

Accuracy of age estimation with Demirjian and Nolla methods in Eastern Turkish children aged 3-17 years old

Purpose

Dental age assessment is one of the most reliable methods of chronological age estimation used for criminal, forensic and anthropologic purposes. This study aimed to determine how accurate it was to estimate the chronological age by looking at the dental age measured with the Nolla and Demirjian methods in a Turkish sample, based on the variables of gender and age-group.

Materials and Methods

A retrospective study was performed on panoramic radiographs of 1587 subjects (774 females and 813 males), aged 3–17 years. The mean dental age according to the Demirjian and Nolla methods were compared to the mean chronological age (CA). Also, the percentage value of prediction of CA was determined by using the both methods.

Results

An under-estimation of the chronological age was observed by using Nolla's method (males -0.003, females -0.32, both -0.16) and an over-estimation of the dental age was observed by using Demirjian's method (males 0.61, females 0.75, both 0.68).

Conclusion




Nolla's method was more accurate in the CA estimation than Demirjian's method in Eastern Turkish population.

Keywords: Nolla method, Demirjian method, dental age, chronological age, Turkish children

Introduction

Age determination has become an important aspect in current practice. The biological age determination method performed via dental age assessment is one of the methods that are easy to use (1). Dental age assessment helps to make decisions for the treatment procedures both in pediatric dentistry and in orthodontics. Chronological age assessment with the help of dental age also provides great convenience for children who do not have birth certificates, in natural disasters and criminal events (2, 3). Age determination methods used in the field of forensic medicine provide important information about unidentified persons, and also play an important role in the determination of child marriages and child labour (3). In addition, age determination has an important place in the field of medicine and dentistry for the treatment programs designed for the refugee families or children with no identity.

There are many methods related to maturation of permanent teeth and chronological age assessment from dental age. Morrees, Kvaal, Willems, Haavikko, Liliequist, Lundberg, Demirjian, and Nolla are

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some of them (4-12). Demirjian and Nolla methods are the two most commonly used methods in chronological age estimation. Different results related to dental age can be found in different geographies. The studies conducted in Turkey on the dental age assessment with the Demirjian and Nolla methods are available in the literature (1, 9, 10, 13-15).

Kirzioglu and Ceyhan (9) compared the Nolla and Demirjian methods in 425 Turkish children aged 7-13 years who share the similar socio-economic status and the ethnic group. An underestimation of -0.53 years was found for boys and -0.57 for girls with the Nolla method, this method being more accurate between 9 and 11 years in both genders and in the group of 13-year-old girls. However, the Demirjian method overestimated boys' age by $+0.52$ and girls' age by $+0.75$. Kirzioglu and Ceyhan (9) reported that both methods are not totally suitable, with makes it necessary to assess specific tables for this population.

Each population may need their own specific standard for an accurate estimation of chronological age. Since different results are obtained in different countries and regions, there are not many studies that utilize the Demirjian and Nolla methods in Turkey. Therefore, in our study, it was aimed to perform the dental age assessment by using the Demirjian and Nolla methods on the panoramic radiographs taken from children in the Eastern Anatolia Region of Turkey and to bridge the gap due to an insufficient number of studies conducted in our country on this subject. The null hypotheses of this study were as follows: There is no statistically significant difference between the chronological age and dental age. There is no statistically significant difference between the chronological age estimation values according to the Demirjian and Nolla methods.

Materials and Methods

Ethical approval

The present study was approved by the Non-Interventional Clinical Research Ethics Committee of İnönü University, Malatya, Turkey (2020/856).

Sample size estimation

This was a retrospective study conducted on panoramic radiographs. For a confidence level of 90% and $\alpha = 0.05$, at least 271 subjects were needed. The sample consisted of 1587 subjects' panoramic radiographs (774 females and 813 males, ages 3-17.9, (Table 1)).

Study materials

Panoramic radiographs from the subjects who underwent treatment at İnönü University, Faculty of Dentistry, Malatya, Turkey, between January 2016 and December 2017 were included in the study. Eastern Turkish subjects with well-documented chronological ages, aged 3-17.9 years with no prior orthodontic treatment history and good quality of panoramic radiographs were included. Our study did not involve the subjects with systemic diseases affecting the

Table 1: Age distribution of the individuals.

