Available online at *www.ujpronline.com*
Universal Journal of Pharmaceutical Research
An International Peer Reviewed Journal
ISSN: 2831-5235 (Print); 2456-8058 (Electronic)

RESEARCH ARTICLE

RELIABILITY OF MODERN RADIOGRAPHIC DENTAL AGE ESTIMATION METHODS AMONG YEMENI CHILDREN IN SANA'A CITY, YEMEN

Arij Lutf Abdulrhman Abdul-Majid[1], Husam Abdullah Anas Aleryani[1], Yusra Ahmed Ali Sharf Aldeen[2], Hassan Abdulwahab Al-Shamahy[2,3]

[1]*Orthodontics, Pedodontics and Prevention Department Faculty of Dentistry, Sana'a University, Yemen.*
[2]*Departement of Basic Sciences, Faculty of Dentistry, Sana'a University, Republic of Yemen.*
[3]*Medical Microbiology and Clinical Immunology Department, Faculty of Medicine and Health Sciences, Sana'a University.*

Article Info:

Article History:
Received: 21 September 2024
Reviewed: 13 November 2024
Accepted: 18 December 2024
Published: 15 January 2025

Cite this article:
Abdul-Majid ALA, Anas Aleryani HA, Sharf Aldeen YAA, Al-Shamahy HA. Reliability of modern radiographic dental age estimation methods among Yemeni children in Sana'a city, Yemen. Universal Journal of Pharmaceutical Research 2024; 9(6): 14-24.
http://doi.org/10.22270/ujpr.v9i6.1234

***Address for Correspondence:**
Prof. Hassan A. Al-Shamahy, Department of Basic Sciences, Faculty of Dentistry, Sana'a University, Republic of Yemen. Medical Microbiology and Clinical Immunology Department, Faculty of Medicine and Health Sciences, Sana'a University. Tel: +967-1-239551; E-mail: *shmahe@yemen.net.ye*

Abstract

Background and aim: Without requiring any more radiographic research, dental age assessment using panoramic X-rays is particularly helpful to children dentists and orthodontists when arranging treatments. The purpose of this study was to evaluate the precision of three contemporary radiography techniques for estimating Yemeni children's dental ages.
Methods: The methods are Demirjian's method, Cameriere's open apex method and Al-Qahtani's London Atlas, in Sana'a City, Yemeni sample. The 1200 radiographs of Yemeni Children (592 girls and 608 boys) aged under the age 18 years were analyzed by the three methods. The accuracy of each method was assessed using the mean difference and t-tests were used to assess the difference between chronological age and dental age within each age category.
Results: Demirjian's method significantly underestimated age for both sexes ($p<0.001$), according to the results, with a mean difference of 0.67 years (a mean difference of 0.69 years for boys and 0.66 years for girls). With a mean difference of 0.93 years (a mean difference of 0.92 years for girls and 0.94 years for boys), the Cameriere's open apex method also significantly underestimated age for both sexes ($p<0.001$). In contrast, only the 6–6.99 and 7–7.99 age groups showed no significant differences between chronological age and dental age in either method or gender.
Conclusion: When it came to determining dental age, the London Atlas approach was the most accurate, followed by Demirjian's method, and the Cameriere's method was the least accurate. Furthermore, all three techniques were determined to be trustworthy and could be helpful in determining the age of Yemeni children whose chronological ages are unknown. For every age group, more research with a larger sample is needed.
Keywords: Cameriere's method, children, Demirjian's method, dental age estimation, London Atlas method, panoramic X-rays.

INTRODUCTION

Age is a key issue that plays a vital effect in all aspects of life. It is established by the date of birth and the number of years that have passed since then to any given point in time; this is known as the chronological age[1]. It is documented in birth certificates, medical records, government databases, and many other places, but without these records, alternative methods of determining age are crucial, particularly considering that approximately one-fourth of all births of children under five worldwide go unrecorded[2]. Only 50% of births in underdeveloped nations are recognized, compared to 70% in rich nations, meaning that 50 million births worldwide go unreported. In order to evaluate legal responsibility or social rights like school attendance, social benefits, adoption, employment, marriage, and asylum, it is crucial to estimate an individual's age when it is uncertain. The age at death offers information about previous inhabitants and is essential for identifying people in mass disasters or crime scene investigations[3].

When the date of birth is unknown, age estimation is used. This is not a precise evaluation; rather, it describes the individual's traits pertaining to the level of development that fluctuates depending on environmental, metabolic, nutritional, and genetic factors. It is utilized in a number of significant medical fields, including orthodontic treatment, endocrinopathy, pediatrics, forensic medicine, and

premature births[4]. When choosing the right orthodontic device and scheduling therapy, children dentists and orthodontists rely on dental age assessment (DAA) [5]. It is essential at the level of diagnosis, prognosis, start treatment in the optimal growth stage (pubertal growth spurt) and evaluation of treatments in order to achieve ideal correction of skeletal discrepancies, use extraoral tractions and functional appliances, and to correctly schedule orthognathic surgery[6]. Thus, research on the dental age estimation is essential.

Numerous techniques have been used to determine a child's age, primarily by evaluating the morphological and developmental changes of their teeth and bones. Even though age is estimated using skeletal methods, it has been discovered that a number of environmental factors affect the variability of bone maturation. Since genes rather than environmental factors influence the rate of tooth calcification, age prediction based on dental development is preferred. As a result, there is less heterogeneity observed in dental indicators[7,8]. Using dental maturity as a guide, a variety of morphological and radiological approaches is used to estimate chronological age.

Yemen is a developing country. Many Yemenis do not know their exact date of births or have their births unregistered. Recently Yemen suffers from war, political unrest, and crisis, that led to increase poverty, illiteracy and immigration. All these factors is overstated obliteration or loss of personal documents if it was exists. So unknown chronological age or unregistered births problem is exacerbated. There was not related study for estimation of the chronological ages of in Yemeni population. For all these reasons, this study was specifically carried out in order to determine and select suitable modern method to dental age estimation in Yemeni children population using panoramic radiographic dental-age estimation methods and available documents. The accuracy of three approaches for estimating age in non-adults using dental radiographs is evaluated in this study. The most widely used scoring method for estimating age was created by Demirjian *et al.*[9], Cameriere *et al.*[10], and AlQahtani *et al.*[11].The aim of this study was to test the accuracy of three modern radiographic methods for dental age estimation on Yemeni children.

MATERIALS AND METHODS

Study design and area: A cross-sectional study with collection of data was performed on a sample of1200 of panoramic X-rays, for Yemeni children from 3 to 17.99 years old who were attending in radiological centers in Sana'a city Yemen during the period of 12 months from 1/1/2022 to 1/1/2023.

Study population: One thousand two hundred children randomly selected from 3 to17.9 years old attended a radiological centers (Al Waleed radiographic center and Taiz radiographic center) in Sana'a city Yemen during the period of 12 months.

Inclusion criteria: Yemeni children under 18 years old, availability of complete patient records (date of birth, date of X-ray) and good quality of the radiographs.

Exclusion criteria: Patients with orthodontic appliances or history of orthodontic treatment, incomplete patient records, history of extractions, systemic disease affecting growth(e.g endocrine disease), and abnormal dental conditions (e.g. impactation, congenitally missing teeth).

