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DENTAL AGE ESTIMATION FROM TOOTH DEVELOPMENT: A LITERATURE REVIEW

(METODE ESTIMASI USIA BERDASARKAN PERKEMBANGAN GIGI: ULASAN LITERATUR)

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ABSTRACT

Age estimation is among several standard methods for identifying unknown individuals in disasters, accidents, crime victims, and identity forgery. Age estimation can be done through observation of the growth and development of dentition. Similar to fingerprints, teeth are unique and specific for each individual. This article discusses the methods of age estimation based on observation of dentition's growth and development process. Demirjian, Gustafson, Kvaal, Gleiser and Hunt, Schour and Massler, and Cameriere are the most commonly used age estimation methods. Each method has its challenges and limitations. Therefore, applying more than one method or conducting a repetition of measurement and calculation could improve the accuracy of the estimation. However, the influence of factors like heredity, ethnicity, and genetic tendencies in a particular population should also be considered.

Keywords: age estimation; Demirjian; forensic odontology

ABSTRAK

Estimasi usia merupakan salah satu prosedur baku dalam mengidentifikasi individu yang tidak dikenal pada kasus bencana, kecelakaan, korban tindak kriminal, dan pemalsuan identitas. Salah satu metode estimasi usia adalah berdasarkan pertumbuhan dan perkembangan gigi. Gigi memiliki karakteristik unik seperti sidik jari tetapi lebih tahan terhadap pengaruh lingkungan sehingga tidak mudah rusak, dan spesifik pada setiap individu. Artikel ini mengulas metode estimasi usia berdasarkan proses pertumbuhan dan perkembangan gigi. Demirjian, Gustafson, Kvaal, Gleiser dan Hunt, Schour dan Massler, dan Cameriere merupakan metode yang paling sering digunakan dalam menentukan estimasi usia. Masing-masing metode memiliki kelebihan dan kekurangan. Penggunaan lebih dari satu metode, atau pengulangan pengukuran dan perhitungan dapat memberikan hasil yang maksimal. Tetapi perlu dicermati adanya faktor-faktor yang dapat mempengaruhi hasil estimasi usia berdasarkan proses pertumbuhan perkembangan gigi yaitu, faktor keturunan, suku, dan kecenderungan genetik di suatu wilayah populasi tertentu.

***Kata kunci**: Demirjian; estimasi usia; odontologi forensik*

INTRODUCTION

Age estimation is a crucial aspect of forensic odontology, serving the purpose of identifying unknown deceased individuals. Teeth and human skeletal remains can be utilized for age estimation. Teeth, the strongest structures in the human body, are protected by the soft and hard tissues of the face, making them resistant to external factors such as decay and extreme temperatures. Additionally, teeth are unique and specific to each individual, akin to fingerprints. These factors make teeth a reliable biological indicator for age estimation.[1,2,3,4]

Several methods based on the condition or growth of teeth have been extensively researched for age estimation.

Some methods are relatively accurate, conservative, and preserve the tooth structure compared to those requiring tooth extraction. Tooth eruption, tooth calcification, attrition, periodontal disease, secondary dentin deposition, root translucency, cementum apposition, and root resorption are the dental changes most commonly analyzed in age estimation methods. Various age estimation methods for both children and adults have been developed based on the relationship between age and dental structure characteristics.[5,6]

This review aims to discuss various age estimation methods based on the growth and development of teeth that have been widely employed.

DISCUSSION

Age Estimation Based on the Demirjian Method

Age estimation can be based on the condition of teeth because teeth begin to grow from the early embryonic period. Additionally, teeth are the most durable structures in the human body and can persist long after death. Age estimation based on the chronological growth and development of teeth is more accurate than methods based on bone development. Due to all these characteristics, human teeth are often used as a parameter for age estimation with the support of anatomical and radiological investigations.[2,6,7,8]

Although many methods use radiographic analysis of tooth development for age estimation, the method designed by Demirjian et al. in 1973, based on a large sample of French-Canadian children, has been used in several studies.[7,9]

Demirjian et al. described eight stages of tooth development from crown formation to apex closure of the seven left permanent mandibular teeth (excluding the third molars). The developmental stages of these seven teeth are then converted into scores, and the scores from each tooth are added and further calculated to determine the age of the teeth. Many researchers have tested the accuracy of the Demirjian et al. method in different populations, including Belgium, the UK, West China, Iran, Northeast Brazil, Malaysia, Korea, Romania, South China, Pakistan, Saudi Arabia, Serbia, Macedonia, South India, Australia, and two specific populations in Thailand.[7,8,9]

