ORIGINAL RESEARCH   ORİJİNAL ARAŞTIRMA

Comparison of Chronological Age and Estimated Age Obtained by Using Hand-Wrist and Panoramic Radiographic Data with Different Age Estimation Methods: A Cross-Sectional Study

El-Bilek ve Panoramik Radyografik Verilerle Farklı Yaş Tayini Metotları Kullanılarak Elde Edilen Tahmini Yaşın Kronolojik Yaşla Karşılaştırılması: Kesitsel Çalışma

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This study was prepared based on the findings of Tuğçe Nur PEKDEMİR's thesis study titled "Comparison of Chronological Age and Estimated Age Obtained by Using Hand-Wrist and Panoramic Radiographic Datas with Different Age Determination Methods" (Diyarbakır: Dicle University; 2020).

ABSTRACT Objective: The aim of the study is to compare the alignment of estimated ages (EA) obtained using the Cameriere open apices method (COAM), Demirjian method (DM), Greulich & Pyle Atlas method (GPAM), and Cameriere hand-wrist method (CHWM) with the chronological ages (CA) of cases and determine which method provides the closest result to CA in the most practical way. **Material and Methods:** Orthopantomography and wrist X-rays of 287 cases aged 9-14 years were used. The difference between CA and EA obtained by COAM, CHWM, DM and GPAM methods and dental age (DA), bone age (BA) were evaluated. We employed Shapiro-Wilk's, Kolmogorov-Smirnov, Mann-Whitney U, Kruskal-Wallis H, and Wilcoxon tests, along with the Kappa coefficient, considering $p<0.05$ as significant. **Results:** In males, the CA-EA difference was found to be underestimated by 0.74 and 0.01 years for COAM and GPAM, and overestimated by 0.65 and 0.32 years for DM and CHWM, respectively. In females, this difference was underestimated by 0.61 years for COAM and overestimated by 0.64, 0.85, and 0.43 years for DM, CHWM, and GPAM, respectively ($p<0.005$). **Conclusion:** GPAM was found to be the closest to CA and the most practical method. When determining age, it's crucial to consider both DA and BA together. Using the evaluated methods for age estimation after necessary modifications are made seems appropriate.

Keywords: Age determination by teeth;
               age determination by skeleton; tooth;
               bone development

ÖZET Amaç: Çalışmanın amacı, Cameriere açık apeks yöntemi [Cameriere open apices method (COAM)], Demirjian yöntemi [Demirjian method (DM)], Greulich & Pyle Atlas yöntemi [Greulich & Pyle Atlas method (GPAM)] ve Cameriere el-bilek yöntemi [Cameriere hand-wrist method (CHWM)] kullanılarak elde edilen tahmini yaşların [estimated ages (EA)] vakaların kronolojik yaşları [chronological ages (CA)] ile karşılaştırılmasıyla hangi yöntemin CA'ya en yakın sonucu en pratik şekilde sağladığını tespit etmektir. **Gereç ve Yöntemler:** Çalışmada yaşları 9-14 arasında değişen 287 olgunun ortopantomografisi ve el-bilek röntgeni kullanıldı. CA ile COAM, CHWM, DM ve GPAM kullanılarak elde edilen EA ve CA ile diş yaşı [dental age (DA)] ve kemik yaşı [bone age (BA)] farkları değerlendirildi. $p<0.05$'i anlamlı kabul ederek Shapiro-Wilk, Kolmogorov-Smirnov, Mann-Whitney U, Kruskal-Wallis H ve Wilcoxon testleri ve Kappa katsayısı istatistiksel değerlendirme amacıyla kullanıldı. **Bulgular:** Erkeklerde CA-EA farkının COAM ve GPAM için 0,74 ve 0,01 yıl eksik tahmin edildiği, DM ve CHWM için ise sırasıyla 0,65 ve 0,32 yıl fazla tahmin edildiği görüldü. Kadınlarda bu fark COAM için 0,61 yıl eksik, DM, CHWM ve GPAM için ise sırasıyla 0,64, 0,85 ve 0,43 yıl fazla tahmin edilmiştir ($p<0,005$). **Sonuç:** GPAM'nin CA'ya en yakın sonucu veren, en pratik yöntem olduğu görüldü. Yaşı belirlerken hem DA hem de BA'yı birlikte düşünmek oldukça önemlidir. Çalışmada incelenmiş olan yöntemlerin gerekli modifikasyonlar yapıldıktan sonra yaş tahmini için kullanılmasının daha uygun olacağı düşünülmektedir.