Sample size: When calculating the sample size using a calculator, it was found that the required sample was 200 children, with a confidence limit of 95%. However, a sample of 1200 children who were scanned with panoramic X-rays was worked on. The number was increased to facilitate data collection and provide more accurate results.

Data collection: Socio-demographic data including, chronological age and gender was collected in questionnaire. The chronological age of the patient was calculated by subtracting the date of birth from the date of taking the radiographic (date of birth – date of taking radiograph).

Estimation of dental age: Every PR was assigned a number and coded. The lead investigator evaluated all of the radiographs, and the morphological appearance of the teeth on PR was used to estimate tooth maturity.

Estimation of dental age by Demirjian's: Demirjian's (1973) stages A through H were used to register tooth maturity on the seven mandibular left permanent teeth. The age score tables were then used to award the appropriate age scores. The estimated dental age of a specific person was calculated by adding the scores for the seven teeth[9].

Estimation of dental age by Cameriere *et al.*: In summary, radiographs of the permanent mandibular teeth on the left side—aside from the third molars—are assessed. The number of teeth that had fully developed roots and closed apical ends (N0) was determined. We also looked at teeth with open apices and insufficient root growth[10]. The distance (Ai, i=1,..., 5) between the inner sides of the open apex was measured for teeth with a single root. The total of the distances between the inner surfaces of the two open apices was assessed for teeth with two roots (Ai, i=6, 7). To account for the impact of any variations in X-ray magnification and angulation, measurements were normalized by dividing by the length of the tooth (Li, i=1,..., 7). Dental maturity is evaluated according to the normalized measurements of the seven left mandibular permanent teeth (xi=Ai/Li, i=1,..., 7), the sum of normalized open apices (*s*),and the number (*N*0) of teeth with root development complete[10]: (1) Age=8.971 + 0.375*g* + 1.631*x*5 + 0.674*N*0 – 1.034*s* – 0.176s**N*0

Where *g* is a variable equal to 1 for boys and 0 for girls.

Estimation of dental age by London Atlas: When estimating age using this method, all of the teeth that were present were taken into account. Each tooth was examined separately, its developmental stage noted, and the age calculator with the closest age match was used, using the written explanations and drawings for each step.

Statistical analysis: Intra-observer and inter-observer error were examined because measurement validity and reliability are extremely important. A paired sample t-test was used to determine the significance of the

difference between DA and CA for the three formulas in order to appraise the correctness of the age estimate approach. For all statistical analyses, SPSS 22.0 was used.

Ethical approval: The Medical Ethics Committee of Sana'a University's Faculty of Dentistry provided ethical approval, reference number 17/2021, dated June 1, 2021, and all data, including the patient's identity, were kept confidential.

RESULTS

Table 1 shows overall distribution of the chronological age. The standard error was ±0.09 and the mean chronological age was 11.68±3.24 years. The minimum and highest ages were 3.80 and 17.9 years old, respectively, while the median age was 11.68 years old. The 11.34 years old were the majority age group (13%). The chronological age distribution of boys and girls is displayed in Table 2. Boys were 12.10±3.12 years old on average, with a SE of ±0.13 years. The average age of the girls was 11.25±3.31 years, with a standard error of ±0.14 years. The mean CA for boys and girls did not differ in a way that was statistically significant (p=0.733). Using Demirjian's technique, Table 3 displays the overall mean age discrepancy between chronological and dental age. The sample's CA-DA was 67±0.13 years, 95% CI 0.42-0.93, with a standard error of 0.13 years. There was a highly significant difference between CA (11.68±3.24 years) and DA (11.01±3.22) (t (1200)=5.112, p=0.000). The DA was often underestimated, with the exception of children aged 3, 4, 5, and 7 years, who were overestimated. With a mean age discrepancy of less than a month (-0.05 years), age group 7-7.99 had the most accurate age estimation, whereas age group 17—which had a mean age difference of 1.55 years—was the most recent age group to be reliably determined. Table 4 compares the dental and chronological ages of boys using Demirjian's method. With a 95% CI of 0.34 to 1.03 and a SE of 0.16 years, the sample's CA-DA was.69±.18 years. It was determined that the difference between DA (11.41±3.08) and CA (12.10±3.12) was highly significant (p=0.000). The DA was often underestimated, with the exception of those aged 4, 5, and 7 years, which were inflated.

Table 1: Overall distribution of the chronological age for 1200 children assessed by panoramic radiographs.

Age group in Years	n	Mean (Yrs.)	SD (Yrs.)	SE (Yrs.)	Min (Yrs.)	Max (Yrs.)	Median (Yrs.)
3-3.99	1	3.80		-	3.80	3.80	3.80
4-4.99	3	4.40	0.17	0.10	4.20	4.50	4.50
5-5.99	39	5.45	0.27	0.04	5.00	5.90	5.50
6-6.99	53	6.44	0.31	0.04	6.00	6.90	6.50
7-7.99	64	7.42	0.35	0.04	7.00	7.90	7.35
8-8.99	91	8.39	0.30	0.03	8.00	8.90	8.40
9-9.99	120	9.42	0.32	0.03	9.00	9.90	9.40
10-10.99	131	10.35	0.30	0.03	10.00	10.90	10.30
11-11.99	157	11.34	0.28	0.02	11.00	11.90	11.30
12-12.99	95	12.41	0.30	0.03	12.00	12.90	12.40
13-13.99	122	13.40	0.30	0.03	13.00	13.90	13.40
14-14.99	77	14.36	0.33	0.04	14.00	14.90	14.30
15-15.99	93	15.45	0.31	0.03	15.00	15.90	15.50
16-16.99	84	16.33	0.29	0.03	16.00	16.90	16.30
17	70	17.27	0.32	0.04	17.00	17.90	17.11
Total	1200	11.68	3.24	0.09	3.80	17.90	11.50

Table 2: Distribution of the chronological age between boys and girls.

	Boys						Girls					
Age group Years	n	Mean (Yrs)	SD (Yrs)	SE (Yrs)	Median	Range (Yrs.)	n	Mean (Yrs)	SD (Yrs)	SE (Yrs)	Median	Range (Yrs)
3-3.99							1	3.80		-	3.80	0.00
4-4.99	2	4.35	0.21	0.15	4.35	0.30	1	4.50		-	4.50	0.00
5-5.99	6	5.47	0.31	0.13	5.50	0.80	33	5.45	0.26	0.05	5.50	0.90
6-6.99	12	6.39	0.36	0.10	6.40	0.80	41	6.46	0.30	0.05	6.50	0.90
7-7.99	26	7.34	0.35	0.07	7.20	0.90	38	7.47	0.35	0.06	7.50	0.90
8-8.99	53	8.48	0.26	0.04	8.50	0.90	38	8.27	0.30	0.05	8.15	0.90
9-9.99	68	9.38	0.32	0.04	9.30	0.90	52	9.47	0.32	0.04	9.40	0.90
10-10.99	74	10.32	0.30	0.03	10.30	0.90	57	10.40	0.29	0.04	10.40	0.90
11-11.99	70	11.40	0.31	0.04	11.40	0.90	87	11.30	0.25	0.03	11.30	0.90
12-12.99	53	12.41	0.28	0.04	12.50	0.90	42	12.41	0.32	0.05	12.35	0.90
13-13.99	56	13.44	0.29	0.04	13.50	0.90	66	13.37	0.31	0.04	13.40	0.90
14-14.99	42	14.42	0.35	0.05	14.35	0.90	35	14.29	0.28	0.05	14.20	0.90
15-15.99	54	15.48	0.29	0.04	15.50	0.90	39	15.41	0.33	0.05	15.40	0.90
16-16.99	46	16.33	0.29	0.04	16.30	0.90	38	16.34	0.29	0.05	16.25	0.90
17	46	17.31	0.35	0.05	17.20	1.00	24	17.20	0.25	0.05	17.10	0.70
Total	608	12.10	3.12	0.13	11.90	13.80	592	11.25	3.31	0.14	11.20	13.90

Table 3: Overall mean age difference between chronological and dental age by Demirjian's method.