The Demirjian 1973 method is still widely used today. Research using the Demirjian 1973 method was conducted on the Turkish population to observe age estimation variations in different regions. The study results indicated that the estimated teeth age is lower than the chronological age in each region. The

Demirjian 1973 method would benefit age estimation by mineralizing third molars.[10-13]

In 1973, Demirjian introduced a method that estimates chronological age based on the development of seven teeth from the left lower jaw. This method is similar to the Tanner, Whitehouse, and Healy method, which estimates chronological age based on hand and wrist maturity. In 1976, Demirjian developed three additional methods. The first method is based on the same seven teeth; the second method is based on four teeth, namely the first premolar, second premolar, first molar, and second molar; and the third method is based on four teeth, namely the second incisor, first premolar, second premolar, and second molar.

In cases where one tooth is missing, making assessment impossible, Demirjian and Goldstein suggested creating a separate assessment system for each combination of the remaining six teeth, selecting the two 4-tooth subsystems mentioned earlier. In these four methods, each tooth is scored based on the observed developmental stage, and the sum of the scores for each tooth is converted into a maturity score according to a standard table.

Other studies have also applied this method and noted a linear correlation between chronological and tooth age. Furthermore, it was observed that ethnic variables are related to specific age parameters in the Brazilian population, providing essential information for forensic evaluation. In the Nigerian population, the Demirjian 1973 and 1976 methods showed higher age estimation results for teeth than chronological age. There is variation between chronological age and tooth development among Nigerian children.[14,15,16]

In 1976, Demirjian incorporated two new additional stages in determining age estimates: first, to widen the age range, and second, to show two distinct groups for the four teeth—males and females. Ambarkova V et al. and Mohammed RB et al. observed that assessing the development of the mandibular third molar can be used to determine the age range of teeth and the estimated age range for individuals with unknown chronological age.[11,17,18]

Causes of age overestimation include various issues such as inaccurate statistical procedures, manual population curve fitting, sample and assessment bias, and differences in environmental characteristics, habits, and nutrition in populations. Therefore, researchers suggest that age estimation of teeth based on chronological age be determined for each specific population.[17,18]

Age Estimation Step Based on the Demirjian Method

Step 1: Each tooth (teeth 31-37) is carefully assessed based on eight developmental stages (from A to H) following the defined criteria for each stage and comparing each tooth with images and radiographic photos according to the Demirjian et al. method.

Step 2: The developmental stage of each tooth is then converted into a score (scores determined subjectively by the researcher) using the tables outlined by the Demirjian et al. method separately for males and females.

Step 3: The previously calculated scores for each tooth are then summed up. The total score is expressed as the tooth maturation score.

Step 4: The tooth maturation scores for each sample are converted into tooth age by comparing them with the tables from the Demirjian et al. method separately for males and females.

Step 5: Different values for each sample are then calculated by subtracting chronological age from tooth age (positive and negative values indicating overestimation and underestimation, respectively).

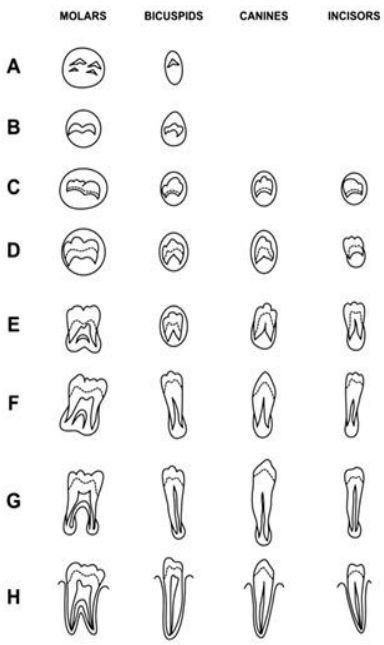

Figure 1. Stages of tooth development according to Demirjian.