Anahtar Kelimeler: Dişlerden yaş tayini;
                       iskeletten yaş tayini; diş;
                       kemik gelişimi

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If the individual's data about their chronological (real) age is found to be insufficient or suspicious, it is requested that their physiologic (estimated) age be determined. Age estimation is performed on the deceased in criminal justice cases such as mass disasters, plane accidents and murders; and on the living in the cases of rape, withholding, determination of whether the child has reached the age of criminal responsibility, child marriages, illegal adoption, child pregnancies, immigration and people smuggling.[1-3]

In age estimation, criteria such as growth and development of teeth and bones, height, psychological and mental development, weight, and puberty symptoms are considered. Bone age (BA) and dental age (DA) have an important role in terms of treatments and forensic cases. In the field of dentistry, it is important for diagnosing and treating (apexification, pulpotomy, space maintainer application, initiation time of orthodontic treatments or in determining the appliances to be used, dental implants, or fixed prosthesis treatments), from a forensic standpoint, it is important for sentencing and punishment.[4,5]

Turkish laws have divided people into certain age groups and brought classifications according to sex. The severity of one's punishment changes depending on their age, type of crime and the victim's age. It is especially important whether the person has completed the ages 6, 12, 15, 18 and 21.[6,7]

When human development is examined, it can be understood that people who share the same chronological ages (CA) can have different body characteristics due to a difference in genetic and environmental factors.[8] Because of this each age estimation method must be tested on their accuracy and usefulness in forensic sciences for the betterment of the population.

Created in 1973, the Demirjian method (DM) is still the most used method for age estimation. According to this method, estimated ages (EA) is found by determining the development stage of the teeth by radiography and comparing the data/the tooth development scales formulated by different researchers.[9,10]

Cameriere et al. discovered the open apex method, in which they correlated the closure speed of the teeth apices with radio morphometric measurements in 2006. EA is calculated by using the data with the formula they developed.[11]

Cameriere et al. have also developed a method which they have stated can be used for diagnostic, prognostic, and therapeutic evaluation in auxologic pathology and in forensic sciences. This method is used for diagnostic, prognostic, and therapeutic evaluation in auxologic pathology and in forensic science. According to this method, data obtained by taking the necessary measurements from the X-rays of one's left hand are placed within the formula and the EA is determined.[12,13]

One of the skeletal methods used in age estimation are the atlases. In the Greulich & Pyle Atlas method (GPAM), 2 separate sections for men and women have included wrist radiographs with an estimated BA at approximately 1-year intervals. EA is determined by comparing the individual's radiography with the ones found in the atlas.[14,15]

The study has been aimed to compare the harmony between EA, BA and the CA determined by using the Cameriere open apices method (COAM), DM, Cameriere hand-wrist method (CHWM) and GPAM, and to determine which one of these methods give the most accurate answer in the most practical manner.

MATERIAL AND METHODS

ETHICAL APPROVAL

This study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Dicle University Faculty of Dentistry Local Ethics Committee with protocol number 2019/40 and date August 25, 2019. Written informed consent was obtained from all patients' parents.

STUDY DESIGN AND DATA SETTING

In our study conducted at the Department of Pediatric Dentistry, Faculty of Dentistry, Dicle University, between 2011 and 2019, a total of 1,352 panoramic and 1,352 hand-wrist radiographs were obtained from the same patients on the same day for diagnostic and treatment purposes before orthodontic treatment were examined. Cases that met the criteria set for our study were selected and included in the research. Inclusion criteria consisted of the absence of systemic disease (98), history of trauma to the maxillofacial or hand-

wrist region (5), presence of any syndrome (17), anomalies, absence of bilateral tooth agenesis in the mandible (287), and absence of artifacts or distortion (658) in the radiographs, allowing clear measurements to be taken.

The CA of the cases were calculated by subtracting the individual's birth date from the date the radiograph was taken and were converted to decimal format for the ease of statistical analysis.

