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Dental age estimation using four Demirjian's, Chaillet's and Willems' methods in Kosovar children

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ABSTRACT

Background: Tooth formation was recognized as useful body system to assess maturity and predict age. Tooth mineralization is much less affected by the endocrine and different nutritional status than bone mineralization, and teeth formation provides a more reliable indication of chronological age. Demirjian et al. in 1973 presented a scoring system and method for dental age estimation on a sample of French-Canadian children. Chaillet et al. and Willems et al. modified original Demirjian method. This study aimed to evaluate the accuracy of four Demirjian's, Chaillet and Willems methods for age estimation in the children of Kosovo.

Materials and methods: The cross-sectional study was based on the evaluation of the sample of 1022 orthopantomograms (OPTs) of healthy Kosovar children, aged between 5 and 14 years. OPTs were taken from the Radiology unit of University Dentistry Clinical Center of Kosova, as part of random clinical treatment. We tested the accuracy of four methods based on seven mandibular teeth, Demirjian from 1973 (Dem73) and 1976 (Dem76), Chaillet from 2005 (Chaillet) and Willems from 2001 (Willems) and two Demirjian's methods based on different sets of four teeth ($Dem76PM_1$ and $Dem76IN_2$).

Results: For most tested methods, we found statistically significant differences between the chronological age (CA) and dental age (DA) ($p < 0.05$). In males, the most accurate method were those using four teeth, $Dem76IN_2$ (0.03 years) following by $Dem76PM_1$ (−0.05 years), following those using seven teeth, Willems (−0.14 years), Chaillet (−0.24 years) and Dem73 (0.43 years). In females, dental age was the most accurate for the Willems method (−0.24 years) following Chaillet (−0.35 years), Dem76 (0.43 years) and Dem73 (0.55 years), while $Dem76PM_1$ and $Dem76IN_2$ overestimated by 0.45 years and 0.46 years, respectively.

The mean absolute difference between DA and CA were between 0.61 years for the Willems, to 0.78 years for the Dem73 in males, and 0.64 years for the Willems to 0.75 years for the $Dem76IN_2$ in females.

Conclusion: The Willems method was the most accurate for estimating a dental age if all seven mandibular teeth are available for analysis, and we found the similar accuracy of Dem76PM1 and Dem76IN2 methods. Therefore, we may encourage their use for age estimation on the Kosovar children.

1. Backgrounds

The perception of physiological age in men is commonly based on the degree of maturation of different body systems [1]. Different types of biological age have been recognized as reliable skeletal age, weight and height increase, secondary sexual character age and dental maturation [2]. There are many studies of dental maturation during the last half century that have described the timing of permanent tooth mineralization [3].

The studying of the mineralization of the teeth may be useful in many scientific and clinical fields of applications; in orthodontists and pediatric dentistry in choosing a timing and treatment plan, forensic dentistry, pediatric endocrinology, orthopedics and comparative anthropological studies [4]. For example, it is mandatory to start

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treatment in the optimal growth stage to achieve ideal correction of skeletal discrepancies, use extra-oral traction, functional appliances and correctly determine the appropriate time for some aspects of facial and skeletal surgery [5]. Also, considerable importance of age estimation is required to assist in the identification process, especially in proceedings of asylum seekers or identification of a specific individual from the mass disasters [2,6,7]. The development of radiographic images for clinical use, especially the orthopantomogram (OPT), which shows the complete dentition on a single X-ray, has provided to clinical investigators inspiration to assess dental maturation [8]. Different radiological methods, which analyze dental mineralization as an indicator of age, have been extensively studied [9]. Dental age can also be estimated by the observing the eruption in the mouth combining to the degree of mineralization of the developing teeth from radiographs [10]. Tooth mineralization is a more reliable indicator of dental maturity than eruption because it is not affected by factors such as loss of primary teeth, lack of space, malnutrition, dental decays, ankylosis or some orthodontic anomalies [2,11]. The most widely used radiologic method for developing permanent teeth was Demirjian's dental maturity scoring system [12]. Demirjian et al. [12], in 1973 on a sample of French-Canadian children, presented an age estimation method which used eight developmental stages, A to H, of the first seven mandibular teeth; the same approach has been used for measurement of skeletal maturity by Tanner- Whitehouse [13]. An updated method was presented by Demirjian and Goldstein [14] in 1976. The authors extended original method from 1973 based on seven teeth with additional two methods based on four teeth [14]. Many authors have tested the Demirjian method on different population groups with varying results [15]. According to literature, it is the most popular dental method for estimating the dental age in children and adolescents, probably due to the detailed description and radiographic illustrations of tooth developmental stages and its relative simplicity and precision [16–18]. Chaillet et al. [19] in 2005 published the international maturity curves for age estimation based on the same seven mandibular teeth, based on the evaluation of the samples from eight different populations. Willems et al. [20] presented in 2001 dental maturity tables for estimation dental age based on the modified scoring system by the statistical analysis of the Belgian children. The Willems method gave better accuracy than Demirjian in the comparative studies [21]. Due to its accuracy and feasibility of six listed methods, we chose to test their accuracy in our study on Kosovar children. Therefore, this study aimed to evaluate the accuracy of four Demirjian's, Willems' and Chaillet's methods for age estimation in the children of Kosovo.