Age group in Years	n	Mean (Yrs)		CA-DA	95% confidence interval for mean		SD (Yrs)	SE (Yrs)	t-test	*p*-value CA vs DA
		CA	DA		Lower Bound	Upper Bound				
3-3.99	1	3.80	4.20	-0.40	0	0	0	0	-	-
4-4.99	3	4.40	6.20	-1.80	-5.17	1.57	1.21	1.07	-1.483-	0.212
5-5.99	39	5.45	5.83	-0.38	-0.66	-0.09	0.14	0.14	-2.685-	0.010*
6-6.99	53	6.44	6.26	0.18	-0.13	0.50	0.16	0.15	1.161	0.250
7-7.99	64	7.42	7.47	-0.05	-0.20	0.11	0.08	0.08	-.616-	0.539
8-8.99	91	8.39	7.98	0.42	0.21	0.62	0.10	0.09	3.979	0.000*
9-9.99	120	9.42	8.64	0.78	0.59	0.96	0.09	0.09	8.376	0.000*
10-10.99	131	10.35	9.54	0.81	0.60	1.03	0.11	0.11	7.462	0.000*
11-11.99	157	11.34	10.53	0.81	0.54	1.08	0.14	0.13	5.962	0.000*
12-12.99	95	12.41	11.38	1.04	0.75	1.33	0.15	0.15	7.101	0.000*
13-13.99	122	13.40	12.68	0.72	0.43	1.00	0.14	0.14	4.967	0.000*
14-14.99	77	14.36	13.87	0.49	0.13	0.85	0.18	0.18	2.723	0.008*
15-15.99	93	15.45	14.81	0.63	0.40	0.87	0.12	0.12	5.322	0.000*
16-16.99	84	16.33	15.54	0.79	0.60	0.97	0.09	0.09	5.059	0.000*
17	70	17.27	15.72	1.55	1.39	1.72	0.08	0.08	18.363	0.000*
Total	1200	11.68	11.01	0.67	0.42	0.93	0.13	0.13	5.112	0.000*

Table 4: Comparison between chronological and dental age by Demirjian's method in boys.

Age group in Years	n	Mean (Yrs)		CA-DA	95% Confidence Interval for Mean		SD (Yrs)	SE (Yrs)	t-test	*p*-value CA vs DA
		CA	DA		Lower Bound	Upper Bound				
3-3.99		-	-	-	-	-	-	-	-	---
4-4.99	2	4.35	6.45	-2.10	-27.57	23.37	2.06	1.51	-1.022	0.492
5-5.99	6	5.47	6.02	-0.55	-1.71	0.61	0.47	0.44	-1.169-	0.288
6-6.99	12	6.39	6.28	0.11	-0.66	0.88	0.36	0.34	0.305	0.766
7-7.99	26	7.34	7.60	-0.26	-0.46	-0.07	0.10	0.09	-2.713	0.009*
8-8.99	53	8.49	8.07	0.42	0.16	0.68	0.13	0.12	3.272	0.002*
9-9.99	68	9.38	8.63	0.75	0.51	0.98	0.12	0.11	6.332	0.000*
10-10.99	74	10.32	9.58	0.74	0.44	1.04	0.15	0.15	4.883	0.000*
11-11.99	70	11.40	10.75	0.65	0.21	1.08	0.22	0.21	2.926	0.005*
12-12.99	53	12.41	11.66	0.75	0.32	1.19	0.22	0.21	3.490	0.001*
13-13.99	56	13.44	12.78	0.66	0.25	1.07	0.21	0.20	3.220	0.002*
14-14.99	42	14.42	13.92	0.50	0.03	0.97	0.22	0.23	2.141	0.038*
15-15.99	54	15.48	14.74	0.74	0.45	1.02	0.14	0.15	5.124	0.000*
16-16.99	46	16.33	15.37	0.96	0.66	1.25	0.15	0.14	6.544	0.000*
17	46	17.31	15.67	1.64	1.41	1.88	0.12	0.11	14.203	0.000*
Total	608	12.10	11.41	0.69	0.34	1.03	0.18	0.16	3.856	0.000

With a mean age discrepancy of less than a month (0.11 years), the age group 6–6.99 had the most accurate age estimation. With a mean age difference of 1.64 years, age group 17 was the most recent to be reliably calculated. Table 5 compares the dental and chronological ages of girls using Demirjian's method. The sample's CA-DA was 66±0.19 years, 95% CI 0.28–1.04, with a standard error of 0.17 years. It was determined that the difference between DA (10.59±3.29) and CA (11.25±3.31) was highly significant (p=0.001). The DA was often under-estimated, with the exception of age groups 3, 4, and 5, which were overestimated. With a mean age discrepancy of less than a month, or 0.09 years, the age group 7-7.99 had the most accurate age estimation. The most recent properly calculated ages were those in the 12–12.99 and 17– age groups, with mean age differences of 1.40 and 1.38 years, respectively. Using Cameriere's Method, Table 6 compares dental and chronological age. With a 95% CI of 0.68 to 1.17 and a SE of 0.12 years, the sample's overall mean age difference (CA-DA) was.93±0.13 years. There was a highly significant difference between CA (11.68±3.24 years) and DA (10.75±2.93). The DA was often underestimated, with the exception of children aged 3, 4, 5, and 7 years, who were overestimated.

Table 5: Comparison between chronological and dental age by Demirjian's method in girls.

Age group in years	n	Mean (Yrs.)		CA-DA	95% confidence interval for mean		SD (Yrs)	SE (Yrs)	t-test	*p*-value CA vs DA
		CA	DA		Lower Bound	Upper Bound				
3-3.99	1	3.80	4.20	-0.40	-		-	-	-	-
4-4.99	1	4.50	5.70	-1.20	-		-	-	-	-
5-5.99	33	5.45	5.80	-0.35	-0.64	-0.05	0.15	0.14	-2.377-	0.022*
6-6.99	41	6.46	6.25	0.21	-0.16	0.57	0.18	0.17	1.152	0.255
7-7.99	38	7.47	7.38	0.09	-0.13	0.32	0.11	0.11	0.865	0.390
8-8.99	38	8.27	7.86	0.41	0.06	0.76	0.17	0.17	2.375	0.022*
9-9.99	52	9.47	8.66	0.81	0.51	1.11	0.15	0.14	5.457	0.000*
10-10.99	57	10.40	9.50	0.90	0.59	1.22	0.16		5.824	0.000*
11-11.99	87	11.30	10.36	0.94	0.61	1.28	0.17	0.16	5.608	0.000*
12-12.99	42	12.42	11.02	1.40	1.04	1.74	0.17	0.16	8.017	0.000*
13-13.99	66	13.38	12.60	0.78	0.36	1.17	0.20	0.20	3.767	0.000*
14-14.99	35	14.28	13.80	0.48	-0.09	1.07	0.28	0.29	1.696	0.099
15-15.99	39	15.41	14.91	0.50	0.08	0.90	0.20	0.20	2.421	0.020*
16-16.99	38	16.34	15.75	0.59	0.38	0.78	0.01	0.09	5.936	0.000*
17	24	17.21	15.83	1.38	1.16	1.59	0.11	0.10	13.023	0.000*
Total	592	11.25	10.59	0.66	0.28	1.04	0.19	0.17	3.444	0.001*

.