A total of 287 cases (144 females, 143 males) between the ages of 9 and 14, meeting the inclusion criteria, were identified. For each case, a total of 287 panoramic and 287 hand-wrist radiographs taken between 2013 and 2019 were used in the study. The average of the EA obtained using COAM and DM was considered as the individual's DA, and the average of the EA obtained using GPAM and CHWM was considered as the individual's BA. For instance, if an individual's EA was 12 by COAM and 11 by DM, the DA was considered as 11.5.

After initial measurements were taken for each method, measurements were repeated by the same researchers under the same conditions for randomly selected cases after 4 weeks, observing intra-observer agreement. Inter-observer agreement was assessed by comparing measurements done by the first observer (T.N.Ş) with measurements done by the second observer (C.G.) on the same radiographs under the same conditions for each method. These data were statistically analyzed.

APPLICATION OF THE DM

For age estimation using this method, the mineralization stages of the left mandibular 7 teeth were evaluated in the obtained panoramic radiographs based on the mineralization table developed by Demirjian et al.[9] Firstly, mineralization stages for each tooth were symbolized with letters A to H according to the corresponding stages in the mineralization table. Then, these symbols were converted into numbers according to the sex-specific tables created by Demirjian et al., and these numbers were added up to obtain the total maturity scores for the cases. The ages corresponding to these scores were determined from the sex-specific maturity score tables prepared by Demirjian et al. to calculate the EA.

APPLICATION OF THE COAM

Using the Image J software (Image J, NIH, Maryland, USA), separate measurements of apical opening and length were performed for the left mandibular 7 teeth. Teeth with closed apices were recorded as N0, and the lengths of these teeth were not measured. If a tooth had dilaceration in its root or there was a loss of clarity in that region of the image, or if the tooth had undergone canal treatment, filling, or extraction, the symmetry on the right side of the same tooth was taken into consideration for evaluation. The values obtained from these measurements were then inserted into the formula to determine the EA of the individual.[11]

APPLICATION OF THE CHWM

Using the Image J software, bone area and carpal area were measured. When overlap was observed among carpal bones, they were measured as a single entity. The known formula was applied, and the required values were inserted to calculate the individual's EA.[12]

APPLICATION OF THE GPAM

The hand-wrist radiographs of the cases were matched with the standards in the section corresponding to sex in the atlas, and the closest standard was determined as the individual's EA.

STATISTICAL ANALYSIS

The G*Power 3.1 software package (Heinrich Heine University, Düsseldorf, Germany) was used to calculate the power value. For a study with a 5% error rate, 95% confidence level, and an effect size of 0.50, conducted with 10 observations in each group and a total of at least 120 observations across 12 groups, the power value was determined as 95%.

The data obtained from this study were analyzed using IBM SPSS V.21 (Chicago, IL, USA) software package. Cases were grouped for each age group, and statistical evaluations were performed. Descriptive statistics were assessed for all parameters. The Shapiro-Wilk's, Kolmogorov-Smirnov, Mann-Whitney U test, Kruskal-Wallis H test, Bonferroni-corrected Mann-Whitney U test, Wilcoxon test, and Kappa coefficient were utilized. A significance level of 0.05 was used for interpreting the results.

RESULTS

There is a statistically significant agreement between the first and second observers in all methods (p=0.01). This agreement is quite high, with intra-class correlation coefficient (ICC) values of 0.97 (0.929-0.988) for COAM, 0.989 (0.972-0.995) for CHWM, 0.993 (0.981-0.997) for GPAM, and 0.973 (0.936-0.989) for DM. The intra-observer agreement values were ICC=0.991 for the first observer and ICC=0.982 for the second observer.

In Figure 1, it can be observed that with CHWM, EA are approximately 1 year older than the CA of cases for the 11-year-old males and for the 9, 10, 11, and 12-year-old female groups.

As seen in Table 1, the CA-COAM difference for males is 0.74 years, the CA-CHWM difference is -0.32 years, and the CA-GPAM difference is 0.01 years (p<0.05). However, the CA-DM difference is -0.65 years (p>0.05).

In Table 2, the CA-COAM difference for females is 0.61 years, the CA-CHWM difference is -0.85 years, the CA-GPAM difference is -0.043 years, and the CA-DM difference is -0.64 years (p<0.05).

Looking at Table 3, it's evident that the most significant discrepancies occur in the 12-year-old group with COAM, 11-year-old group with DM, 11-year-

old group with CHWM, and the 11-year-old group with GPAM.