2. Materials and methods

The sample in this cross-sectional study was based on the evaluation of 1022 OPTs of healthy Kosovar children, aged between 5 and 14 years (Table 1). OPTs were retrieved as digitalized images (JPEG format) from OPT machine (OWANDY 6), from the Radiology unit of University Dentistry Clinical Center of Kosovo, as part of randomly clinical treatment between year2009 to 2015. A data management and statistical analysis were done by using Microsoft Excel (MS Office 2010 Microsoft Corp., Redmond, WA, USA) and the Statistical Package for Social Science (SPSS) version 20.0 for Windows (SPSS Inc, Chicago, IL, USA). Individual's data were collected: the date of birth, the date of radiography and gender. Inclusion criteria: Kosovo origin, age between 5 and 14 years, all permanent teeth in the left side of lower jaw present, no apparent dental pathology on OPT related to the left side of the jaw. Exclusion criteria for OPTs: incomplete dental records, including the absence of the recorded date of birth and date of the radiography, low-quality radiographs, agenesis of permanent teeth, extraction of permanent teeth from both jaws of one side of the face, recorded systemic diseases, premature birth, and congenital anomalies. The third molars were not evaluated. The chronological age (CA) of children was calculated as the difference between the date of the OPT and the birth date. Age groups were based on one-year increment.

Table 1
Distribution of the panoramic radiographs of the children from the Kosovo.

Age group	Males	Females	Total
5.0–5.9	21	12	55
6.0–6.9	32	38	70
7.0–7.9	57	52	109
8.0–8.9	49	57	106
9.0–9.9	55	65	120
10.0–10.9	58	65	123
11.0–11.9	60	64	124
12.0–12.9	54	63	117
13.0–13.9	57	64	121
14.0–14.9	55	44	99
Total	**498**	**524**	**1022**

The stages of dental development were evaluated on the seven permanent teeth from the left side of the mandible, except third molars, according to Demirjian et al. [3]. Briefly, dental development of permanent teeth was divided into eight mineralization stages (A to H), from cone-shaped calcifications of the upper portion of the crypt or stage A to fully closed apices or stage H. Demirjian et al. [12] provided a specific scheme, Fig. 1. The time mineralization of within stages of all evaluated teeth was presented as mean, standard deviation and additionally minimum age of last stage 'H' was recorded. Independent-samples T test tested a possible difference in age between genders at each stage. For the Demirjian method from 1973 (Dem73), dental age was calculated by the specific self-weighted scores for dental stages to calculate the maturity score which was converted to dental age by using the conversion tables [12]. The specific maturity scores for dental stages were used for the three Demirjian methods from 1976 [14]. One method uses the same seven teeth (Dem76). Two methods use the sets of four teeth, one uses both premolars and both molars, PM_2, PM_1, M_1, and M_2, (Dem76PM_2), and another uses both premolars, second molar and the first incisor, PM_1, PM_2, M_2 and I_1 (Dem76IN_1) [14]. A 50th dental maturity percentile was used to calculate dental age [14]. For the Chaillet method (Chaillet), dental age was calculated by using specific international maturity tables and median curves for males and females from Chaillet et al. [19]. Dental age was also calculated by using Willems' modified and simplified Demirjian system (Willems) [20]. Willems suggested new calculation tables based on the regression analysis on a sample of Belgian children [20].

Kappa statistics were used to test intraobserver and interobserver agreement [22]. A fifty randomly selected OPTs were evaluated after two weeks after first evaluation by the first (JK) and the last author (IG). All OPTs were examined by the blind approach, without the possibility to evaluate age and gender. An independent-sample *T*-test was used to compare mean ages of specific tooth stage between gender and a Mann-Whitney *U* test was used if any gender listed less than 20 participants within tooth stage [23]. A paired-samples *T*-test was used to compare the accuracy of different methods, with the null hypothesis that there is no difference between dental age (DA) and chronological age (CA) [24]. A Repeated-measures ANOVA within General Linear Model was used to compare DA-CA among all six methods [24]. We also calculated an absolute accuracy of DA-CA or mean absolute error (MAE). Analyses were also made for each gender and age cohort. If the *p*-value was less than 0.05, the results were considered statistically significant.

3. Results

There were no differences in the mean age between males and females in our sample ($p = 0.850$) (Table 1). Kappa values of the intraobserver agreement for stages of dental mineralization of 50 randomly selected OPTs varied from 0.74 for the first molars to 0.91 for the

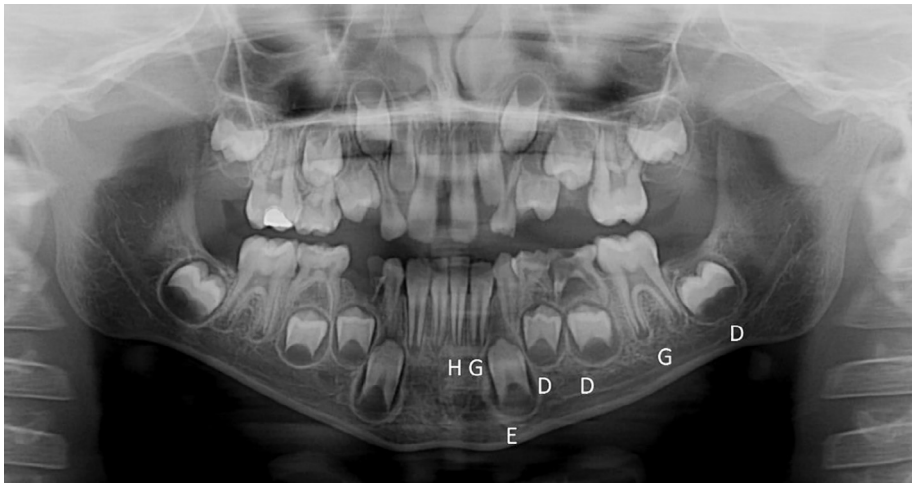

Fig. 1. A sample of Demirjian's developmental stages on the first seven left mandibular teeth.