Table 6: Comparison between chronological and dental age by Cameriere's method.

Age group in years	n	Mean (Yrs.)		CA-DA	95% Confidence Interval for Mean		SD (Yrs.)	SE (Yrs.)	t-test	-value CA vs DA
		CA	DA		Lower Bound	Upper Bound				
3-3.99	1	3.80	6.20	-2.40	0	0	0	0	-	-
4-4.99	3	4.40	6.98	-2.58	-8.25	3.12	1.34	1.18	-1.921-	0.193
5-5.99	39	5.45	5.87	-0.42	-0.72	-0.11	0.15	0.16	-2.725-	0.009*
6-6.99	53	6.44	6.35	0.09	-0.19	0.37	0.14	0.14	0.655	0.515
7-7.99	64	7.42	7.49	-0.07	-0.29	0.15	0.11	0.11	-0.626-	0.533
8-8.99	91	8.40	8.07	0.33	0.09	0.55	0.11	0.11	2.842	0.005*
9-9.99	120	9.42	8.76	0.66	0.46	0.86	0.09	0.10	6.662	0.000*
10-10.99	131	10.35	9.66	0.69	0.52	0.88	0.09	0.09	7.831	0.000*
11-11.99	157	11.34	10.14	1.2	1.04	1.37	0.08	0.08	14.425	0.000*
12-12.99	95	12.41	10.90	1.51	1.29	1.74	0.11	0.11	13.189	0.000*
13-13.99	122	13.40	12.02	1.38	1.10	1.66	0.14	0.13	9.778	0.000*
14-14.99	77	14.36	13.53	0.83	0.42	1.23	0.20	0.19	4.096	0.000*
15-15.99	93	15.45	14.45	1	0.77	1.23	0.12	0.12	8.589	0.000*
16-16.99	84	16.33	15.01	1.32	1.18	1.47	0.08	0.07	17.913	0.000
17	70	17.27	14.87	2.4	2.17	2.63	0.12	0.11	20.461	0.000*
Total	1200	11.68	10.75	0.93	0.68	1.17	0.13	0.12	7.352	0.000*

The age groups 7-7.99 and 6-6.99 had the most accurate estimates, with mean age differences of less than a month (-0.07 years) and 0.09 years, respectively. With a mean age difference of 2.4 years, age group 17 was the most recent to be reliably calculated. A comparison of dental and chronological age is presented in Table 7 in boys, by Cameriere's method. The sample's CA-DA was 0.94±0.18 years, 95% CI 60–1.27, with a standard error of 0.17 years. It was determined that there was a highly significant difference between CA (12.10±3.12) and DA (11.16±2.82) (t-test=5.504, *p*=0.000). The DA was often underestimated, with the exception of those aged 4, 5, and 7, who were inflated. With a mean age discrepancy of less than a month (0.06), the age group 6–6.99 had the most accurate age estimation with a mean age difference of 2.60 years, age group 17 was the most recent to be reliably calculated.

Table 8 presents a comparison between dental and chronological age in girls, by the Cameriere's method. The sample's CA-DA was 0.92±0.18 years, 95% CI: 56–1.28, with a standard error of 0.17 years. There was a highly significant difference between CA (11.25±3.31) and DA (10.33±2.98). The DA was often underestimated, with the exception of children aged 3, 4, 5, and 7, who were overestimated. Age group 7-7.99 had the most accurate age estimate; with a mean age discrepancy of less than a month (0.01) years. The most recent age group to be reliably approximated was 17 years old, with a mean age difference of 2.02 years.

Table 7: Comparison between chronological and dental age by Cameriere's method in boys.

Age group in years	n	Mean (Yrs)		CA-DA	95% Confidence Interval for Mean		SD (Yrs)	SE (Yrs)	t-test	*p*-value CA vs DA
		CA	DA		Lower Bound	Upper Bound				
3-3.99	-	-	-	-	-	-		-	-	-
4-4.99	2	4.35	7.45	-3.10	-29.86	23.67	2.16	1.58	-1.438	0.385
5-5.99	6	5.47	6.43	-0.96	-1.97	0.03	0.45	0.42	-2.157	0.056
6-6.99	12	6.39	6.33	0.06	-0.55	0.69	0.30	0.29	0.222	0.826
7-7.99	26	7.34	7.51	-0.17	-0.48	0.15	0.16	0.15	-1.066	0.291
8-8.99	53	8.49	8.21	0.28	-0.02	0.57	0.15	0.13	1.834	0.069
9-9.99	68	9.38	8.79	0.59	0.33	0.84	0.13	0.13	4.493	0.000**
10-10.99	74	10.32	9.72	0.60	0.35	0.83	0.12	0.13	4.924	0.000**
11-11.99	70	11.40	10.20	1.20	0.89	1.49	0.15	0.16	7.923	0.000**
12-12.99	53	12.41	11.11	1.30	0.94	1.66	0.18	0.13	7.176	0.000**
13-13.99	56	13.44	12.27	1.17	0.74	1.60	0.22	0.21	5.406	0.001**
14-14.99	42	14.42	13.69	0.73	0.16	1.29	0.28	0.28	2.603	0.013*
15-15.99	54	15.48	14.45	1.03	0.73	1.32	0.15	0.14	6.938	0.000**
16-16.99	46	16.33	14.94	1.39	1.21	1.57	0.10	0.09	15.27	0.000**
17	46	17.31	14.71	2.60	2.29	2.91	0.16	0.15	16.69	0.000**
Total	608	12.10	11.16	0.94	0.60	1.27	0.18	0.17	5.504	0.000**

Table 8: Comparison between chronological and dental age by Cameriere's method in girls.