AGE	Score	AGE	Score	AGE	Score	AGE	Score	AGE	Score
3.1	12.9	6.1	34.7	9.1	84.3	12.1	94.2	15.1	97.7
3.2	13.5	6.2	35.8	9.2	85	12.2	94.4	15.2	97.8
3.3	14	6.3	36.9	9.3	85.6	12.3	94.5	15.3	97.8
3.4	14.5	6.4	38	9.4	86.2	12.4	94.6	15.4	97.9
3.5	15	6.5	39.2	9.5	86.7	12.5	94.8	15.5	98
3.6	15.6	6.6	40.6	9.6	87.2	12.6	95	15.6	98.1
3.7	16.2	6.7	42	9.7	87.7	12.7	95.1	15.7	98.2
3.8	17	6.8	43.6	9.8	88.2	12.8	95.2	15.8	98.2
3.9	17.6	6.9	45.1	9.9	88.6	12.9	95.4	15.9	98.3
4	18.2	7	46.7	10	89	13	95.6	16	98.4
4.1	18.9	7.1	48.3	10.1	89.3	13.1	95.7		
4.2	19.7	7.2	50	10.2	89.7	13.2	95.8		
4.3	20.4	7.3	52	10.3	90	13.3	95.9		
4.4	21	7.4	54.3	10.4	90.3	13.4	96		
4.5	21.7	7.5	56.8	10.5	90.6	13.5	96.1		
4.6	22.4	7.6	59.6	10.6	91	13.6	96.2		
4.7	23.1	7.7	62.5	10.7	91.3	13.7	96.3		
4.8	23.8	7.8	66	10.8	91.6	13.8	96.4		
4.9	24.6	7.9	69	10.9	91.8	13.9	96.5		
5	25.4	8	71.6	11	92	14	96.6		
5.1	26.2	8.1	73.5	11.1	92.2	14.1	96.7		
5.2	27	8.2	75.1	11.2	92.5	14.2	96.8		
5.3	27.8	8.3	76.4	11.3	92.7	14.3	96.9		
5.4	28.6	8.4	77.7	11.4	92.9	14.4	97		
5.5	29.5	8.5	79	11.5	93.1	14.5	97.1		
5.6	30.3	8.6	80.2	11.6	93.3	14.6	97.2		
5.7	31.1	8.7	81.2	11.7	93.5	14.7	97.3		
5.8	31.8	8.8	82	11.8	93.7	14.8	97.4		
5.9	32.6	8.9	82.8	11.9	93.9	14.9	97.5		
6	33.6	9	83.6	12	94	15	97.6		

Figure 2. Conversion table based on male gender according to Demirjian.

AGE	Score	AGE	Score	AGE	Score	AGE	Score	AGE	Score
3.1	14.4	6.1	39.1	9.1	87.8	12.1	96.4	15.1	99.3
3.2	15.1	6.2	40.2	9.2	88.3	12.2	96.5	15.2	99.4
3.3	15.8	6.3	41.3	9.3	88.8	12.3	96.6	15.3	99.4
3.4	16.6	6.4	42.5	9.4	89.3	12.4	96.7	15.4	99.5
3.5	17.3	6.5	43.9	9.5	89.8	12.5	96.8	15.5	99.6
3.6	18	6.6	45.2	9.6	90.2	12.6	96.9	15.6	99.6
3.7	18.8	6.7	46.7	9.7	90.7	12.7	97	15.7	99.7
3.8	19.5	6.8	48	9.8	91.1	12.8	97.1	15.8	99.8
3.9	20.3	6.9	49.5	9.9	91.4	12.9	97.2	15.9	99.9
4	21	7	51	10	91.8	13	97.3	16	100
4.1	21.8	7.1	52.9	10.1	92.1	13.1	97.4		
4.2	22.5	7.2	55.5	10.2	92.3	13.2	97.5		
4.3	23.2	7.3	57.8	10.3	92.6	13.3	97.6		
4.4	24	7.4	61	10.4	92.9	13.4	97.7		
4.5	24.8	7.5	65	10.5	93.2	13.5	97.8		
4.6	25.6	7.6	68	10.6	93.5	13.6	98		
4.7	26.4	7.7	71.8	10.7	93.7	13.7	98.1		
4.8	27.2	7.8	75	10.8	94	13.8	98.2		
4.9	28	7.9	77	10.9	94.2	13.9	98.3		
5	28.9	8	78.8	11	94.5	14	98.3		
5.1	29.7	8.1	80.2	11.1	94.7	14.1	98.4		
5.2	30.5	8.2	81.2	11.2	94.9	14.2	98.5		
5.3	31.3	8.3	82.2	11.3	95.1	14.3	98.6		
5.4	32.1	8.4	83.1	11.4	95.3	14.4	98.7		
5.5	33	8.5	84	11.5	95.4	14.5	98.8		
5.6	34	8.6	84.8	11.6	95.6	14.6	98.9		
5.7	35	8.7	85.3	11.7	95.8	14.7	99		
5.8	36	8.8	86.1	11.8	96	14.8	99.1		
5.9	37	8.9	86.7	11.9	96.2	14.9	99.1		
6	38	9	87.2	12	96.3	15	99.2		

Figure 3. Conversion table based on female gender according to Demirjian.

