6 (0.5)	0.011		10.6 (0.9)	0.1 (0.8)	0.6 (0.6)	0.929		10.6 (0.8)	0.2 (0.8)	0.6 (0.5)	< 0.001
	Six-teeth model		10.6 (0.6)	0.2 (0.6)	0.5 (0.4)	0.009		10.6 (0.9)	0.1 (0.8)	0.6 (0.5)	0.892		10.6 (0.7)	0.2 (0.7)	0.5 (0.5)	< 0.001
	Five-teeth model		10.7 (0.6)	0.3 (0.6)	0.5 (0.4)	< 0.001		10.6 (1.0)	0.1 (0.9)	0.7 (0.6)	0.543		10.7 (0.8)	0.2 (0.8)	0.6 (0.5)	< 0.001
	Four-teeth model		10.6 (0.6)	0.2 (0.6)	0.5 (0.4)	0.006		10.6 (1.0)	0.1 (0.9)	0.7 (0.6)	0.363		10.6 (0.8)	0.1 (0.8)	0.6 (0.5)	< 0.001
	Three-teeth model		10.7 (0.6)	0.2 (0.6)	0.5 (0.4)	0.011		10.6 (1.0)	0.1 (0.9)	0.7 (0.6)	0.388		10.6 (0.8)	0.1 (0.8)	0.6 (0.5)	< 0.001
	Two-teeth model		10.5 (0.8)	0.1 (0.8)	0.6 (0.6)	0.396		10.6 (1.0)	0.02 (0.9)	0.7 (0.6)	0.287		10.5 (0.9)	0.03 (0.9)	0.6 (0.6)	< 0.001
	One-tooth model		9.0 (1.2)	-1.4 (1.3)	1.7 (0.9)	< 0.001		9.9 (1.2)	-0.7 (1.1)	1.1 (0.7)	< 0.001		9.4 (1.3)	-1.1 (1.3)	1.4 (0.8)	< 0.001
11-11.9	Cameriere	11.5 (0.3)	11.0 (1.1)	-0.4 (1.0)	1 (0.6)	0.007	11.5 (0.3)	11.7 (1.0)	0.2 (1.0)	0.8 (0.6)	0.120	11.5 (0.3)	11.5 (1.1)	-0.04 (1.0)	0.8 (0.6)	< 0.001
	Seven-teeth model		11.8 (1.0)	0.3 (0.9)	0.7 (0.6)	0.281		11.7 (0.9)	0.2 (0.9)	0.8 (0.5)	0.226		11.7 (0.9)	0.2 (0.9)	0.7 (0.6)	< 0.001
	Six-teeth model		11.7 (1.0)	0.2 (0.9)	0.7 (0.6)	0.467		11.6 (0.9)	0.1 (0.9)	0.8 (0.5)	0.420		11.7 (0.9)	0.2 (0.9)	0.7 (0.5)	< 0.001
	Five-teeth model		11.6 (1.0)	0.2 (0.9)	0.7 (0.6)	0.608		11.7 (1.0)	0.2 (0.9)	0.8 (0.5)	0.163		11.7 (1.0)	0.2 (0.9)	0.8 (0.5)	< 0.001
	Four-teeth model		11.7 (0.9)	0.2 (0.9)	0.7 (0.6)	0.443		11.7 (1.0)	0.13 (0.9)	0.8 (0.5)	0.195		11.7 (1.0)	0.2 (0.9)	0.8 (0.5)	< 0.001
	Three-teeth model		11.7 (0.9)	0.2 (0.9)	0.7 (0.6)	0.443		11.6 (0.9)	0.1 (0.9)	0.8 (0.5)	0.316		11.7 (0.9)	0.2 (0.9)	0.7 (0.5)	< 0.001
	Two-teeth model		11.6 (0.9)	0.1 (0.9)	0.7 (0.6)	0.835		11.6 (0.9)	0.1 (0.9)	0.8 (0.4)	0.268		11.6 (0.9)	-0.7 (1.0)	0.7 (0.5)	< 0.001
	One-tooth model		10.5 (1.1)	-1.0 (0.9)	1.1 (0.9)	< 0.001		11 (1.1)	-0.5 (1.0)	0.9 (0.8)	0.001		10.8 (1.1)	-0.03 (1.0)	0.9 (0.8)	0.388
12-12.9	Cameriere	12.5 (0.3)	11.9 (1.2)	-0.6 (1.2)	1 (0.8)	0.002	12.5 (0.3)	12.8 (0.9)	0.3 (0.8)	0.7 (0.5)	0.020	12.5 (0.3)	12.4 (1.1)	-0.1 (1.0)	0.8 (0.7)	< 0.001
	Seven-teeth model		12.5 (1.1)	0.02 (1.0)	0.9 (0.4)	0.997		12.7 (0.8)	0.2 (0.8)	0.7 (0.5)	0.014		12.6 (0.9)	0.1 (0.9)	0.8 (0.4)	< 0.001
	Six-teeth model		12.4 (1.1)	-0.1 (1.0)	0.9 (0.5)	0.411		12.6 (0.8)	0.1 (0.8)	0.6 (0.4)	0.040		12.5 (0.9)	0.0 (0.9)	0.8 (0.5)	< 0.001
	Five-teeth model		12.5 (1.1)	-0.04 (1.0)	0.9 (0.4)	0.651		12.7 (0.7)	0.1 (0.7)	0.5 (0.5)	0.004		12.6 (0.9)	0.1 (0.9)	0.7 (0.5)	< 0.001
	Four-teeth model		12.4 (1.1)	-0.1 (1.0)	0.9 (0.4)	0.505		12.7 (0.7)	0.2 (0.7)	0.6 (0.5)	0.002		12.6 (0.9)	0.1 (0.9)	0.7 (0.5)	< 0.001
	Three-teeth model		12.4 (1.1)	-0.1 (1.0)	0.9 (0.4)	0.573		12.6 (0.6)	0.04 (0.6)	0.4 (0.4)	0.056		12.5 (0.9)	-0.01 (0.8)	0.7 (0.5)	< 0.001
	Two-teeth model		12.3 (1.1)	-0.2 (1.0)	0.8 (0.5)	0.120		12.6 (0.6)	0.02 (0.6)	0.5 (0.4)	0.098		12.4 (0.9)	-0.1 (0.8)	0.6 (0.5)	0.006
	One-tooth model		11.3 (1.0)	-1.2 (0.9)	1.4 (0.4)	< 0.001		12.1 (0.7)	-0.4 (0.7)	0.6 (0.6)	0.001		11.7 (0.9)	-0.8 (0.9)	1 (0.6)	0.001