Table 2
Intra and inter-observer agreement of Demirjian's stages of the tooth mineralization.

Tooth	31	32	33	34	35	36	37	Mean
Intra-observer (kappa)	0.88	0.90	0.87	0.86	0.82	0.74	0.87	0.85
Inter-observer (kappa)	0.82	0.78	0.82	0.88	0.80	0.72	0.82	0.81

second molars, while that of inter-observer agreement of the same sample ranged from 0.72 for the first molars to 0.88 for the first premolar (Table 2).

The differences between genders in mean ages of mineralization stages for all seven mandibular teeth for the full sample (n = 1022) are shown in Table 3. The mineralization of permanent teeth in females was ahead than in males. Dental development in males was ahead, only for stage E in the first incisors (p = 0.087), stage C for the first premolars (p = 0.270) and stage E for the first molars (p = 0.440). The values of the mean age for the stage H are not reliable because it records only finished mineralization, without knowing when it happened, e.g., before a month or a year.

The accuracy of the methods was estimated as the difference between DA and CA or DA-CA. In the whole sample, we found significant differences between DA and CA (DA-CA) for all six methods ($p < 0.05$). In males, the smallest DA-CA showed the $Dem76IN_2$ method (0.03 ± 0.90 years), following $Dem76PM_1$ (−0.05 ± 0.86 years), Willems (-0.14 ± 0.77 years), Dem76 (0.20 ± 0.80 years), Chaillet (−0.24 ± 0.85 years) and Dem73 (0.43 ± 0.90 years). In females, the smallest DA-CA showed Willems method (−0.24 ± 0.75 years), following Chaillet (−0.35 ± 0.74 years), Dem76 (0.43 ± 0.76 years), $Dem76IN_2$ (0.45 ± 0.81 years), $Dem76PM_1$ (0.46 ± 0.83 years) and Dem73 (0.55 ± 0.72 years), Table 4.

Repeated measures ANOVA was performed to test the differences of DA-CA among all six methods in males and females. Mauchly's test indicated that the assumption of sphericity had been violated, $\chi^2(14) = 623.03$, $p < 0.001$ and $\chi^2(14) = 939.44$, $p < 0.001$ in males and females, respectively. Therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity, ($\varepsilon = 0.68$ and $\varepsilon = 0.59$ in males and females, respectively). The results of repeated measures ANOVA for the within-subjects variable shows that there was a significant difference of DA-CA among six tested methods ($p < 0.001$) in males and females, respectively (Table 5). Post-hoc pairwise comparisons, after Bonferroni adjustment, showed that there were not a statistically significant difference of DA-CA only between Dem76 and $Dem76PM_1$ (0.01 years, p = 1.0), Dem76 and $Dem76IN_2$ (0.03 years, p = 0.898) and $Dem76PM_1$ and $Dem76IN_2$ (0.02 years, p = 1.0) in females. All other pairwise comparisons were statistically significantly different ($p < 0.001$).

The smallest mean absolute error or MAE was found for Willems method, 0.61 years in males and 0.64 years in females while the greatest MAE was for Dem73 in males, 0.78 years, and $Dem76IN_2$ in females, 0.75 years, Table 4. Repeated measures ANOVA was performed to test the differences of MAE among all six methods in males and females. Mauchly's test indicated that the assumption of sphericity had been violated, $\chi^2(14) = 921.50$, $p < 0.001$ and $\chi^2(14) = 2242.37$, $p < 0.001$ in males and females, respectively. Therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity, ($\varepsilon = 0.59$ and $\varepsilon = 0.33$ in males and females, respectively). The results of repeated measures ANOVA for the within-subjects variable shows that there was a significant difference of MAE among six tested methods ($p < 0.001$) in males and females, respectively (Table 5). Post-hoc pairwise comparisons, after Bonferroni adjustment, showed that there were a statistically significant differences of MAE in males between Dem73 and Dem76 (0.13 years, $p < 0.001$), Dem73 and Willems (0.16 years, $p < 0.001$), Dem76 and $Dem76IN_2$ (0.07 years, p = 0.001), Dem76 and Chaillet (0.07 years, p = 0.017), $Dem76PM_1$ and Willems (0.08 years, p = 0.001), $Dem76IN_2$ and Willems (0.1 years, $p < 0.001$), Chaillet and Willems (0.1 years, $p < 0.001$). The statistically significant differences in females were between Dem73 and $Dem76IN_2$ (0.06 years, p = 0.002), Dem76 and $Dem76PM_1$ (0.06 years, $p < 0.001$), Dem76 and $Dem76IN_2$ (0.08 years, $p < 0.001$), $Dem76PM_1$ and $Dem76IN_2$ (0.03 years, p = 0.031), $Dem76PM_1$ and Willems (0.08 years, p = 0.044), $Dem76IN_2$ and Willems (0.11 years, p = 0.001).