Age (years)	Female (n)	Male (n)	n	%
3 (3-3.9)	4	4	8	0.5
4 (4-4.9)	17	24	41	2.6
5 (5-5.9)	33	48	81	5.1
6 (6-6.9)	35	49	84	5.3
7 (7-7.9)	71	75	146	9.2
8 (8-8.9)	85	96	181	11.4
9 (9-9.9)	113	117	230	14.5
10 (10-10.9)	105	91	196	12.4
11 (11-11.9)	87	99	186	11.7
12 (12-12.9)	82	84	166	10.5
13 (13-13.9)	72	60	132	8.3
14 (14-14.9)	31	38	69	4.3
15 (15-15.9)	19	14	33	2.1
16 (16-16.9)	12	12	24	1.5
17 (17-17.9)	8	2	10	0.6
Total	774	813	1587	100.0

growth and development of the teeth and tooth agenesis other than third molars, vagueness in dental structures due to contrast problems, movements or artifacts, impacted teeth; radiopaque obturations or crowns, periapical lesions, and endodontically treated teeth.

Observers' characteristics

All assessments were performed by two investigators (GD, TPGÖ) with at least five years of experience in their field in a darkened room with a radiographic illuminator to ensure the contrast enhancement of the images. The assessments were done double-blinded. In order to avoid the examiners bias at the time of collecting data, CA was first recorded on a data collection sheet and the DA scores were tabulated later on a separate sheet.

Chronological age

CA was calculated by subtracting the date of the birth from the date of the panoramic radiograph after having converted both to a decimal age.

Dental age with Demirjian method

The development of the seven left permanent mandibular teeth was rated on an 8-stage scale (from A to H) (Figure 1). Being associated with a stage, each tooth was converted into quantitative values through a specific table. The scores taken from the seven teeth were added up as a gender function, and the sum of dental maturity was obtained on a scale of 0 to 100. The dental maturity score of each subject was then converted to dental age by using standard tables and/or percentile curves which were given for each gender, separately (16).

Table 2: Comparisons between the chronological and estimated (by Demirjian and Nolla methods) ages in females, males, and overall.

Age (years)	Mean	SD		
Chronological	9.69	2.82		
Demirjian estimation	10.36	3.28		
Nolla estimation	9.53	3.23		
Comparisons	Difference between means	SE		
Demirjian vs. Chronological	0.68***	0.04		
Nolla vs. Chronological	-0.16***	0.04		
Demirjian vs. Nolla	0.833***	0.03		
Females		Males		
Age (years)	Mean	SD	Mean	SD
Chronological	9.85	2.81	9.54	2.82
Demirjian estimation	10.59	3.25	10.15	3.30
Nolla estimation	9.53	3.19	9.54	3.27
Comparisons	Difference between means	SE	Difference between means	SE
Demirjian vs. Chronological	0.75***	0.06	0.61***	0.06
Nolla vs. Chronological	-0.33***	0.06	0.003	0.05
Demirjian vs. Nolla	1.07***	0.05	0.61***	0.04

SD: Standard Deviation, SE: Standard Error. ***p<0.001.

Table 3: Difference between means for the chronological and estimated by Demirjian and Nolla methods for ages, for genders and age groups.

Age (years)	Female		Male	
	DA – CA (SD)	NA – CA (SD)	DA - CA (SD)	NA - CA (SD)
3	-0.29 (0.19)	0.22 (0.32)	0.24 (0.86)	0.47 (0.67)
4	0.23 (1.53)	0.23 (1.36)	0.56 (1.46)	0.15 (0.58)
5	0.82 (1.09)***	-0.11 (0.58)	0.66 (1.04)***	0.08 (0.65)
6	0.79 (0.67)***	-0.34 (0.76)*	0.66 (0.89)***	-0.26 (0.63)**
7	0.81 (1.44)***	-0.43 (1.12)**	0.73 (1.39)***	0.07 (1.28)
8	0.61(1.53)***	-0.42 (1.17)***	0.31 (0.91)***	-0.15 (0.94)
9	0.58 (1.40)***	-0.45 (0.92)***	0.43 (1.61)**	-0.26 (1.22)*
10	0.82 (1.81)***	-0.31 (1.68)	0.40 (1.77)*	-0.32 (1.44)*
11	0.91 (1.90)***	-0.68 (1.37)***	0.63 (1.66)***	-0.16 (1.57)
12	1.22 (1.77)***	-0.12 (2.18)	1.03 (2.06)***	0.33 (2.11)
13	1.02 (2.12)***	0.18 (2.15)	0.91 (2.20)**	0.59 (2.01)*
14	1.23 (1.22)***	0.66 (1.74)*	1.42 (1.47)***	0.99 (1.43)***
15	0.70 (0.76)***	0.06 (1.58)	-0.34 (2.08)	-0.37 (2.09)
16	-1.78 (2.68)*	-1.97 (2.66)*	-0.21 (0.68)	-0.42 (0.94)
17	-3.07 (2.57)*	-3.67 (2.57)**	-1.92 (0.80)	-2.32 (1.36)
Total	0.75 (1.72)***	-0.32 (1.60)***	0.61 (1.61)***	-0.003 (1.45)