Table 4 (continued)

Age	Method	Boy					Girl					Total				
		CA Mean (SD)	DA Mean (SD)	DA-CA Mean (SD)	MAE (SD)	*p value	CA Mean (SD)	DA Mean (SD)	DA-CA Mean (SD)	MAE (SD)	*p value	CA Mean (SD)	DA	DA-CA Mean (SD)	MAE (SD)	*p value
13-13.9	Cameriere	13.5 (0.3)	13.3 (0.9)	-0.2 (0.8)	0.6 (0.6)	0.208	13.5 (0.3)	13.7 (0.8)	0.3 (0.8)	0.7 (0.5)	0.004	13.5 (0.3)	13.5 (0.9)	0.03 (0.8)	0.6 (0.5)	< 0.001
	Seven-teeth model		13.5 (0.7)	0.02 (0.7)	0.5 (0.5)	0.553		13.3 (0.7)	-0.2 (0.7)	0.6 (0.5)	0.042		13.4 (0.7)	-0.1 (0.7)	0.5 (0.5)	< 0.001
	Six-teeth model		13.5 (0.7)	-0.008 (0.7)	0.5 (0.5)	0.685		13.3 (0.7)	-0.2 (0.7)	0.6 (0.5)	0.021		13.4 (0.7)	-0.1 (0.7)	0.5 (0.5)	< 0.001
	Five-teeth model		13.4 (0.7)	-0.1 (0.6)	0.5 (0.5)	0.657		13.2 (0.7)	-0.3 (0.7)	0.6 (0.5)	0.001		13.3 (0.7)	-0.2 (0.7)	0.5 (0.5)	< 0.001
	Four-teeth model		13.4 (0.7)	-0.1 (0.7)	0.5 (0.5)	0.537		13.2 (0.7)	-0.3 (0.7)	0.6 (0.4)	< 0.001		13.3 (0.7)	-0.2 (0.7)	0.6 (0.5)	< 0.001
	Three-teeth model		13.5 (0.7)	-0.002 (0.7)	0.5 (0.5)	0.969		13.1 (0.7)	-0.3 (0.7)	0.7 (0.4)	0.001		13.3 (0.7)	-0.2 (0.7)	0.6 (0.5)	0.001
	Two-teeth model		13.2 (0.7)	-0.3 (0.7)	0.5 (0.5)	0.001		13.1 (0.7)	-0.4 (0.7)	0.7 (0.4)	< 0.001		13.2 (0.7)	-0.3 (0.7)	0.6 (0.5)	0.006
	One-tooth model		11.8 (0.9)	-1.7 (0.9)	1.8 (0.7)	< 0.001		12.8 (0.9)	-0.7 (0.9)	1 (0.4)	< 0.001		12.3 (1.0)	-1.1 (1.0)	1.4 (0.7)	< 0.001