Tables 6 and 7 show the data of DA, CA and MAE across different age groups. The relationship between age groups age and DA-CA of four Demirjian, Chaillet and Willems methods were presented in Fig. 2.

4. Discussion

This study evaluated the accuracy of six age estimation methods based on the development of the mandibular teeth by Demirjian scoring system. Four methods evaluated seven teeth while two methods evaluated different sets of four teeth. Sample size and age distribution designate that the sample can be representative of the population of Kosovo [15,25].

The accuracy of four Demirjian's methods, based on the French-Canadians, Willems' on Belgian and Chaillet's international standards was also tested in this study. We presented accuracy as the mean difference between DA and CA or DA-CA and the absolute value of the DA-CA or MAE. The best accuracy or the difference between dental and

Table 3
Mean age (years) within Demirjian's tooth stages and difference between genders of 498 male and 524 female orthopantomograms from Kosovo.

Tooth	Stage	Males						Females						t(df)	Mann-Whitney U(Z)	P
		N	Mean	SD	SEM	Min	Max	N	Mean	SD	SEM	Min	Max			
31	D	2	5.53	0.22	0.16	5.37	5.69	1	5.01					–	2(1.22)	1.00
	E	16	5.69	0.34	0.08	5.24	6.48	10	6.05	0.58	0.18	5.24	7.30	–	47(1.74)	0.087
	F	32	6.87	0.82	0.14	5.50	8.42	14	6.60	0.66	0.18	5.49	7.90	–	264(0.95)	0.340
	G	38	7.43	0.71	0.12	5.52	9.11	33	6.85	0.87	0.15	5.01	8.51	3.07(69)		0.003
	H	410	11.29	2.13	0.11	6.32	14.99	466	11.03	2.16	0.10	6.44	14.98	1.82(874)		0.069
32	D	11	5.55	0.22	0.07	5.24	5.96	3	5.53	0.57	0.33	5.01	6.16	–	17(0.08)	1.00
	E	31	6.64	0.87	0.16	5.41	8.38	19	6.33	0.61	0.14	5.24	7.40	–	344(0.99)	0.322
	F	53	7.28	0.73	0.10	5.52	8.57	40	6.86	0.85	0.13	5.01	8.51	2.55(91)		0.012
	G	60	8.36	0.73	0.09	6.78	9.64	55	7.87	0.62	0.08	6.44	9.14	3.92(113)		< 0.001
	H	343	11.89	1.76	0.09	7.47	14.98	407	11.49	1.89	0.09	6.65	14.98	2.97(748)		0.003
33	C	3	7.48	0.41	0.23	7.00	7.75	1	6.67					–	3(1.34)	0.500
	D	56	6.61	0.85	0.11	5.24	8.31	27	6.40	0.74	0.14	5.1	7.55	1.08(81)		0.284
	E	77	7.67	0.96	0.11	5.41	10.31	75	7.32	0.87	0.10	5.01	8.91	2.36(150)		0.020
	F	158	10.17	1.11	0.09	7.82	12.66	133	9.29	1.07	0.09	6.44	12.21	6.85(289)		< 0.001
	G	107	12.31	1.18	0.11	9.90	14.38	104	10.93	0.89	0.09	8.66	13.90	9.57(196.5)*		< 0.001
	H	97	13.66	0.90	0.09	10.71	14.99	184	13.15	1.02	0.08	10.46	14.99	4.19(279)		< 0.001
34	C	13	6.09	0.61	0.17	5.24	7.01	7	6.41	0.91	0.34	5.01	7.23		31(1.15)	0.275
	D	91	7.04	0.89	0.09	5.37	9.08	70	6.89	0.81	0.10	5.01	8.30	1.08(159)		0.280
	E	90	8.93	0.96	0.10	6.78	11.82	103	8.50	0.96	0.09	6.21	10.51	3.23(191)		0.002
	F	121	10.81	0.99	0.09	8.89	13.32	104	10.35	0.90	0.09	8.41	12.48	3.62(223)		< 0.001
	G	69	12.30	1.09	0.13	10.29	14.38	100	11.62	1.01	0.10	8.66	13.52	4.21(167)		< 0.001
	H	114	13.62	0.89	0.08	10.71	14.99	140	13.44	0.91	0.08	10.46	14.98	1.63(252)		0.104
35	B	2	5.49	0.27	0.19	5.30	5.69	2	5.12	0.17	0.12	5.01	5.24	1.65(2)	4(1.55)	0.333
	C	43	6.72	0.84	0.13	5.24	8.35	17	6.68	0.66	0.16	5.46	7.50	0.18(58)	379(0.22)	0.825
	D	82	7.53	1.08	0.12	5.49	10.56	89	7.26	0.98	0.10	5.01	9.71	1.75(169)		0.081
	E	97	9.36	1.05	0.11	6.78	11.82	117	9.27	1.03	0.10	7.23	11.86	0.66(212)		0.510
	F	132	11.51	1.24	0.11	9.26	14.38	96	10.90	1.03	0.11	8.66	13.11	3.97(226)		< 0.001
	G	71	12.80	1.14	0.14	10.31	14.53	116	12.34	1.11	0.10	10.25	14.16	2.75(185)		0.007
	H	70	13.79	0.82	0.10	12.10	14.99	87	13.68	0.83	0.09	11.57	14.98	0.82(156)		0.416
36	D	1	5.69													
	E	17	5.58	0.20	0.05	5.24	5.96	8	5.82	0.70	0.25	5.01	7.30		54(0.82)	0.440
	F	27	6.70	0.61	0.12	5.85	7.99	15	6.19	0.47	0.12	5.41	7.21		288(2.24)	0.025
	G	123	8.43	1.28	0.12	5.52	11.56	93	7.47	0.85	0.09	5.01	10.37	6.64(210.5)*		< 0.001
	H	330	11.86	1.89	0.10	6.78	14.99	408	11.49	1.88	0.09	7.23	14.98	2.68(736)		0.007
37	B	5	7.29	1.75	0.78	5.30	9.15	1	5.01						5(1.46)	0.333
	C	81	6.86	0.97	0.11	5.24	9.86	32	6.54	0.77	0.14	5.24	7.97	1.68(111)		0.096
	D	98	8.79	1.22	0.12	5.49	12.61	125	7.97	1.14	0.10	5.01	11.36	5.13(221)		< 0.001
	E	105	10.29	1.20	0.12	6.78	12.92	125	10.00	1.03	0.09	7.23	12.32	1.98(228)		0.049
	F	99	12.06	1.13	0.11	9.47	14.63	73	11.46	0.83	0.10	9.32	13.52	4.00(170)*		< 0.001
	G	110	13.69	0.83	0.08	10.74	14.99	168	13.24	1.00	0.08	10.46	14.98	3.90(276)		< 0.001
	H															