Although the Demirjian method published in 1976 was designed to address the limitations and improve the accuracy of the Demirjian 1973 method, current research still utilizes it for evaluation and comparison with other dental age estimation methods.[18]

Age Estimation Based on the Willems Method

When the calculations produced by the Demirjian method showed results that were too high for chronological age, Willems et al. revised the method by creating a new assessment table based on their patient data. The conversion of maturity scores to tooth age was eliminated, making this method practical for use while still retaining the advantages of the original Demirjian technique.[11]

The Willems method takes into account the developmental stages of seven permanent left upper jaw teeth. Scores are obtained for each tooth from gender-specific tables. Willems' tooth age estimation is obtained by using scores corresponding to each letter code for males and females.[11]

Willems modified the Demirjian method because age estimation using the Demirjian method yielded results that exceeded chronological age in the Caucasian population in Belgium. Willems differentiated measurements based on gender, as shown in Figure 3. Other researchers who compared this method indicated that the Willems method is the most accurate. In contrast, the Demirjian methods from 1973 and 1976 for dental age estimation were not suitable for children in the population of the former Yugoslavia.[11]

Gender	Tooth	A	B	C	D	E	F	G	H
Boys	Central incisor	-	-	1.68	1.49	1.5	1.86	2.07	2.19
	Lateral incisor	-	-	0.55	0.63	0.74	1.08	1.32	1.64
	canine	-	-	-	0.04	0.31	0.47	1.09	1.9
	First bicuspid	0.15	0.56	0.75	1.11	1.48	2.03	2.43	2.83
	Second bicuspid	0.08	0.05	0.12	0.27	0.33	0.45	0.4	1.15
	First molar	-	-	-	0.69	1.14	1.6	1.95	2.15
	Second molar	0.18	0.48	0.71	0.8	1.31	2	2.48	4.17
Girls	Central incisor	-	-	1.83	2.19	2.34	2.82	3.19	3.14
	Lateral incisor	-	-	-	0.29	0.32	0.49	0.79	0.7
	canine	-	-	0.6	0.54	0.62	1.08	1.72	2
	First bicuspid	−0.95	−0.15	0.16	0.41	0.6	1.27	1.58	2.19
	Second bicuspid	−0.19	0.01	0.27	0.17	0.35	0.35	0.55	1.51
	First molar	-	-	-	0.62	0.9	1.56	1.82	2.21
	Second molar	0.14	0.11	0.21	0.32	0.66	1.28	2.09	4.04

Figure 4. Conversion table based on gender for the Willems method.

When comparing the Demirjian 1973 and 1976 methods, there are significant differences overall and within individual age groups with average chronological ages. Age estimates based on the Demirjian 1973 and 1976 methods consistently yield higher age results than chronological age.[19,20]

Age Estimation Based on the Gustafson Method

Age estimation based on dental conditions can be carried out in two stages of the developmental period. The first period is during the initial 20 years of dental development, and the subsequent period is when all teeth have fully erupted. The Gustafson method correlates the formation of secondary dentin, periodontal recession, enamel attrition, cementum apposition, and external root resorption as dental changes related to chronological age.[23]

Six physiological changes in teeth, namely attrition, periodontitis, deposition of secondary dentin, root translucency, cementum apposition, and root resorption, are examined, with each parameter having scores ranging from 0 to 3. The total score is calculated by summing the scores of these six physiological factors. Regression analysis is performed by plotting the total score against the individual's actual age. This regression line is used to obtain the regression formula, resulting in $y = 3.71x + 16.03$; subsequently, age can be calculated.[23]

The calculated regression equation can be recommended for age estimation in living individuals, although the quality of X-ray images limits the application of the presented method. Among these dental changes, dentin translucency in the root portion is considered the best parameter for age estimation. Additionally, age calculation using the total score assessed subjectively by each researcher was found to be more accurate than age calculated using scores of individual physiological factors.[4,23,24]