Age group in years	n	Mean (Yrs.)		CA-DA	95% Confidence Interval for Mean		SD (Yrs)	SE (Yrs)	t-test	*p*-value CA vs DA
		CA	DA		Lower Bound	Upper Bound				
3-3.99	1	3.80	6.20	-2.40	-	-	-	-	-	-
4-4.99	1	4.50	6.00	-1.50	-	-	-	-	-	-
5-5.99	33	5.45	5.76	-0.31	-0.63	0.004	0.15	0.16	-2.001	0.053
6-6.99	41	6.46	6.36	0.10	-0.22	0.41	0.16	0.15	0.619	0.539
7-7.99	38	7.47	7.48	-0.01	-0.31	0.30	0.15		-0.017	0.986
8-8.99	38	8.27	7.88	0.39	0.05	0.73	0.17	0.15	2.306	0.026
9-9.99	52	9.47	8.71	0.76	0.45	1.07	0.15	0.14	4.937	0.000**
10-10.99	57	10.40	9.57	0.83	0.57	1.10	0.13	0.12	6.306	0.000**
11-11.99	87	11.30	10.08	1.22	1.04	1.40	0.09	0.10	13.476	0.000**
12-12.99	42	12.41	10.64	1.77	1.55	2.00	0.11	0.13	15.897	0.000**
13-13.99	66	13.36	11.80	1.56	1.20	1.93	0.18	0.15	8.526	0.000**
14-14.99	35	14.29	13.34	0.95	0.35	1.53	0.29	0.21	3.244	0.003**
15-15.99	39	15.41	14.44	0.97	0.58	1.35	0.19	0.16	5.086	0.000**
16-16.99	38	16.33	15.09	1.24	1.00	1.48	0.12	0.10	10.310	0.000**
17	24	17.21	15.19	2.02	1.71	2.32	0.15	0.17	13.407	0.000**
Total	592	11.25	10.33	0.92	0.56	1.28	0.18	0.17	5.001	0.000**

The overall mean age difference between the London Atlas and chronological is displayed in Table 9. The sample's total mean age difference (CA-DA) was.5±0.13 years, with a 95% confidence interval (CI) of 0.23 to 0.75 and a standard error (SE) of 0.13 years. There was a highly significant difference between CA (11.68±3.24 years) and DA (11.18±3.25) (t (1200)= 3.731, *p*=0.000). The DA was often underestimated, with the exception of children aged three to five, who were overestimated. With a mean age discrepancy of less than a month (-0.08 years), age group 55.99 had the most accurate age estimation. The most recent age group to be accurately assessed was 13–13.99, with a mean age difference of 0.88 years.

Table 10 compares the dental and chronological ages of boys using the London Atlas Method. The sample's CA-DA was 0.42±0.18 years, 95% CI.07–0.77, with a standard error of 0.17 years. There was a highly significant difference between CA (12.10±3.12) and DA (11.68±3.25). The DA was often underestimated, with the exception of children aged 4 and 5, who were overestimated. With a mean age discrepancy of less than a month (0.06), the age group 6–6.99 had the most accurate age estimation.

Table 9: Overall mean age difference between chronological by London Atlas.

Age group in years	n	Mean (Yrs)		CA- DA	95% Confidence Interval for Mean		SD (Yrs)	SE (Yrs)	t-test	*p*-value CA vs DA
		CA	DA		Lower Bound	Upper Bound				
3-3.99	1	3.80	4.50	-0.70	-	-	0	0	-	-
4-4.99	3	4.40	6.50	-2.10	-8.63	4.43	1.53	1.32	-1.372	0.303*
5-5.99	39	5.45	5.53	-0.08	-0.33	0.19	0.13	0.13	-0.545	0.587
6-6.99	53	6.44	6.20	0.24	0.01	0.49	0.12	0.11	2.067	0.043*
7-7.99	64	7.42	7.26	0.16	-0.02	0.33	0.09	0.08	1.795	0.076
8-8.99	91	8.40	8.08	0.32	0.13	0.49	0.09	0.08	3.460	0.001*
9-9.99	120	9.42	9.02	0.40	0.24	0.56	0.08	0.08	4.823	0.000*
10-10.99	131	10.35	9.89	0.46	0.28	0.65	0.09	0.10	4.847	0.000*
11-11.99	157	11.34	10.80	0.54	0.36	0.73	0.09	0.10	5.785	0.000*
12-12.99	95	12.41	11.69	0.72	0.48	0.96	0.12	0.11	5.966	0.000*
13-13.99	122	13.40	12.52	0.88	0.65	1.11	0.11	0.12	7.600	0.000*
14-14.99	77	14.36	13.81	0.55	0.26	0.83	0.15	0.14	3.769	0.000*
15-15.99	93	15.45	14.94	0.51	0.30	0.72	0.11	0.10	4.785	0.000*
16-16.99	84	16.33	15.80	0.53	0.34	0.73	0.09	0.10	5.483	0.000*
17	70	17.27	16.59	0.68	0.23	1.13	0.22	0.23	3.041	0.003*
Total	1200	11.68	11.18	0.50	0.23	0.75	0.13	0.13	3.731	0.000*

Table 10: Comparison between Chronological and dental age by London Atlas method in boys.

Age group in years	n	Mean (Yrs)		CA-DA	95% Confidence Interval for Mean		SD (Yrs)	SE (Yrs)	t-test	*p*-value CA vs DA
		CA	DA		Lower Bound	Upper Bound				
3-3.99	-	-	-	-	-	-		-	-	-
4-4.99	2	4.35	7.00	-2.65	-33.94	28.64	2.50	1.84	-1.058-	0.481
5-5.99	6	5.47	5.83	-0.36	-1.45	0.72	0.44	0.41	-0.832	0.438
6-6.99	12	6.39	6.33	0.06	-0.50	0.62	0.26	0.25	0.222	0.827
7-7.99	26	7.34	7.23	0.11	-0.14	0.36	0.12	0.12	0.893	0.377
8-8.99	53	8.49	8.31	0.18	-0.05	0.40	0.11	0.11	1.525	0.132
9-9.99	68	9.38	8.99	0.39	0.17	0.61	0.11	0.11	3.518	0.001**
10-10.99	74	10.32	10.10	0.22	-0.02	0.46	0.12	0.12	1.851	0.068
11-11.99	70	11.40	10.94	0.46	0.13	0.77	0.16	0.15	2.830	0.006**
12-12.99	53	12.41	12.12	0.29	-0.05	0.62	0.17	0.16	1.721	0.091
13-13.99	56	13.44	12.64	0.8	0.49	1.11	0.16	0.15	5.152	0.000**
14-14.99	42	14.42	13.88	0.54	0.14	0.93	0.20	0.19	2.715	0.009**
15-15.99	54	15.48	14.91	0.57	0.30	0.84	0.13	0.14	4.239	0.000**
16-16.99	46	16.33	15.76	0.57	0.30	0.84	0.14	0.13	4.164	0.000**
17-	46	17.31	16.49	0.82	0.19	1.46	0.32	0.31	2.601	0.012*
Total	608	12.10	11.68	0.42	0.07	0.77	0.18	0.17	2.368	0.018*

The most recent age group to be reliably determined was 4–4.99, with a mean age difference of -2.65 years; nevertheless, this difference is not statistically significant. Table 11 compares the dental and chronological ages of girls using the London Atlas Method. The sample's CA-DA was 0.57±.19 years, 95% CI: 19–0.95, with a standard error of 0.18 years. There was a highly significant difference between CA (11.25±3.31) and DA (10.68±3.31) (t-test)=2.949, *p*=0.000). The DA was often underestimated, with the exception of children aged 3, 4, and 5, who were overestimated. Age group 7-7.99 had the most accurate age estimation, with a mean age difference of.19 years. The most recent age group to be reliably approximated was 12-129, with a mean age difference of 1.28 years.