* Equal variances not assumed; N, number of participants; Mean, mean age; SD, standard deviation; SEM, standard error of the mean; Min, minimal age; Max, maximum age; t, independent-samples *t*-test; df, degrees of freedom; Mann-Whitney, independent-samples Mann-Whitney *U* test; P, statistically significant if < 0.05.

Table 4
Comparison of chronological age (CA) and dental age (DA) (years) calculated using Demirjian's, Chaillet's and Willems' methods.

Method	Gender	N	CA ± SD	DA ± SD	(DA-CA) ± SD	L*	U*	MAE ± SD[b]	t(df)	*P*[a]
Dem73	Males	498	10.51 ± 2.60	10.94 ± 2.74	**0.43** ± 0.90	0.35	0.51	0.78 ± 0.63	10.75(497)	< 0.001
Dem76				10.71 ± 2.62	**0.20** ± 0.80	0.13	0.27	0.65 ± 0.51	5.64(497)	< 0.001
Dem76PM_1				10.46 ± 2.48	**−0.05** ± 0.86	−0.13	0.02	0.70 ± 0.57	−1.32(497)	0.188
Dem76IN_2,				10.54 ± 2.60	**0.03** ± 0.90	−0.05	0.11	0.71 ± 0.54	0.67(497)	0.501
Chaillet				10.26 ± 2.58	**−0.24** ± 0.85	−0.32	−0.17	0.72 ± 0.52	−6.39(497)	< 0.001
Willems				10.36 ± 2.55	**-0.14** ± 0.77	−0.21	−0.08	0.61 ± 0.49	−4.20(497)	< 0.001
Dem73	Females	524	10.54 ± 2.48	11.09 ± 2.50	**0.55** ± 0.72	0.49	0.61	0.69 ± 0.58	17.59(523)	< 0.001
Dem76				10.97 ± 2.62	**0.43** ± 0.76	0.37	0.50	0.67 ± 0.56	13.13(523)	< 0.001
Dem76PM_1				10.99 ± 2.57	**0.45** ± 0.81	0.38	0.52	0.72 ± 0.58	12.64(523)	< 0.001
Dem76IN_2,				11.00 ± 2.61	**0.46** ± 0.83	0.39	0.54	0.75 ± 0.59	12.72(523)	< 0.001
Chaillet				10.19 ± 2.27	**−0.35** ± 0.74	−0.31	−0.18	0.66 ± 0.49	−7.47(523)	< 0.001
Willems				10.29 ± 2.45	**−0.24** ± 0.75	−0.31	−0.18	0.64 ± 0.46	−10.85(532)	< 0.001

A paired t-test between DA and CA; DA-CA—difference between dental and chronological age; L—lower interval and U—upper interval of 95% Confidence Interval of DA-CA ; MAE—mean absolute error between dental and chronological age; SD—standard deviation; df—degrees of freedom.

* Significant if $p < 0.05$.

Table 5
The summary of repeated-measures ANOVA for the within-subjects variables DA-CA and MAE of four Demirjian's, Chaillet's and Willems' methods (Methods).

Gender	Source	Type III Sum of Squares	Degrees of freedom	Mean Square	F	*P*
Males	DA-CA	150.56	3.38	44.57	345.90	< 0.001
	Error (DA-CA)	216.32	1678.73	0.13		
Females	DA-CA	423.57	2.94	143.97	1212.02	< 0.001
	Error (DA-CA)	182.78	1538.76	0.12		
Males	MAE	8.22	2.93	2.81	14.68	< 0.001
	Error (MAE)	287.53	1455.02	0.19		
Females	MAE	4.71	1.67	2.82	6.13	0.004
	Error (MAE)	401.70	873.23	0.46		

DA-CA, difference between dental and chronological age; MAE, mean absolute error.

chronological age in males showed the methods based on four teeth, $Dem76IN_2$ (0.03 years) and $Dem76PM_1$ (−0.05 years) following Willems method, based on seven teeth, (−0.14 years), the least accurate methods were Dem73 (0.43 years) and Chaillet method (−0.24 years). In females, the best accuracy showed the Willems method (−0.24 years) following Chaillet method (−0.35 years), the least accurate methods were Dem73 (0.55 years) and Dem76 (0.43 years).