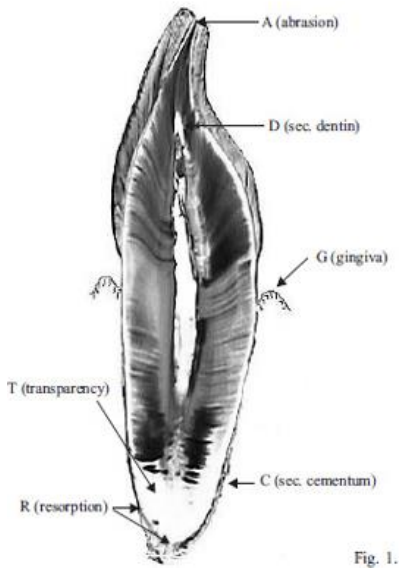

Figure 5. Tooth Development based on Gustafson method.

Age Estimation Based on the Kvaal

Method

The decreasing pulp space in teeth due to secondary dentin deposition is an age indicator, according to Kvaal et al. 1995. This method can be applied to living individuals and is non-invasive, reliable, and accurate. However, one study on the Turkish population reported that age estimation using this method has low accuracy.[1,5]

Simple linear regression analysis was conducted, where the mean variable (M) (average of variables: complete pulp length/root length [from CEJ to apex] [p], total pulp length/total tooth length [r], total pulp length/root width at the CEJ level [a], pulp width/root width at the midpoint between the CEJ surface and the root surface [b], and pulp width/root width at the root surface [c]) differences between width and length (W - L) were found to contribute to the estimation of chronological age significantly and were used in the regression equation for the Kvaal method according to the provided formula: [26]

Usia= 129. 8 - (316,4 × M) (6,8 × [P - L])

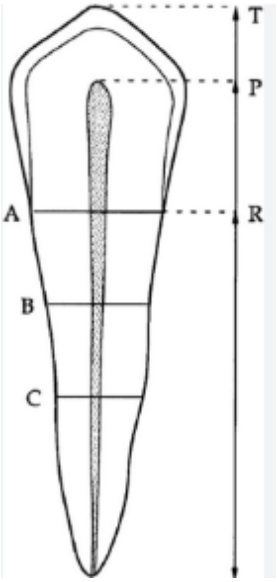

Figure 6. Measurement level based on Kvaal method.

Significant errors in studies using the Kvaal method may be attributed to variations in the rate of secondary dentin deposition in the Indian population influenced by environmental and genetic variations. In the adult age category, the Kvaal technique can provide more accurate age estimates, provided that this method demonstrates that periapical X-rays (preferably taken with a parallel technique) need to be performed.[25,26]

Age Estimation Based on the Gleiser and Hunt Method

Research in the United Arab Emirates on the development of third molars is measured using a ten-point assessment system employing the Gleiser and Hunt method modified by Köhler in 1994. When third molars begin to develop in children, they are arranged into groups

according to Köhler's technique. It allows for linking permanent teeth with the development of third molars, but concerning important forensic age, and there is no need to systematically incorporate the development of third molars in assessing the age of children's teeth. In the adult group, age estimation should be based solely on the development of third molars. In a study in Iran, in cases where all four third molars have fully erupted, the individual is likely over 18 years old. Furthermore, the age associated with third molars enhances age prediction, especially in the early stages of third molar development.[9,14,2]

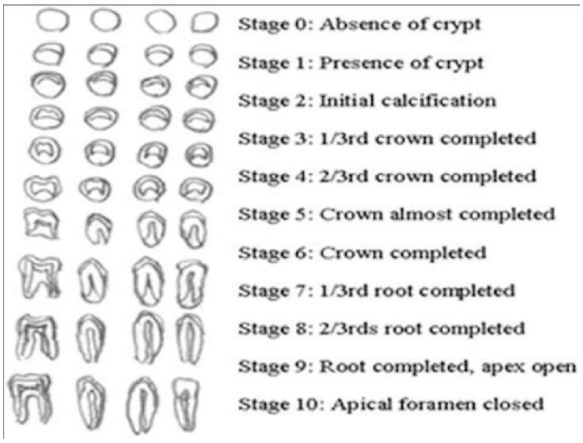

Figure 7. Tooth Development is based on the Gleiser and Hunt method.