CA: Chronological Age, DA: Demirjian Age, NA: Nolla Age, SD: Standard Deviation, *p<0.05, **p<0.01, ***p<0.001.

Discussion

Recently, there has been an increasing need for fast and inexpensive methods for age determination (18). Chronological age assessment methods with the help of dental maturation follow-up have been performed by many researchers (13, 14, 19-21). However, dental age assess-

ment methods vary according to races and geography. Although there have been studies in different regions of Turkey (Figure 4), their samples were not as large as in our study (1, 9-11, 13-15, 22, 23). In addition, there are only 3 studies comparing Demirjian and Nolla methods within the same study protocol (9, 10, 14). The aim of the present study was to evaluate the usability of Demirjian's (16) and

Table 4: Simple regression analysis of chronological age estimated by the Demirjian and Nolla methods for total and males-females.

Demirjian					Nolla				
	B	SE B	β	t		B	SE B	β	t
Constant	2.012	0.119		16.886***	Constant	2.363	0.105		22.512***
Predictor	0.741	0.011	0.86	67.588***	Predictor	0.769	0.010	0.88	73.663***
Model summary: $R^2 = 0.742, p < 0.001$					Model summary: $R^2 = 0.774, p < 0.001$				
gender	B	SE B	β	t	gender	B	SE B	β	t
Female	Constant	2.087	0.183	11.429***	Female	Constant	2.592	0.160	16.230
	Predictor	0.733	0.016	0.848		44.444***	Predictor	0.761	0.016
Model summary: $R^2 = .719, p < 0.001$					Model summary: $R^2 = 0.748, p < 0.001$				
Male	Constant	1.941	0.156	12.425***	Male	Constant	2.147	0.136	15.803
	Predictor	0.749	0.015	0.874		51.120***	Predictor	0.775	0.013
Model summary: $R^2 = 0.763, p < 0.001$					Model summary: $R^2 = 0.803, p < 0.001$				

CA: Chronological Age, SE: Standard Error, *** $p < 0.001$

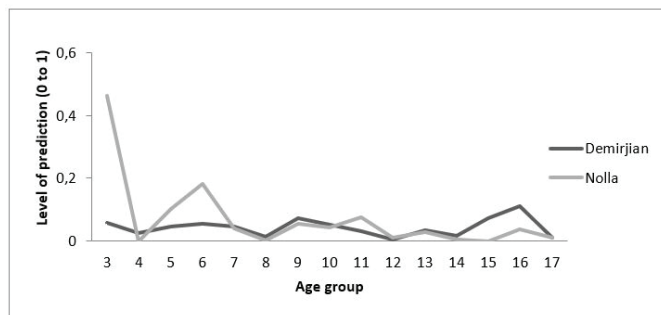


Figure 2. The prediction levels in the Demirjian and Nolla methods by age group.



Figure 4. The provinces where dental age determination has made on the map of Turkiye.