Numerous previous studies of Demirjian maturity standards showed an overestimation of dental age when applied to different populations [9,15,26,27]. Our results of overestimation of dental age are generally in line with most previous studies but show the smaller difference between DA and CA. A meta-analysis by Yan et al. [28], of a 370 peer-reviewed articled, in which 26 studies were selected for Demirjian's method with a total of 11,499 children, showed a mean overestimation of 0.35 years and 0.39 years in males and females, respectively [28]. A stratified analysis by ethnicity showed that in males dental age was lesser overestimated in Asians, 0.28 years (95%CI, 0.19 to 0.37 years), than in Caucasians, 0.38 years (95%CI, 0.09–0.68 years). In females, dental age overestimated by 0.24 years for Asians (95% CI, 0.14 to 0.34 years) and 0.52 years for Caucasians (95% CI, 0.17 to 0.88 years) [28]. Another meta-analysis, by Jayaraman et al. [29], identified 274 studies, published between 1973 and December 2011, with 34 studies available for the qualitative analysis, from which finally included 12 studies for quantitative synthesis [29]. Demirjian methods on seven teeth overestimated on average by 0.60 years and 0.65 years in males and females, respectively [29]. Differences between dental and chronological age showed an overestimation in the most studies, except in Venezuelan Indians in both males and females. The age difference was from −0.23 years to 3.04 years for males and from −0.10 years to 2.82 years for females [29,30]. Both meta-analyses did not analyze the Demirjian methods from 1973 and 1976 separately.

There are very few studies in which system of four teeth, $Dem76PM_1$ and $Dem76IN_2$ methods, was used. Flood et al. [31] reported an average overestimation by 0.04 years and 0.25 years for $Dem76PM_1$ method and underestimation by −0.20 years and an overestimation by 0.37 years for $Dem76IN_2$ for males and females, respectively. Ambarkova et al. [15] reported an overestimation for a $Dem76PM_1$ method by 0.65 years and 0.98 years while for a $Dem76IN_2$ method by 0.75 years and 1.08 years in males and females, respectively. The recent study on four Demirjian's and Willems' methods was performed by Akkaya et al. [32] in Turkish children. The mean overestimations were 0.21 years and 0.57 years for a $Dem76PM_1$ method and 0.18 years and 0.61 years for a $Dem76IN_2$ method for males and females, respectively. Chaillet's international maturity curves were the last published among all tested methods [19]. Chaillet et al. [19] studied dental maturity on 9577 OPTs from eight different countries with the main aim to use international standards in cases when the ethnic origin is unknown. Galić et al. [33], in the Bosnian-Herzegovina study of 1772 children, reported an overestimation by 0.28 years and 0.09 years in males and females, respectively. Study on 743 French children by Urzel and Bruzek [34] reported an underestimation by −0.18 years for males and −0.59 years for females. In the study on Spanish and Venezuelan children by Cruz-Landeira et al. [30], Chaillet's method overestimated dental age by 0.37 years for males and 0.21 years for females for Spanish while underestimated by −0.48 years for males and −0.61 years for females. Willems et al. [20] have modified and simplified original Demirjian's method on seven teeth, and according to many comparative studies, accuracy was superior to Demirjian's [15,35,36]. The most recent systematic review and meta-analysis on Willems method have been conducted by Sehrawat and Singh [21], on totally 983 studies and selected 15 studies for meta-analysis. An average overestimation for Willems method was 0.04 years (95% CI, −0.05 to 0.14 years) and 0.02 years (95% CI, −0.08 to 0.12 years) in males and females, respectively.

According to our findings, Willems method showed the smallest difference between dental age and chronological age and may be recommended for age estimation if all seven teeth are available. In cases where some of the permanent teeth are missing, alternative methods on four available teeth may be used. In our study, the repeated-measures ANOVA verified the statistically significant differences of mean DA-CA among tested methods, DA-CA was not statistically significantly different only in three Demirjian methods from 1976 in females.

In our study, the mean ages of the Demirjian's stages were lower in females when compared to males in most stages of all seven mandibular teeth. The statistically significant difference was mostly found in Demirjian's stages G and F in almost all teeth with sporadical findings of specific stages in different teeth. These findings of advanced dental development in females are in line with many previous studies [15,37–39]. The mean age of the final stage H is affected by the sample distribution because it is not possible to determine the timing of the final closure of the root apices [37]. The comparison of mean age within the specific stage to other similar studies should be observed in the light of the influence of various factors, such as sample size, structure, and distribution of the sample which may refer to the existence of population differences, when in reality do not exist [15,40]. Liversidge [41] pointed that the significant differences in dental maturity score do not reflect any biological difference in the timing of tooth formation stages at the population level.