As seen in Table 4, both sexes have similar dental maturity compared to their peers, while in terms of bone maturity, both sexes are ahead of their peers, with females being approximately 6 months ahead of males.

DISCUSSION

Pediatric dentists and orthodontists frequently require age determination for both forensic reasons and in the diagnosis and treatment process.[16]

Sex-based differences in age determination have been highlighted by many researchers, and it's important to consider these differences. Previous studies have reported that females tend to exhibit faster dental maturation compared to males.[17,18] However, in the study, no significant sex-based difference was found in terms of dental maturation.

In addition to the information found in the literature, it's known that the pubertal growth spurt occurs about 2 years later in males compared to females.[19] In the study, although both skeletal age determination methods yielded more advanced values in both sex in terms of BA, statistically significant advancement was observed in females compared to males. This finding might be influenced by the geographical conditions of the region where the cases reside.
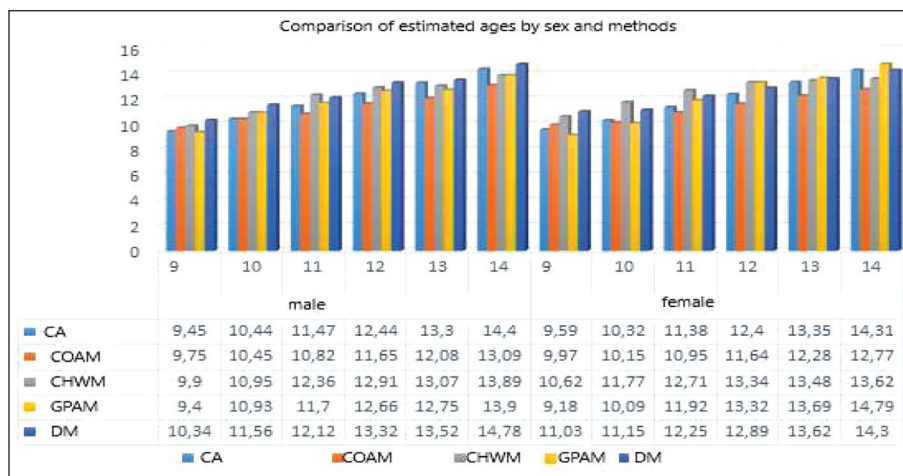

FIGURE 1: Comparison of estimated ages by sex and methods.

CA: Chronological age; COAM: Cameriere open apices method; CHWM: Cameriere hand-wrist method; GPAM: Greulich & Pyle Atlas method; DM: Demirjian method.

TABLE 1: Difference in CA-EA discrepancies among age groups for males.									
		Male					Kruskal-Wallis h test		
		n	Mean	Median	Minimum	Maximum	SD	Mean rank	H	p value
CA-COAM	9-9.99 age	10	-0.31	-0.28	-1.4	0.7	0.78	29.45	34.145	**0.001***
	10- 10.99 age	15	-0.01	-0.1	-0.5	0.65	0.39	34.1		
	11-11.99 age	37	0.64	0.7	-1.6	1.8	0.65	69.69		
	12-12.99 age	34	0.79	1.05	-1.2	2.3	0.96	77.06		
	13-13.99 age	32	1.22	1.57	-0.7	2.8	1.09	89.58		
	14-14.99 age	15	1.31	1.15	0.1	3.4	0.92	95		
	Total	143	0.74	0.7	-1.6	3.4	0.97	9-12 9-13 9-14		
								10-12 10-13 10-14		
CA-CHWM	9-9.99 age	10	-0.45	-0.58	-4.1	2.2	1.95	75.05	14.578	**0.012***
	10- 10.99 age	15	-0.51	-0.3	-3.3	3.1	1.54	68.43		
	11-11.99 age	37	-0.89	-0.8	-2.7	2.25	1.03	55.78		
	12-12.99 age	34	-0.47	-0.58	-2.4	2.05	1.21	66.82		
	13-13.99 age	32	0.24	-0.18	-2.1	5.5	1.52	86.78		
	14-14.99 age	15	0.51	0.6	-1.2	3.3	1.37	93.73		
	Total	143	-0.32	-0.4	-4.1	5.5	1.42	11-13 11-14		
CA-GPAM	9-9.99 age	10	0.05	0	-2.3	3.2	1.74	74.6	15.956	**0.007***
	10- 10.99 age	15	-0.5	-0.8	-2.3	2.6	1.41	53.27		
	11-11.99 age	37	-0.23	-0.7	-2	3.6	1.25	60.85		
	12-12.99 age	34	-0.22	-0.23	-1.4	1.3	0.77	66.06		
	13-13.99 age	32	0.55	0.5	-1.9	5.1	1.42	89.31		
	14-14.99 age	15	0.5	0.75	-1.25	1.8	0.98	93.03		
	Total	143	0.01	-0.1	-2.3	5.1	1.26	10-13 10-14		
								11-13 11-14		
								12-13 12-14		
CA-DM	9-9.99 age	10	-0.9	-0.95	-2.75	0.7	1.27	64.8	9.564	0.089
	10- 10.99 age	15	-1.12	-1.15	-2.2	0.7	0.98	52.33		
	11-11.99 age	37	-0.65	-0.7	-3.2	1.1	0.87	72.72		
	12-12.99 age	34	-0.88	-0.75	-3.1	0.95	0.9	64.76		
	13-13.99 age	32	-0.21	0.13	-2.45	2.35	1.25	87.58		
	14-14.99 age	15	-0.38	-0.6	-1.9	2.4	1.17	77.87		
	Total	143	-0.65	-0.75	-3.2	2.4	1.07			