DISCUSSION

In this study, the mean DA was estimated by the Demirjian method to be 11±3.22 years with a standard error of ±0.09 years (Table 3). Consequently, compared to French-Canadian children from the Demirjian study, Yemeni children had an overall lower estimate of dental development and dental age 9.

Table 11: Comparison between chronological and dental age by London Atlas method in girls.

Age group in years	n	Mean (Yrs)		CA-DA	95% Confidence Interval for Mean		SD (Yrs)	SE (Yrs)	t-test	*p*-value CA vs DA
		CA	DA		Lower Bound	Upper Bound				
3-3.99	1	3.80	4.50	-0.70	--	-	-	-	-	-
4-4.99	1	4.50	5.50	-1.00	--	-	-	-	-	-
5-5.99	33	5.45	5.47	-0.02	-0.29	0.25	0.13	0.13	-.135	0.893
6-6.99	41	6.46	6.16	0.30	0.03	0.56	0.13	0.13	2.245	0.029*
7-7.99	38	7.47	7.28	0.19	-0.05	0.43	0.12	0.11	1.561	0.124
8-8.99	38	8.27	7.76	0.51	0.25	0.75	0.13	0.12	3.955	0.000**
9-9.99	52	9.47	9.05	0.42	0.16	0.66	0.13	0.12	3.288	0.002**
10-10.99	57	10.40	9.62	0.78	0.48	1.07	0.15	0.14	5.227	0.000**
11-11.99	87	11.30	10.68	0.62	0.40	0.84	0.11	0.10	5.626	0.000**
12-12.99	42	12.42	11.14	1.28	0.99	1.54	0.14	0.13	9.348	0.000**
13-13.99	66	13.37	12.42	0.95	0.61	1.28	0.17	0.16	5.617	0.000**
14-14.99	35	14.29	13.73	0.56	0.12	0.99	0.21	0.21	2.597	0.013*
15-15.99	39	15.41	14.99	0.42	0.07	0.76	0.17	0.19	2.434	0.019*
16-16.99	38	16.34	15.84	0.50	0.21	0.78	0.14	0.14	3.526	0.001**
17	24	17.21	16.79	0.42	-0.10	0.93	0.25	0.26	1.653	0.111
Total	592	11.25	10.68	0.57	0.19	0.95	0.19	0.18	2.949	0.003**

In both sexes, the mean discrepancy between dental age and chronological age was significant (*p*-value <0.000*), with dental age being underestimated by an average of 0.67±0.13 years (Table 3). Boys (Table 4) and females (Table 5) had mean differences of 0.69 and 0.66 years, respectively. The sex-to-sex difference was not statistically significant. To sum up, this study's findings show that the Demirjian approach greatly underestimated Yemeni people's ages. The study's findings indicated that the age groups 7-7.99 and 6-6.99 had the least significant differences in CA-DA, with *p*-values of 0.539 and 0.250 and 0.18 and -0.05, respectively (Table 4). According to Cunha and Heckman[12], this precision might result from the fact that tooth development in this age range is heavily influenced by genetics, making it less susceptible to environmental factors. Additionally, there was no statistically significant difference between the age groups of 4–4.99 and 5–5.99. This outcome is comparable to Hägg and Matsson's[13] study. The lengthy creation timeframes for enamel and dentine[14] may be a contributing factor to the delayed growth of the Yemeni population and other populations. The process of enamel and dentine formation is an extremely regulated process.

Only girls in age groups 5–5.99 had an overestimation of dental age (-0.35±0.15 with *p*-value 0.022). Age groups 7–7.99 showed overestimation of dental age in males (-0.26±0.10 with *p*-value 0.009). Dentition growth spurts and the variations in growth spurts between the sexes may be the subject of this[12]. Girls in the 5.5–6.4 and 11.5–14.4 year groups in Ogodescu's study had higher advanced dental ages[15]. However, the biggest CA-DA underestimate was 1.40 ±0.17 in girls aged 12–12.99 (except for those aged 17–17.9). This is consistent with other authors who obtained an underestimation of dental age of girls only in this age group in Romania while the same study showed overestimated dental ages contrasting our result[16]. This result might be a secular trend in dental development. To compare the dental age of girls. This finding contradicts the earlier maturation of other developmental characteristics in girls. In terms of skeletal age, height, and sexual maturation, girls show an earlier maturation. A big sample size is required in order to compare sexual dimorphism effectively. Age group17-17.99 had the highest underestimation CA-DA 1.55±0.08, and it has a statically high significant *p*-value 0.000. This may be because little numbers children from this age group had been included in the analysis, since most of them reached a dental score of 100, except 3 boys and 5 girls. In the present study, the decline in DA as determined by Demirjian's system when compared to CA with mean different 0.67 years (0.66 years in girls and 0.69 years in boys).

In another study conducted in Yemen by Al-Qadi and Abu-Afan[17], the Demirjian method significantly underestimated CA by 0.58±1.25 years in the total sample and by 0.73±1.30 and 0.40±1.17 years in males and females, respectively ($p<0.001$). Similar to Yemen, underestimation of age is observed in Middle Eastern countries where a study conducted on Kuwaiti children showed that they had delayed tooth eruption (mean difference in tooth maturity 0.69 years, SD=1.25 years, CI=0.58-0.80). The mean delay for girls was 0.67 years (standard deviation=1.30 years, confidence interval= 0.51-0.83) and for boys the mean delay was 0.71 years (standard deviation=1.18 years, confidence interval= 0.56-0.86)[18].

Dental age under estimation also observed in Saudi Arabia[19], in Sudanese children[20], in Turkish children[21], and in Venezuela[22,23]. The discrepancies between dental maturity and chronologic age as determined by the Dermijan technique that have been noted in numerous researches may be the likely origins of these variations. Additionally, because the sample structure

varies among various demographic groups in terms of size, socioeconomic position, dietary habits, age, sex, ethnicity, nationality, and/or nutrition of patients, the statistical analysis method employed, and/or the subjectivity of the examiner. Lastly, the fact that there is a limit and that a single tooth can foretell a child's later age is one of the disadvantages of the Demirjian approach[24]. Additionally, the dental maturity score was calculated using correspondence analysis with endpoint limitations and is the total of the weighted scores of the 41 distinct dental phases. Certain subjectively weighted ratings, particularly at early ages, have zero weight, according to an analysis of the dental stages' scores. G of M1 weighs the most in males and girls, and it is 17 and 14, respectively[9]. A single stage may produce a significant increase in dental age since fewer stages contribute more towards the conclusion of dental maturity.