There are different ways to quantify the quality of age estimation method, including the lack of bias, mean or median absolute difference, as well as high percentage of age within six months [42]. According to Liversidge et al. [42], the most important is the lack of error including the smallest mean absolute error. In our study, we reported both, error or DA-CA and MAE as recommended by Liversidge [43]. The best performance according to MAE also showed the Willems method with MAE of 0.61 years in males and 0.64 years in females. Consequently, in this research, the effectiveness of the six methods was compared regarding a mean absolute error between the estimated and actual age, and the number of age estimates that were either $< \pm 1$ year considered as accurate from actual age, otherwise $> \pm 1$ year were considered as inaccurate [44]. The age difference of up to 1.0 years is considered accurate in forensic anthropology in most cases [31]. Mean age difference across different age groups in our study mostly fulfill these criteria.

Procedures for age estimation in children have been established to estimate biological age and maturity of the individual child [45]. Also, may help in identification of a particular child in casualties in mass disasters and can be of crucial importance in legal and criminal proceedings [46]. The radiography, including three-dimensional

Table 6
A comparisons of chronological age (CA) and dental age (DA) (years) calculated using Demirjian's, Chaillet's and Willems' methods across different age groups in males.

Age groups	N	Method	CA ± SD	DA ± SD	(DA-CA) ± SD	L	U)	MAE ± SD[b]	t(df)	P[a]
5.0–5.9	21	Dem73	5.61 ± 0.20	6.45 ± 0.64	0.84 ± 0.60	0.56	1.11	0.91 ± 0.47	6.37(20)	< 0.001
		Dem76		6.01 ± 0.70	0.40 ± 0.65	0.11	0.70	0.60 ± 0.47	2.82(20)	0.011
		$Dem76PM_1$		6.14 ± 0.67	0.53 ± 0.63	0.25	0.82	0.67 ± 0.47	3.91(20)	< 0.001
		$Dem76IN_2$		6.19 ± 0.73	0.58 ± 0.68	0.27	0.89	0.76 ± 0.45	3.94(20)	< 0.001
		Chaillet		5.53 ± 0.61	−0.08 ± 0.57	−0.34	0.18	0.42 ± 0.39	−0.63(20)	0.537
		Willems		5.51 ± 0.70	−0.10 ± 0.66	−0.41	0.20	0.44 ± 0.50	−0.72(20)	0.478
6.0–6.9	32	Dem73	6.51 ± 0.26	7.39 ± 0.62	0.88 ± 0.53	0.69	1.07	0.88 ± 0.53	9.45(31)	< 0.001
		Dem76		7.12 ± 0.72	0.60 ± 0.61	0.38	0.82	0.61 ± 0.60	5.56(31)	< 0.001
		$Dem76PM_1$		7.06 ± 0.84	0.55 ± 0.77	0.27	0.82	0.82 ± 1.15	4.02(31)	< 0.001
		$Dem76IN_2$		7.06 ± 0.82	0.55 ± 0.75	0.28	0.82	0.66 ± 0.65	4.15(31)	< 0.001
		Chaillet		6.61 ± 0.84	0.10 ± 0.74	−0.17	0.36	0.52 ± 0.52	0.75(31)	0.458
		Willems		6.90 ± 0.77	0.39 ± 0.66	0.15	0.62	0.51 ± 0.56	3.32(31)	0.002
7.0–7.9	57	Dem73	7.56 ± 0.27	7.78 ± 0.59	0.22 ± 0.57	0.06	0.37	0.45 ± 0.42	2.85(56)	0.006
		Dem76		7.61 ± 0.68	0.04 ± 0.65	−0.13	0.21	0.49 ± 0.42	0.48(56)	0.633
		$Dem76PM_1$		7.60 ± 0.78	0.03 ± 0.73	−0.16	0.22	0.57 ± 0.45	0.32(56)	0.750
		$Dem76IN_2$		7.51 ± 0.74	−0.05 ± .71	−0.24	0.13	0.57 ± 0.42	−0.58(56)	0.563
		Chaillet		7.27 ± 0.91	−0.30 ± 0.87	−0.53	−0.07	0.76 ± 0.50	−2.59(56)	0.012
		Willems		7.53 ± 0.72	−0.03 ± 0.70	−0.22	0.15	0.53 ± 0.45	−0.35(56)	0.724
8.0–8.9	49	Dem73	8.58 ± 0.22	8.76 ± 0.69	0.18 ± 0.63	0.00	0.36	0.50 ± 0.41	2.01(48)	0.050