*Wilcoxon

DA dental age, *CA* chronological age, *SD* standard deviation, *MAE* mean absolute error, *Std* standard

Discussion

On February 6, 2023, two earthquakes, known as the Turkey-Syria Earthquakes, occurred with their epicenters in the Pazarcık and Ekinözü districts of According to official data, a minimum of 50,783 individuals in Turkey and 8,476 individuals in Syria perished, with over 122,000 individuals sustaining injuries due to the earthquakes. The earthquakes impacted cities along the Eastern Anatolian Fault line, including Hatay, Kahramanmaraş, Adıyaman, and Malatya [28]. Authorities have had difficulties in identifying and estimating the age of many adults and children who died as a result of these earthquakes. In the aftermath of the earthquake in Malatya province, the researchers involved in this study came to recognize the continued significance of identification and age estimation methodologies. They thus sought to highlight these techniques in the present study.

The main goal of studies on age estimation is to find the most accurate method for determining the age of individuals in specific societies and to ensure accuracy when needed This study aims to investigate the effectiveness of CF and Bedek models on a group of children aged 5-13.9 years in eastern Turkey. Çarıkçıoğlu and Sezer [21], in their study conducted in 2022, conducted a study on the effectiveness of the Willems and Bedek models for tooth age estimation in children living in northwestern Turkey.

As a result of the study, it was shown that all Bedek models as a whole gave results 0.1 to 0.2 years shorter than expected. Specifically, the one-tooth and two-, five- and six-tooth models by Bedek in this study underestimated age in the total sample, while the other models overestimated age. In a study conducted in South Indian children in 2020, it was shown that among the Bedek models, the seven-tooth model was the most reliable model for predicting age, and the combination of seven- and four-tooth models was the best predictor of age [29]. A study in children living in northwestern Turkey found that the best predictor of age among Bedek models was the four-tooth model in the whole sample [21]. The best predictor of age among Bedek models was the four-tooth model in the whole sample of this study. At the same time, it was found that the four-tooth model in boys and the two-tooth model in girls were the best predictors of age in the Bedek models.

MAE is a parameter routinely used to evaluate the success of the DA estimation method. A MAE value close to zero is generally desirable in studies [2, 21–23]. The reason is that MAE is used to objectively measure accuracy. In this study, MAE values for both methods in the whole sample ranged between zero and one (approximately 0.6-1 year).

The DA-CA difference and MAE values for both sexes in all Bedek models were higher in children from South India [30] compared to children from northwestern

Table 5 Correlation between dental age and chronological age in both sexes and total sample with Cameriere method and Bedek models according to Spearman correlation test

Method	Cameriere		Seven-teeth model		Six-teeth model		Five-teeth model		Four-teeth model		Three-teeth model		Two-teeth model		One-tooth model	
	r	**p*	*r*	**p*	*r*	**p*	*r*	**p*	*r*	**p*	*r*	**p*	*r*	**p*	*r*	**p*
Boys	0.956	< 0.001	0.949	< 0.001	0.949	< 0.001	0.954	< 0.001	0.954	< 0.001	0.950	< 0.001	0.940	< 0.001	0.920	< 0.001
Girls	0.964	< 0.001	0.953	< 0.001	0.952	< 0.001	0.950	< 0.001	0.958	< 0.001	0.956	< 0.001	0.952	< 0.001	0.931	< 0.001
Total	0.954	< 0.001	0.949	< 0.001	0.950	< 0.001	0.951	< 0.001	0.953	< 0.001	0.954	< 0.001	0.944	< 0.001	0.907	< 0.001

*Spearman's rank correlation coefficient

Turkey [21] and children from eastern Turkey presented in this study. This result shows that Bedek models predict age more accurately for children living in northwestern and eastern Turkey than for children from South India. In the whole sample of children living in the northwestern [21] and eastern parts of Turkey, the MAE values of the Bedek models were similar only in the three-tooth model (0.6 years), whereas in all other samples, the MAE values of the Bedek models were found to be higher than those of children living in the northwestern part of Turkey in this study. It was concluded that the Bedek models were more suitable for predicting the age of children in northwestern Turkey when evaluated on a regional basis.