Dental age estimation by Cameriere method: In our study the mean DA was estimated to be 10.75±2.93 years with a standard error of ±0.08 years (Table 6). In general, Yemeni children underestimated dental development and dental age when compared to Italian children from the Cameri study where the mean difference between chronological age and dental age was 0.93±.13 years (*p*-value 0.000*) in both sexes (Table 3), and the mean difference was 0.94±0.18 years in boys (Table 7) and 0.92±0.18 years in girls (Table 8). The difference between sexes was not statistically significant (t-test=-0.133, *p*=0.895) (Table 6). The present study found that the European Cameri formula significantly underestimated the age of Yemeni individuals. Even though in the current study, there was a general underestimation of the DA in almost all age groups, while in age group 5-5.99 in both genders was over estimation (Table 6). Also in a Brazilian study, there was a slight tendency to overestimate the ages of 5–10 years and underestimate the ages of 11–15 years[25]. In addition, as in Yemen, underestimation of age is almost noticed in Middle East countries, when assessing our results with the results of studies conducted in other countries. In European population: under estimation of dental age was also noticed in Germany, age was underestimated by Cameriere's method the mean different of boys by 0.56±1.04 years and of girls by −0.32±0.96[26]. Although under estimation of dental age was increased in Brazil and Croatia the mean age under estimation were 1.03 and 1.19 respectively[27], while under estimation of dental age was decreased in Chinese children the mean difference of around 0.23 year[28]. Un like this study, studies in which dental age was more advanced than the chronological age in 0.803±1.29 in boys and 0.587±1.31 in girls in Australia[29]. The differences between dental maturity and chronologic age as determined by Cameriere's method in various studies, the sample structure's variability in terms of size, socioeconomic status, dietary habits, patient age, sex, ethnicity, nationality, and/or nutrition, the statistical analysis method employed, and/or the examiner's subjectivity, which differ among various population groups, are likely the causes of these variations. New scores and grading standards must be established for each group in light of ethnic diversity. Obtained results contribute to know the effect of race in the dental growth. In this study, it appear that completion of apical closer of all teeth is a factor that contribute to decline in overall accuracy of this method in older individuals thus the upper limit for application this method is 15-15.99. Because all children in age groups 16-16.99 and 17-17.99 had maximum dental age calculated (Table 6).

Estimation of dental age by London Atlas: The present study also assessed the London Atlas dental chart as a method for estimating age. The mean difference between chronological age and dental age was 0.50±.13 years in both genders Table 9, 0.42±0.18 years in boys table 10, and 0.57±0.18 years in girls table 11. The differences in accuracy was not significant based on sex Table 3.4.6 (t-test=-0.018, *p*=0.986). Our results indicate that the Yamani children are, in general, underestimation in dental development (dental age) when compared to London atlas.

In the current analysis, age groups 5-5.99, 6-6.99, 7-7.99, 8-8.99, 10-10.99 and 12-12.99 chronological age and dental age were similar and the difference is not statically significant (less than three months).While the difference between chronological age and dental age in remaining age groups were statically significant, but the different was less than 6 months (except age groups 13-13.99, 17). There was a general underestimation of the DA. The most accurately estimated age groups 5-5.99, and 7-7.99 age groups were not significant differences between chronological age and dental age. The reason for this accuracy could be due to the maturation of dentition is under greater genetic control and therefore, less susceptible or exposure to environmental influences in those early age groups[12]. That indicate Yemeni population has its specific variation and need to create specific growth chart.

In girls Table 11; there was a general underestimation of the DA except in the age 3, 4, and 5 years old which were overestimated. The most accurately estimated age was for age group 7-7.99 which had a mean age difference that was 0.19 years while age group 12-12.99 was the latest accurately estimated age which had a mean age difference that was 1.28 years. We compared our results with the results of studies conducted in other countries. Similar to this study, a study in a sample of Saudi children by The London Atlas the mean difference between the Chronological Age (CA) and Dental Age (DA) was underestimated (0.59 years) with a standard deviation of 1.45 years[30]. Also in Iranian study, the London Atlas was under estimating 0.16 year[31]. Other in Hispanic children the mean difference between chronological and estimated ages for males was 0.30 years for males was 0.30 and for females was 0.40 years, but the difference between sexes was not significant (*p*=0.324)[32].

Nevertheless, overestimation was noticed in two different studies conducted in Portugal. In the Portuguese population significant difference between chronological and estimated age was overestimation of age by one month approximately. However, the significant difference was observed in a sample coming from males 3 months not observed in the females[33], but

in the another study on the same population overestimation was 0.1 years and 1 month[34]. The discrepancies between dental maturity and chronologic age as determined by the London Atlas method that have been noted in numerous researches may be the likely origins of these variations. In addition, the statistical analysis method and/or the examiner's subjectivity fluctuate among various population groups, as does the sample structure's diversity with respect to size, socioeconomic status, eating habits, age, sex, ethnicity, nationality, and/or nutrition of patients[35]. New scores and grading standards must be established for each group in light of ethnic diversity. Our findings help us understand how race affects dental growth.

Limitations of the study

Our study's findings indicate that these criteria are only relevant for specific age groups and that all three approaches have certain drawbacks in the Yemeni community. Even though the assessed approach has demonstrated suitability for forensic age estimation, it must be modified for the population under study. More studies with a bigger sample size are required. The systematic errors inherent in each method, intra- and inter-observer variability, and study population factors like ethnicity, socioeconomic status, and pathological changes are the main causes of the fact that no method is 100% accurate in estimating dental age. Depending on the method used, these factors can result in cases of overestimation or underestimation.

CONCLUSIONS

The study reveals that Demirjian's method has limitations in estimating the dental age of Yemeni children, causing significant differences between dental and chronological age, delayed growth, and no significant age differences for boys and girls. Cameriere's method also has limitations, and the London atlas method is recommended for Yemeni children's age estimation.

ACKNOWLEDGEMENTS

The authors express their gratitude to Yemen and the Sana'a University Faculty of Dentistry for their cooperative efforts.

AUTHOR'S CONTRIBUTIONS

Abdul Majid ALA: Writing the original draft, methodology, investigation, conceptualization. **Anas Aleryani HA:** critical review, **Sharf Aldeen YAA:** review and editing, **Al-Shamahy HA**: Formal analysis, data processing, conceptualization. All authors reviewed and approved the final version of the article.

DATA AVAILABILITY

Upon request, the accompanying author can furnish the empirical data used to bolster the findings of the study.

CONFLICT OF INTEREST

None to declare.