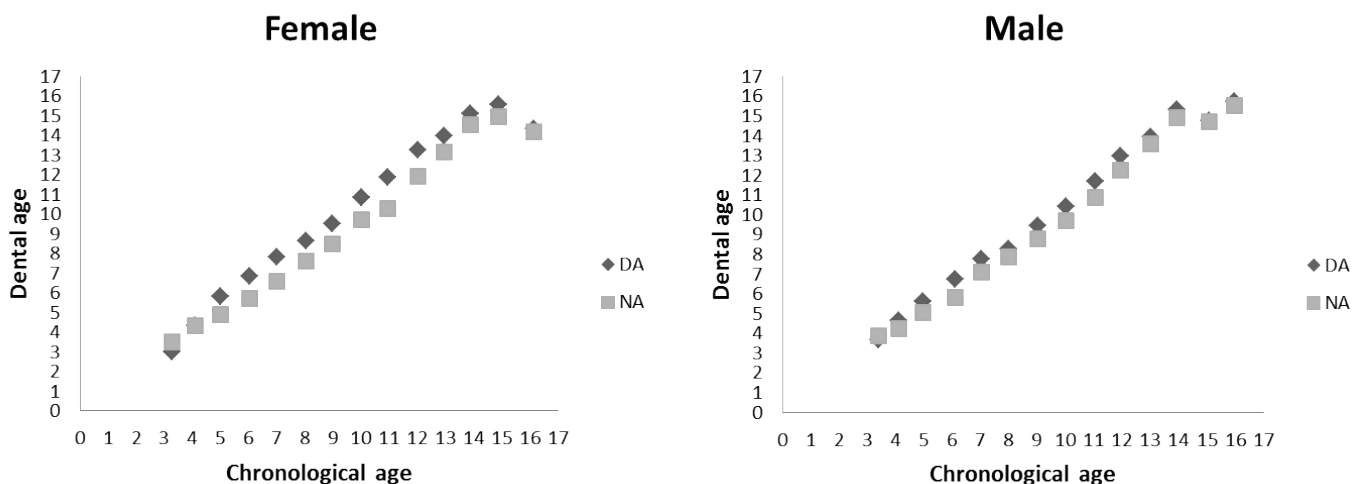


Figure 3. The correlation between dental age and chronological age (DA: Demirjian Age, NA: Nolla Age).

Nolla’s (17) methods for assessing the eastern Turkish population. In this study, we also emphasized and evaluated male and female differences, and age differences. This radiological dental age assessment study on a large population of people in Eastern Turkey can shed light on the age determination methods that can be applied in this region.

The age determination methods should be evaluated separately for male and female participants. Since physiological development and dental development are compatible with each other and male and female physiological development is different, individuals were divided into two groups according to gender while performing an evaluation in this study (16, 17). In this study, the mean difference between the

Table 5: Studies conducted in Turkey about age estimation by Demirjian and Nolla methods.

	Localization	Altitude	n	Age (years)	Male		Female	
					The mean difference between the chronological and dental ages ranged	The mean difference (chronological and dental ages)	The mean difference between the chronological and dental ages ranged	The mean difference (chronological and dental ages)
Demirjian								
The present study	Eastern Turkey (Malatya)	970 m	1587	3-17.9	-1.92 to 1.42 years	0.61 years	-3.07 to 1.23	0.75 years
Altunsoy et al. (1)	Western Turkey (İzmir)	25 m	635	7-16	0.10 to 0.76 years	0.52 years	0.28 to 0.87 years	0.56 years
Tunc et al. (23)	Northern Turkey (Samsun)	4 m	900	4-12	0.36 to 1.43 years		0.50 to 1.44 years	
Nur et al. (14)	Northeastern Turkey (Trabzon)	37 m	673	5-15.9	0.27 to 1.60 years	0.84 years	0.15 to 1.24 years	0.89 years
Mentes et al. (22)	(İstanbul)		419	5-11.9	0.18 to 0.54	0.39 years	-0.07 to 0.73	0.30 years
Celikoglu et al. (13)	Eastern Turkey (Erzurum)	1900 m	807	7-15	0.4 to 1.3 years	0.9 years	0.2 to 1.9 years	1.1 years
Cantekin et al. (15)	Eastern Turkey (Erzurum)	1900 m	471	7-14.9	-0.45 to 2 years	Central Anatolian population was dentally advanced compared with the Eastern Anatolian population. 0.91 years	-0.93 to 0.77 years	Central Anatolian population was dentally advanced compared with the Eastern Anatolian population. 0.81 years
	Central Turkey (Kayseri)	1071 m	473	7-14.9	0.70 to 3.15 years		0.24 to 1.28 years	
	Total		944	7-14.9			0.87 years	
Kirzioglu et al. (9)	Western Turkey (Isparta)	1043 m	425	7-13	0.37 to 0.68 years	0.52 years	0.34 to 1.17 years	0.75 years
Celik et al. (11)	Southern Turkey (Hatay)	100 m	932	4-18	-1.02 to 1.69 years		-1.20 to 1.36 years	
Nolla								
The present study	Eastern Turkey (Malatya)	970 m	1587	3-17.9	-2.32 to 0.99 years	-0.001 years	-3.67 to 0.66 to years	-0.33 years
Miloglu et al. (10)	Eastern Turkey (Erzurum)	1900 m	719	6-18	0.0 to -0.6 years	-0.2 years	-0.1 to -1.0 years	-0.5 years
Nur et al. (14)	Northeastern Turkey (Trabzon)	37 m	673	5-15.9	-0.01 to -0.93 years	-0.50 years	-0.01 to -0.94 years	-0.57 years
Kirzioglu et al. (9)	Western Turkey (Isparta)	1043 m	425	7-13	-0.54 to 0.25 years	-0.53 years	-0.67 to 0.27 years	-0.57 years

CA and the dental age according to the Demirjian method ranged from -3.07 to 1.23 years (mean: 0.75) in females and -1.92 to 1.42 years (mean: 0.61) in males. Similarly, the results from other studies, used the Demirjian method, supported that the dental age assessment performed by the Demirjian method shows more value than the chronological age.