*The results in bold are statistically significant; CA: Chronological age; EA: Estimated age; SD: Standard deviation; COAM: Cameriere open apices method; CHWM: Cameriere hand-wrist method; GPAM: Greulich & Pyle Atlas method; DM: Demirjian method.

While some studies in the literature suggest that using teeth for age determination provides more accurate results compared to other structures in the body due to their hard tissues and lower metabolism rates, there are also studies indicating that skeletal methods yield more accurate results compared to dental methods.[7,20] In our study, both skeletal and dental methods were compared, and the results showed that the skeletal method (GPAM) provided the closest results to CA (p<0.005).

In many studies conducted in Türkiye evaluating COAM on cases, the results were found to be un-derestimated.[6,21,22] Similarly, in this study, the results obtained with COAM also showed an underestimation of approximately 0.67 years.

From the perspective of Turkish laws, ages 12 and 15 are highly significant.[6,7] Similarly to this study, Ozveren et al. reported that using the COAM method, the most erroneous results were obtained in the 12-year-old age group.[22] To avoid causing legal injustices, it's considered beneficial to support the COAM method with additional methods when used in this age group.

In most studies evaluating DM in the Turkish population, overestimated results have been ob-

TABLE 2: Difference in CA-EA discrepancies among age groups for females.									
		Female					Kruskal-Wallis H test		
		n	Mean	Median	Minimum	Maximum	SD	Mean rank	H	p value
CA-COAM	9-9.99 age	13	-0.38	-0.6	-1.8	1.1	0.75	29.08	37.798	**0.001***
	10-10.99 age	21	0.17	0.1	-1.25	1.9	0.71	50.6		
	11-11.99 age	31	0.43	0.35	-1.2	2.1	0.79	65.27		
	12-12.99 age	46	0.76	0.75	-0.6	2.1	0.79	80.08		
	13-13.99 age	21	1.07	1	-0.2	2.6	0.8	93.43		
	14-14.99 age	12	1.54	1.45	0.6	4.1	0.95	110.88		
	Total	144	0.61	0.6	-1.8	4.1	0.91	9-12 9-13 9-14		
								10-13 10-14		
								11-14		
CA-CHWM	9-9.99 age	13	-1.03	-1.1	-3.4	0.9	1.2	66.35	46.948	**0.001***
	10- 10.99 age	21	-1.45	-1.6	-3.4	1	1.09	49.9		
	11-11.99 age	31	-1.33	-1.25	-2.5	0.25	0.65	50.79		
	12-12.99 age	46	-0.94	-0.9	-3.1	0.6	0.86	70.78		
	13-13.99 age	21	-0.13	-0.1	-1.8	1.3	0.7	103.83		
	14-14.99 age	12	0.69	0.9	-1.65	1.5	0.84	126.54		
	Total	144	-0.85	-0.83	-3.4	1.5	1.06	9-14		
								10-13 10-14		
								11-13 11-14		
								12-13 12-14		
CA-GPAM	9-9.99 age	13	0.4	0.6	-0.5	1.45	0.62	105.12	24.081	**0.001***
	10-10.99 age	21	0.24	0.25	-2.9	2.95	1.42	96.62		
	11-11.99 age	31	-0.54	-0.25	-3.25	1.5	1.17	70.32		
	12-12.99 age	46	-0.92	-0.8	-2.9	1.3	1.05	54.14		
	13-13.99 age	21	-0.35	-0.25	-1.9	2.2	1.22	73.57		
	14-14.99 age	12	-0.48	-0.5	-1.75	0.5	0.62	69.08		
	Total	144	-0.43	-0.35	-3.25	2.95	1.18	12-10 12-9		
CA-DM	9-9.99 age	13	-1.44	-1.5	-3.3	0.05	0.99	41.54	21.756	**0.001***
	10- 10.99 age	21	-0.83	-1.15	-3.1	2.5	1.45	58.19		
	11-11.99 age	31	-0.87	-0.8	-2.7	1.3	0.88	63.39		
	12-12.99 age	46	-0.5	-0.53	-2.3	1.1	0.97	78.84		
	13-13.99 age	21	-0.27	-0.45	-2.5	1.8	0.97	87.57		
	14-14.99 age	12	0.01	-0.1	-0.6	1	0.47	103.96		
	Total	144	-0.64	-0.7	-3.3	2.5	1.06	9-13 9-14		
								10-14		