Age Estimation Based on the Schour and Massler Method

The graph depicting the development of teeth and the formation of specific crown or root features, such as the Schour and Massler atlas from 1941, consists of a series of 21 images from prenatal stages to adulthood. Research results indicate that the 2010 London Atlas has better accuracy than the 1941 Schour and Massler and the 1978 Ubelaker atlases. It suggests a substantial improvement in the accuracy of age estimation for developing teeth. On the other hand, there are overestimations for males and underestimations for females. This discrepancy may be attributed to the dental anatomy representation covering internal tooth structures and lacking information about eruption references. [8,27]

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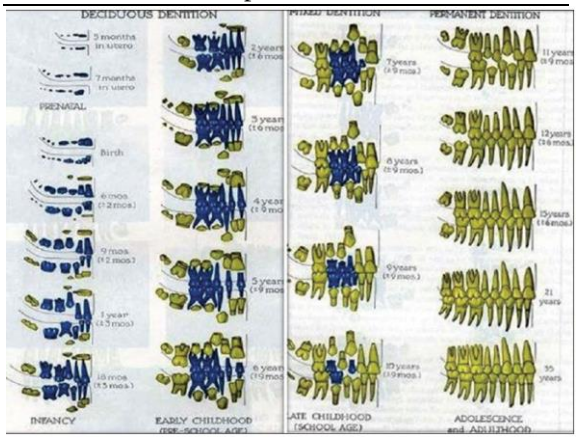

Figure 8. Tooth Development is based on the Schour and Masler method.

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Age Estimation Based on the Cameriere Method

The Cameriere method measures the apex of the root of seven permanent left mandibular teeth (excluding the third molars). The number of teeth with closed

apices (N0) is calculated. In cases where the root apex is open, the distance between the inner sides of the open apex is measured for teeth with a single root (Ai, i = 1, 5), while for multi-rooted teeth, the total distance is obtained by adding each root measurement (Ai, i = 6, 7). The total score calculated is the average score for teeth with open root apices (s= X1+X2+...+X7). Cameriere's age estimation is computed using a regression model.[28]

The regression equation used is by summing 8.387 + 0.282g + 1.692X5 + 0.835N0 - 0.116s - 0.139sN0, where "g" is considered as "1" for males and "0" for females. The Cameriere regression model was developed for the European population and may not be suitable for the Turkish population due to ethnic factors. Therefore, the Cameriere formula must be validated for the Turkish population and updated if necessary.[28]

The Cameriere method assesses chronological age in children based on the relationship between age and measurements of open apical teeth. Additionally, the pulp-to-tooth ratio in canine teeth through periapical radiography and this ratio are measured to quantify the amount of secondary dentin apposition. Furthermore, Cameriere et al.'s threshold values, using the method for the third molar index evaluated at 18, have shown a high probability for subjects aged 18 or older.[28]

There is a significant correlation between age and measurements of teeth with open apices. This method can assess age in both forensic and legal contexts. Although incisor teeth are less reliable than canine or lower premolar teeth, incisors can estimate age at death when those teeth are absent.[29]

The pulp-to-tooth area ratio is helpful in assessing age with reasonable accuracy. Cameriere et al. propose a suitable method for estimating dental age in children in Mexico. According to Cameriere et al., methods related to Demirjian's 1973 method of tooth and cervical vertebral maturation can be reliable and helpful in assessing the level of dental and bone maturation.[30,31]

Many researchers have used Willems and Cameriere methods for different populations. Some studies only use the Willems or Cameriere method, while both techniques have also been used and compared in other research. Some researchers have reported that the Cameriere method is more accurate than the Willems method, while others report the opposite. The Cameriere and Willems methods show the highest accuracy in the Turkish population. Only one previous study examined the Willems and Cameriere methods in the Turkish population, but the

sample size in that study was relatively small.

CONCLUSION

It should be noted that various methods for dental age estimation can be employed. Each method has its strengths and weaknesses, and ideally, it is advisable to use more than one method, repeating measurements and calculations to obtain optimal results. Therefore, for dental age estimation, it is essential to consider population-specific differences with genetic tendencies in geographical regions. Additionally, it is crucial, first and foremost, to document the reliability of the applied dental age estimation method concerning chronological age and compare different dental age estimation methods with each other.

CONFLICT OF INTEREST

The authors reported no potential conflict of interest.

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