These studies showed the following results (range): 0.14 to 2.79 in a Serbian population (24); -0.1 to 1.15 (0.75) years in females, -0.22 to 0.80 (mean:0.49) years in males in a South Australia population (25); 0.28 to 0.87 years in females, 0.10 to 0.76 years in males in a western Turkish population (1); 0.50 to 1.44 years in females and 0.36 to 1.43 years in males

in a northern Turkish population (23). In a study conducted in Saudi Arabia, the ages were overestimated by 0.3 years in males and 0.4 years in females (26). In another study from Saudi Arabia, the Saudi boys were 0.57 years, and girls were 0.44 years ahead of their chronological ages (27).

In the dental age assessment performed by the Nolla method, it was shown in the studies that it exhibits a lower value than chronological age (10, 14, 28). Miloglu *et al.*'s (10) study which was done in the east of Turkey by using the Nolla method, dental age was calculated 0.5 years lower in females and 0.2 years lower in males than chronological age. In an another study conducted in the north of Turkey with the Nolla method, dental age was found to be 0.57 years lower in females and 0.50 years lower in males compared to the actual chronological age (14).

In a study conducted in the south of Turkey, dental age indicated an underestimation of 0.53 and 0.57 years for males and females, respectively, according to the Nolla method, and an overestimation of 0.52 and 0.75 years for males and females, respectively, according to the Demirjian method (9). Similarly, in our study, there was an overestimation of 0.61 years for males and 0.75 years for females according to the Demirjian method, while there was an underestimation of 0.32 years for females and 0.003 years for males according to the Nolla method. The dental development was more advanced in girls than in boys, and this result is consistent with others (1, 9, 13-15, 25).

The differences between the studies can be caused by climate conditions, nutrition, and socioeconomic level (29). In addition, the studies conducted in Turkey were carried out especially in geographic areas that exhibit significant altitude differences. Previous studies have also demonstrated differences between geographical areas and cities within the same country (11, 15). Turkey, affected by different climates, is surrounded by the sea on three sides and also has one of the highest altitude cities of the world, namely Erzurum. The Turkish studies are presented in Table 5, and the results show how effective geographic differences could be in tooth development. For example, Miloglu *et al.* (10) conducted the study in the highest altitude region of Turkey (altitude = 1900 m, which is one of the highest altitude regions in the world), Altunsoy *et al.* (1)' study included participants who live at an altitude of 25 m, Nur *et al.* (14) at 37 m, Kirzioglu *et al.* (9) at 1043 m, while the present one at 970 m. Although our study was conducted in the eastern area which is similar to the Miloglu *et al.* (10), the altitude in that province was much lower than that of the Erzurum province. The altitude is an important parameter affecting climatic conditions, and causes changes in human biological structure and is thought to be a factor that should be evaluated in terms of dental development. Cantekin *et al.* (15), comparing eastern Anatolia (altitude: 1900 m) and Central Anatolia (altitude: 1054 m), suggested that regional conditions could affect dental maturation. The results of our study were consistent to that of the Kirzioglu *et al.*'s study (9). According to the Demirjian method, the overestimation was 0.61 years for males and 0.75 years for females in our study (altitude=970 m), and 0.52 years for males and 0.75 years for females in Kirzioglu *et al.*'s study (altitude=1043m).

As girls have precocious puberty compared to boys, the physiological age of girls is mostly older than boys (15).

In our study, the difference between the dental age and chronological age of females (0.75 years) was found to be higher than that of males (0.61 years) in the assessment made with the Demirjian method.

Altunsoy *et al.* (1), Celikoglu *et al.* (13), and Kirzioglu *et al.* (9) from Turkey reported that Demirjian method was not suitable for Turkish population. Nolla's method was found to be more accurate than Demirjian method (14). In an another study from Turkey, the accuracy of this method (Nolla) was reported to be acceptable for boys, which is in consistent with our findings, but it was not suitable for girls (10). In the present study, we found that Nolla method was more accurate than Demirjian method, and more suitable for boys.