*The results in bold are statistically significant; CA: Chronological age; EA: Estimated age; SD: Standard deviation; COAM: Cameriere open apices method; CHWM: Cameriere hand-wrist method; GPAM: Greulich & Pyle Atlas method; DM: Demirjian method.

tained.[16] Similarly, in this study, an overestimated result of 0.64 years was obtained. When using DM for age determination in a Turkish case, it's important to keep in mind the likelihood of obtaining overestimated results.

Many researchers find the atlas method easy to learn, practical, fast, and repeatable. Therefore, in many countries, including our country, since there is no valid atlas specific to each country, the GPA method is still used.[23,24] Büken et al. suggested using GPA instead of the Gök atlas for age determination in cases aged 11 to 18 in Türkiye, especially due to its legal importance.[25-27] Similarly, Acungil reported that using GPA instead of the Gök atlas is more suitable for the Turkish population based on their study results.[15] Both researchers also added that GPA needs

TABLE 3: Distribution of EA according to CA.												
		EA<12				EA≥12				EA≥15			
CA	n	COAM	CHWM	GPAM	DM	COAM	CHWM	GPAM	DM	COAM	CHWM	GPAM	DM
9-9.99 age	23	100.0%	87.0%	100.0%	87.0%	-	13.0%	-	13.0%	-	-	-	-
10-10.99 age	36	100.0%	55.6%	80.6%	66.7%	-	44.4%	-	33.3%	-	-	-	-
11-11.99 age	68	91.2%	25.0%	47.1%	36.8%	8.8%	75.0%*	51.5%*	63.2%*	-	-	1.5%	-
12-12.99 age	80	61.3%*	8.8%	12.5%	13.8%	38.8%	88.8%	80.0%	83.8%	-	2.5%	7.5%	2.5%
13-13.99 age	53	41.5%	15.1%	15.1%	9.4%	58.5%	79.2%	62.3%	81.1%	-	5.7%	22.6%	9.4%
14-14.99 age	27	11.1%	3.7%	-	3.7%	88.9%	77.8%	55.6%	70.4%	-	18.5%	44.4%	25.9%

*Bold values indicate the highest discrepancies; EA: Estimated age; CA: Chronological age; COAM: Cameriere open apices method; CHWM: Cameriere hand-wrist method; GPAM: Greulich & Pyle Atlas method; DM: Demirjian method.