When evaluating a study by Sezer and Çarıkçıoğlu [22] on children in northwestern Turkey, they found that the MAE value in the CF method was 0.44±0.34 for boys, 0.48±0.36 for girls, and 0.46±0.35 for the total sample of the study. In this study, the MAE value for the CF method was 0.6±0.5 for boys, girls, and the total sample. The CF method was more successful in estimating age in children in northwestern Turkey compared to the findings of this study.

Gannepalli et al. [30] compared the CF method and the age estimation method with the South Indian formula, which was developed by the researchers themselves, in children aged 10–15 years from South India, and reported that the DA-CA was −1.5±1.19 for boys and 1.54±1.31 for girls in the CF method, while it was −0.2±0.8 for boys and 0.3±0.7 for girls according to their own formula. In this study, the CF was more successful in children living in eastern Turkey than in children from South India.

Duruk et al. [23] compared the Nolla and Demirjian methods of tooth age estimation in 1587 children in a study conducted in eastern Turkey.(the same region as the current study). In this study, the difference in dental age minus chronological age (DA-CA) was 0.3 years for girls and −0.2 years for boys in the CF method. In the Bedek method, the smallest DA-CA was observed in the two-tooth model for girls (0.002 years) and in the four-tooth model for boys (0 years). When these two similar studies in eastern Turkey were compared, it was observed that except for the Demirjian method, the remaining 3 methods were more suitable for children in this region.

A study conducted on children in South India showed that in the Bedek models, the boys had the smallest mean absolute error (MAE) in the six-tooth model (0.75 years), and the largest MAE in the one-tooth model (1.05 years). Girls, on the other hand, had the smallest MAE in the seven-tooth model (0.88 years) and the largest MAE in the two-tooth model (1.01 years). The study also found that boys had the largest MAE in the two-tooth model (0.7 years) and girls in the one-tooth model (0.7 years). The smallest MAE for boys showed a wide variation, while for girls it was found in the four-tooth model (0.5 years). In this study, the highest Mean Absolute Error (MAE) was found in the one-tooth model for both boys (0.8–1.2 years) and girls, whereas the MAE across all tooth models ranged from 0.6 to 1.2 years for boys and 0.6 to 0.8 years for girls. The differences in the findings of these studies may be attributed to the different sample sizes, ethnic groups of the participants and regional differences (weather, nutrition and socioeconomic status.

A prior study on tooth age conducted in Malatya province underscored the disparities between the region situated at sea level and one situated at an altitude of 970 m [23]. The difference in the results between the study conducted by Çarıkçıoğlu et al. [21] in Çanakkale province (altitude: 0) in northwestern Turkey and our study in Malatya province (altitude: 970) in eastern Turkey is an expected result.

The strongest feature of this study is that it is the first study to compare the CF and Bedek methods. Therefore, the results obtained from this study should be interpreted carefully. Such studies are valuable as they offer insight into the best method for a certain population, age group, and crucial time. However, the study's limitation is that it only includes a specific number of individuals in one location. It's also crucial to consider the potential impact of various external factors like nutrition, economy, culture, and environment on children's development.

Conclusion

As a result of our study, CF and all Bedek models were found to be appropriate for children living in eastern Turkey. CF was found to be much more successful in age estimation compared to Bedek models. Among the Bedek models, the three-tooth model was the closest predictor of tooth age in the whole sample. In Bedek models, the four-tooth model was the most appropriate model for boys and the two-tooth model was the most appropriate model for girls. The best predicted age range in the CF method was 13-13.9 years. More dental age estimation studies are needed in different populations and geographical regions in Turkey. The hypothesis that the CF and Bedek methods would predict dental age with similar accuracy in children living in eastern Turkey could not be confirmed.

Abbreviations

CA Chronological age
CF Cameriere's European formula
DA Dental age

Author contributions

Conceptualization: Z.Ş.G, G.D; Methodology: E.Ö, T.A, A.Ş.K; official analysis and research: E.Ö, T.A, A.Ş.K; writing-original draft preparation: G.D, Z.Ş.G; writing – review and editing: G.D, Z.Ş.G.

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Data availability

The datasets generated during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Ethical approval for this study was provided by the Non-Interventional Clinical Research Ethics Committee of Inonu University, Malatya, Turkey (Ethic vote: 2022/3617) and the study was conducted in accordance with all the principles stated in the Declaration of Helsinki. Informed consent for participation has been obtained from the parent or legal guardian of any participant under the age of 16.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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