Tomas *et al.* (12) stated that for chronological age the predictive capacity of the Nolla method was 64.4% and the predictive capacity of the Demirjian method was 47.5%. In our study, the chronological age predictive capacity of the Nolla method was found to be 77% and the predictive capacity of the Demirjian method was 74%. Also, comparison of the gender indicated that the predictive capacity in males was greater than in females, for both methods. There are some limitations in this study. First, dental development does not depend solely on the ethnicity, as there are other variables such as nutrition, familial factors, genetic, lifestyle, hormonal state, all of which could be expected to affect dental development. In the present study, however, all these factors could not be examined. Secondly, although individuals with known systemic problems had been excluded from the study, there may be a possibility that undiagnosed ones may have participated in the study. On the other hand, although the number of children aged 3 and 17 was small, the large sample size was the strongest aspect of the present study, and this was the main difference from the previous studies conducted on a Turkish sample by using the same methods. No other studies had as many samples as this study did. In addition, these two methods, which are widely used in our country and in the literature to evaluate the tooth development, were preferred to estimate the chronological age, considering that the results of the study could be compared.

Conclusion

The Nolla and Demirjian methods can be applied to Turkish children for the estimation of chronological age with an approximate error of 25%. But it is worth noting that the Nolla method was found to be more accurate than the Demirjian method in our sample. Both methods are sensitive to gender and age. The correction factors must be established to make the Demirjian and Nolla methods applicable to each population. The authors of the present study suggest that the Nolla method should be preferred primarily for estimating the chronological age of the child population in Turkey.

Türkçe Özet: 3-17 Yaş Arası Türkiye'nin Doğusundaki Çocuklarda Demirjian ve Nolla Yöntemlerine Göre Yaş Tahmininin Doğruluğu. Amaç: Diş yaşı değerlendirmesi, suç, adli tıp ve antropolojik amaçlar için kullanılan en güvenilir kronolojik yaş tahmini yöntemlerinden biridir. Bu çalışma, cinsiyet ve yaş grubu değişkenlerine göre bir Türk örnekleminde Nolla ve Demirjian yöntemleriyle ölçülen diş yaşına bakarak kronolojik yaşın tahmin edilmesinin ne kadar doğru olduğunu belirlemeyi amaçlamaktadır. Gereç ve Yöntem: 3-17 yaşları arasındaki 1587 deneğin (774 kadın ve 813 erkek) panoramik radyografileri üzerinde retrospektif bir

çalışma gerçekleştirildi. Demirjian ve Nolla yöntemlerine göre ortalama diş yaşı, ortalama kronolojik yaş (KY) ile karşılaştırıldı. Ayrıca, KY tahmininin yüzde değeri her iki yöntem kullanılarak belirlendi. Bulgular: Nolla yöntemi kullanılarak kronolojik yaşın düşük tahmin edildiği (erkek $-0,003$, kadın $-0,32$, her ikisi $-0,16$) ve Demirjian yöntemi kullanılarak kronolojik yaşın yüksek tahmin edildiği (erkek $+0,61$, kadın $+0,75$, her ikisi de $+0,68$) gözlemlendi. Sonuç: Türkiye'nin doğusundaki nüfusta KY tahmininde Nolla yöntemi Demirjian yönteminden daha doğrudur. Anahtar kelimeler: Nolla yöntemi, Demirjian yöntemi, diş yaşı, kronolojik yaş, Türk çocukları

Ethics Committee Approval: The study was approved by the Non-Interventional Clinical Research Ethics Committee of İnönü University, Malatya, Türkiye (2020/856).

Informed Consent: Participants provided informed consent.

Peer-review: Externally peer-reviewed.

Author contributions: GD, TPGO, SD participated in designing the study. GD, TPGO participated in generating the data for the study. GD, TPGO participated in gathering the data for the study. GD participated in the analysis of the data. GD, TPGO wrote the majority of the original draft of the paper. GD, TPGO participated in writing the paper. GD, TPGO, SD have had access to all of the raw data of the study. GD, TPGO, SD have reviewed the pertinent raw data on which the results and conclusions of this study are based. GD, TPGO, SD have approved the final version of this paper. GD, TPGO, SD guarantee that all individuals who meet the Journal's authorship criteria are included as authors of this paper.

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