TABLE 4: Differences between CA and DA, and CA and BA discrepancies across sex.										
		Sex						Mann-Whitney U test		
		n	Mean	Median	Minimum	Maximum	SD	Mean rank	z	p value
CA-DA	Male	143	0.05	0.05	-2.4	2.9	0.96	146.78	-0.565	0.572
	Female	144	-0.01	-0.03	-2.55	2.25	0.93	141.24		
	Total	287	0.02	0.01	-2.55	2.9	0.94			
CA-BA	Male	143	-0.15	-0.25	-2.75	5.3	1.24	159.9	-3.234	0.001*
	Female	144	-0.64	-0.65	-2.9	1.75	0.86	128.22		
	Total	287	-0.4	-0.5	-2.9	5.3	1.09			

*The results in bold are statistically significant; CA: Chronological age; DA: Dental age; BA: Bone age; SD: Standard deviation.

to be modified for the Turkish population.[15,25-27] Considering this information, GPAM was included among the evaluated methods in our study, instead of the Gök atlas.

In a meta-analysis conducted in 2019, they reported that the GPA standard is not precise, and caution should be exercised when using it on Asian male and African female populations, especially for age determination for forensic/legal purposes.[28] However, in contrast to these findings, the method evaluated in both female and male cases in our study yielded the closest results to CA using GPAM. This could be attributed to the familiarity of the evaluating researcher with the standards in the GPAM atlas or their experience in reading wrist X-rays.

Particularly, Cameriere et al., who emphasized the good correlation between the ossification processes of carpal bones and CA, developed a formula based on the measurement of the areas of bones in this region.[13] Cameriere et al. revised and improved this formula according to the Italian population, achieving results very close to CA, such as 0 years

for females and -0.3 years for males. They suggested that each population should modify the formula according to its own characteristics and conduct numerous validation tests before using the method for forensic purposes.[29] Similarly, considering the limited number of studies conducted in our country regarding this method and the significant age discrepancies observed between EA and CA using the CHWM in our study, we believe that this method should be subjected to more validation tests with a larger sample size for Turkish children before being used for forensic purposes.[30]

Kanbur et al. conducted a study in 2006 comparing the dental and skeletal ages of children with growth and developmental retardation to those with normal growth and development, in comparison with their CA.[31] They used GPAM for skeletal age determination and DM for DA determination. In the control group, there was no significant difference between CA, DA, and BA. In the group with growth retardation, they found no significant difference between CA and DA, but they did find a significant dif-

ference between DA and skeletal age, as well as between CA and skeletal age. They stated that the DM is a suitable method for DA determination and that the dental development of adolescents with growth retardation can be considered acceptable based on their CA, while their skeletal ages are not acceptable based on their CA. In the study with healthy children, we found that using DM, the dental development of our cases was ahead of their peers in terms of DA, but their BA was ahead of their peers in terms of skeletal age. However, when using another dental method, COAM, the dental maturity of cases was behind their peers. Looking at the average EA compared to the obtained DA, we determined that the cases had the same dental maturity as their peers. As a result, when age determination is performed, it is believed that using both skeletal age and DA determination methods together can provide more accurate results closer to the CA.

In a study conducted by Kumar et al. on children aged 8-14, in addition to panoramic radiographs, wrist radiographs were evaluated.[32] This allowed for an assessment of growth and development before determining DAs and investigating the relationship between DA, skeletal age, and CA.[33] They emphasized that both dental and skeletal development should be assessed to diagnose short stature (growth retardation) in children.[32] In another study involving 288 white Italian children aged 5-15, Cameriere et al. evaluated the COAM, CHWM, and their combined method for age determination.[34] They concluded that the combined method was the most suitable for age determination among these methods. A review of age determination in forensic dentistry stated that using multiple methods together is necessary for more reliable age estimation.[35] Considering the results of our study on children in our region, there was no significant difference between the estimated DAs obtained using COAM and DM, when averaged, and the CA. This finding indicates that these methods provide values closest to CA for both sexes. When used separately, the GPAM method provided the ages closest to CA. GPAM was also identified as the most practical method.

The reason GPAM was identified as the most practical method is that it doesn't require various measurements or reference tables. However, this might appear practical for an eye familiar with GPA, but it might not be practical for an unfamiliar eye. The limitations of the study could include its focus on a limited region and population, as well as the subjective interpretation in assessing practicality.

CONCLUSION

GPAM was found to be the closest to CA and the most practical method. It should be considered that it may be useful to evaluate several methods together while determining the age. Specifically, it's crucial to consider both DA and BA together. The atlas method's practicality and ability to closely match CA suggest that an atlas encompassing both DA and BA could be highly successful in age determination. As a short-term solution, using the methods after necessary modifications are evaluated made seems appropriate.

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