REFERENCES

1. Krogman WM. Biological timing and the dento-facial complex. ASDC J Dent Child 1968 May;35(3):175-85 contd. PMID: 4296973.
2. United Nations Children's Fund (UNICEF). Birth Registration. *https://data.unicef.org/topic/child-protection/birth-registration/*
3. Tassi NG, Franchi L, Baccetti T, Barbato E. Diagnostic performance study on the relationship between the exfoliation of the deciduous second molars and the pubertal growth spurt. Am J Orthod Dentofacial Orthop 2007 Jun; 131(6):769-71. *https://doi.org/10.1016/j.ajodo.2006.09.039*
4. Smith T, Brownlees L. Age assessment practices: A literature review and annotated bibliography. United Nations Children's Fund (UNICEF), New York 2011.
5. Al-Subbary IA, Obeyah AA, Al-Mogahed NM, Al-Ammari MH. Dental caries and treatment needs among children with physical disabilities in Dhamar city, Yemen: A comparative study. Universal J Pharm Res 2024; 9(2): 34-39. *http://doi.org/10.22270/ujpr.v9i2.1086*
6. Graber LW, Vanarsdall JR, VIG RL, *et al*. 2016. Orthodontics: Current principles and techniques, Elsevier Health Sciences.
7. Shrestha A., Yadav R, Shrtestha S, Majarjan I, Camelio S. Measurement of open apices in teeth for estimation of age in children. Health Renaissance 2015: 12, 33-37.
8. Maled V, Manjunatha B, Patil K, Balaraj BM. The chronology of third molar root mineralization in south Indian population. Med Sci Law 2014 Jan;54(1):28-34. *https://doi.org/10.1177/0025802413491557*
9. Demirjian A, Goldstein H, Tanner J. A new system of dental age assessment. Human Biol 1973; 211-227. PMID: 4714564
10. Cameriere R, Ferrante L, Liversidge HM, Prieto JL, Brkic H. Accuracy of age estimation in children using radiograph of developing teeth. Forensic Sci Int 2008 Apr 7;176(2-3):173-7. *https://doi.org/10.1016/j.forsciint.2007.09.001*
11. AlQahtani SJ, Hector MP, Liversidge HM. Brief communication: The London atlas of human tooth development and eruption. Am J Phys Anthropol 2010 Jul; 142(3):481-90. *https://doi.org/10.1002/ajpa.21258*
12. Cunha E, Baccino E, Martrille L, *et al*. The problem of aging human remains and living individuals: A review. Forensic Sci Int 2009 Dec 15;193(1-3):1-13. *https://doi.org/10.1016/j.forsciint.2009.09.008*
13. Hägg U, Matsson L. Dental maturity as an indicator of chronological age: The accuracy and precision of three methods. Eur J Orthod 1985 Feb; 7(1):25-34. *https://doi.org/10.1093/ejo/7.1.25*
14. Reid DJ, Dean MC. Variation in modern human enamel formation times. J Hum Evol 2006 Mar;50(3):329-46. *https://doi.org/10.1016/j.jhevol.2005.09.003*
15. Ogodescu AE, Bratu, E, Tudor, A, Ogodescu A. Estimation of child's biological age based on tooth development. Rom J Leg Med 2011; 19: 115-24. *https://doi.org/10.4323/rjlm.2011.115*
16. Jurca A, Lazar L, Pacurar M., Bica C, Chibelean M, Bud E. Dental age assessment using demirjian's method – A radiographic study. European Sci J 2014; 10(36).
17. Alqadi MA, Abuaffan AH. Validity of the Demirjian and Fishman methods for predicting chronological age amongst Yemeni Children. Sultan Qaboos Univ Med J 2019 Feb;19(1):e26-e31. *https://doi.org/10.18295/squmj.2019.19.01.006*
18. AlQahtani SJ, Hector MP, Liversidge HM. Accuracy of dental age estimation charts: Schour and Massler,

Ubelaker and the London Atlas. Am J Phys Anthropol. 2014 May; 154(1):70-8. *https://doi.org/10.1002/ajpa.22473*

19. Qudeimat MA, Behbehani F. Dental age assessment for Kuwaiti children using Demirjian's method. Annals of human biology 2009; 36: 695-704. *https://doi.org/10.3109/03014460902988702*
20. Al-Emran S. Dental age assessment of 8.5 to 17 Year-old Saudi children using Demirjian's method. J Contemp Dent Pract 2008 Mar 1;9(3):64-71. PMID: 18335121.
21. Rizig AO, Elamin F, Zeidan ZA, Kasim K, Mohamed Z. Age estimation and dental maturity for Sudanese children using Demirjian's system. J Med Med Sci 2013; 4, 123-27.
22. Karataş O, Özturk F, Dedeoğlu N, Çolak C, Altun O. Dental age assessment: The applicability of Demirjian method in southwestern of eastern Anatolia region Turkish children. Cumhuriyet Dental J 2012; 15, 130-137. *https://doi.org/10.7126/cdj.2012.1096*
23. Martínez Gutierrez VM, Ortega-Pertuz A. Comparison of Nolla, Demirjian and Moorrees methods for dental age calculation for forensic purposes. Revista Odontológica Mexicana 2017; 21, 155-164. *https://doi.org/10.1016/j.rodmex.2017.09.011*
24. Cruz-Landeira A, Linares-Argote J, Martínez-Rodríguez M, Rodríguez-Calvo MS, Otero XL, Concheiro L. Dental age estimation in Spanish and Venezuelan children. Comparison of Demirjian and Chaillet's scores. Int J Legal Med. 2010 Mar; 124(2):105-12. *https://doi.org/10.1007/s00414-009-0380-5*
25. Chaillet N, Nyström M, Demirjian A. Comparison of dental maturity in children of different ethnic origins: international maturity curves for clinicians. J Forensic Sci 2005; 50, JFS2005020-11**.** *https://doi.org/10.1520/JFS2005020*
26. Fernandes MM, Tinoco RL, de Braganca DP, de Lima SH, Francesquini Junior L, Daruge Junior E. Age estimation by measurements of developing teeth: Accuracy of Cameriere's method on a Brazilian sample. J Forensic Sci 2011 Nov; 56(6):1616-9. *https://doi.org/10.1111/j.1556-4029.2011.01860.x*
27. Halilah T, Khdairi N, Jost-Brinkmann PG, Bartzela T. Age estimation in 5-16-year-old children by measurement of open apices: North German formula. Forensic Sci Int 2018 Dec; 293:103.e1-103.e8. *https://doi.org/10.1016/j.forsciint.2018.09.022*
28. da Luz LCP, Anzulović D, Benedicto EN, Galić I, Brkić H, Biazevic MGH. Accuracy of four dental age estimation methodologies in Brazilian and Croatian children. Sci Justice 2019 Jul; 59(4):442-447. *https://doi.org/10.1016/j.scijus.2019.02.005*
29. Guo YC, Yan CX, Lin XW, *et al*. Age estimation in northern Chinese children by measurement of open apices in tooth roots. Int J Legal Med 2015 Jan;129(1):179-86. *https://doi.org/10.1007/s00414-014-1035-8*
30. Barville AJ. 2018. Age estimation from the measurement of open apices in the developing permanent dentition.
31. Alsudairi DM, AlQahtani SJ. Testing and comparing the accuracy of two dental age estimation methods on saudi children: Measurements of open apices in teeth and the London Atlas of tooth development. Forensic Sci Int 2019 Feb; 295:226.e1-226.e9. *https://doi.org/10.1016/j.forsciint.2018.11.011*
32. Ghafari R, Ghodousi A, Poordavar E. Comparison of the accuracy of the London atlas and Smith method in dental age estimation in 5-15.99-year-old Iranians using the panoramic view. Int J Legal Med. 2019 Jan;133(1):189-195. *https://doi.org/10.1007/s00414-018-1808-6*
33. McCloe D, Marion I, da Fonseca MA, Colvard M, AlQahtani S. Age estimation of Hispanic children using the London Atlas. Forensic Sci Int 2018 Jul;288:332.e1-332.e6. *https://doi.org/10.1016/j.forsciint.2018.04.013*
34. Pavlović S, Palmela Pereira C, Vargas de Sousa Santos RF. Age estimation in Portuguese population: The application of the London atlas of tooth development and eruption. Forensic Sci Int. 2017 Mar; 272:97-103. *https://doi.org/10.1016/j.forsciint.2017.01.011*
35. Cesário C, Santos R, Pestana D, Pereira CP. Medico-Legal Age Estimation in a Sub-adult Portuguese Population: Validation of Atlas Schour and Massler and London. J Civil Legal Sci 2016; 5: 196. *https://doi.org/10.4172/2169-0170.1000196*