		Dem76		8.67 ± 0.71	0.08 ± 0.65	−0.10	0.27	0.52 ± 0.40	0.89(48)	0.376
		$Dem76PM_1$		8.56 ± 0.66	−0.02 ± 0.64	−0.21	0.16	0.51 ± 0.39	−0.26(48)	< 0.001
		$Dem76IN_2$		8.53 ± 0.69	−0.05 ± 0.65	−0.24	0.13	0.50 ± 0.41	−0.56(48)	0.577
		Chaillet		8.46 ± 0.77	−0.12 ± 0.71	−0.32	0.08	0.60 ± 0.38	−1.20(48)	0.236
		Willems		8.48 ± 0.56	−0.10 ± 0.51	−0.25	0.05	0.40 ± 0.33	−1.38(48)	0.174
9.0–9.9	55	Dem73	9.55 ± 0.31	10.11 ± 0.89	0.55 ± 0.77	0.35	0.76	0.79 ± 0.52	5.32(54)	< 0.001
		Dem76		10.04 ± 0.90	0.49 ± 0.78	0.28	0.70	0.77 ± 0.49	4.63(54)	< 0.001
		$Dem76PM_1$		9.09 ± 0.88	0.19 ± 0.84	−0.03	0.42	0.74 ± 0.44	1.72(54)	0.091
		$Dem76IN_2$		9.72 ± 1.00	0.17 ± 0.82	−0.05	0.39	0.68 ± 0.47	1.55(54)	0.126
		Chaillet		9.76 ± 0.74	0.21 ± 0.62	0.04	0.38	0.57 ± 0.32	2.47(54)	0.017
		Willems		9.61 ± 0.70	0.06 ± 0.61	−0.10	0.23	0.49 ± 0.37	0.74(54)	0.463
10.0–10.9	58	Dem73	10.52 ± 0.27	10.95 ± 1.02	0.43 ± 0.99	0.17	0.69	0.83 ± 0.69	3.32(57)	0.002
		Dem76		10.91 ± 0.97	0.39 ± 0.95	0.14	0.64	0.80 ± 0.63	3.12(57)	0.003
		$Dem76PM_1$		10.54 ± 1.00	0.02 ± 1.00	−0.24	0.28	0.81 ± 0.58	0.130(57)	0.897
		$Dem76IN_2$		10.70 ± 0.97	0.18 ± 0.98	−0.08	0.43	0.83 ± 0.54	1.36(57)	0.178
		Chaillet		10.46 ± 0.79	−0.06 ± 0.77	−0.27	0.14	0.59 ± 0.49	−0.64(57)	0.526
		Willems		10.50 ± 0.91	−0.02 ± 0.88	−0.25	0.21	0.64 ± 0.59	−0.21(57)	0.838
11.0–11.9	60	Dem73	11.49 ± 0.29	11.55 ± 0.77	0.06 ± 0.75	−0.13	0.25	0.56 ± 0.49	0.63(59)	0.532
		Dem76		11.50 ± 0.74	0.01 ± 0.72	−0.18	0.19	0.54 ± 0.46	0.08(59)	0.938
		$Dem76PM_1$		11.20 ± 1.17	−0.29 ± 0.73	−0.48	−0.10	0.62 ± 0.49	−3.09(59)	0.003
		$Dem76IN_2$		11.25 ± 1.04	−0.24 ± 0.73	−0.43	0.05	0.59 ± 0.49	−2.53(0.59)	0.014
		Chaillet		10.85 ± 0.62	−0.64 ± 0.60	−0.80	−0.49	0.79 ± 0.40	−8.27(59)	< 0.001
		Willems		10.95 ± 0.79	−0.54 ± 0.76	−0.74	−0.34	0.81 ± 0.45	−5.53(59)	< 0.001
12.0–12.9	54	Dem73	12.48 ± 0.25	13.10 ± 1.37	0.62 ± 1.27	0.28	0.97	1.08 ± 0.91	3.61(53)	0.001
		Dem76		12.81 ± 1.09	0.33 ± 1.00	0.06	0.61	0.87 ± 0.59	2.46(53)	0.017
		$Dem76PM_1$		12.42 ± 1.05	−0.06 ± 0.98	−0.33	0.21	0.81 ± 0.55	−0.45(53)	0.658
		$Dem76IN_2$		12.50 ± 1.20	0.02 ± 1.13	−0.29	0.33	0.90 ± 0.68	0.14(53)	0.888
		Chaillet		12.19 ± 1.19	−0.29 ± 1.09	−0.58	0.01	0.96 ± 0.58	−1.93(53)	0.060
		Willems		12.40 ± 1.09	−0.07 ± 0.98	−0.34	0.20	0.83 ± 0.52	−0.54(53)	0.591
13.0–13.9	57	Dem73	13.41 ± 0.29	13.90 ± 1.12	0.49 ± 1.16	0.18	0.80	1.02 ± 0.73	3.21(56)	0.002
		Dem76		13.51 ± 0.81	0.10 ± 0.86	−0.13	0.33	0.71 ± 0.49	0.89(56)	0.379
		$Dem76PM_1$		13.17 ± 0.90	−0.24 ± 0.95	−0.49	0.01	0.85 ± 0.46	−1.94(56)	0.057
		$Dem76IN_2$		13.33 ± 1.11	−0.08 ± 1.15	−0.38	0.23	1.04 ± 0.48	−0.52(56)	0.605
		Chaillet		12.94 ± 1.01	−0.47 ± 1.06	−0.75	−0.19	0.98 ± 0.60	−3.34(56)	0.001
		Willems		13.19 ± 0.75	−0.22 ± 0.80	−0.43	−0.01	0.71 ± 0.42	−2.07(56)	0.043
14.0–14.9	55	Dem73	14.40 ± 0.26	14.91 ± 0.94	0.51 ± 0.86	0.28	0.74	0.88 ± 0.47	4.38(54)	< 0.001
		Dem76		14.27 ± 0.69	−0.13 ± 0.62	−0.29	0.04	0.49 ± 0.39	−1.52(54)	0.135
		$Dem76PM_1$		13.83 ± 0.62	−0.57 ± 0.59	−0.73	−0.41	0.60 ± 0.57	−7.17(54)	< 0.001
		$Dem76IN_2$		14.17 ± 0.82	0.23 ± 0.77	−0.44	−0.02	0.58 ± 0.56	−2.21(54)	0.031
		Chaillet		13.91 ± 0.89	−0.49 ± 0.81	−0.71	−0.27	0.68 ± 0.66	−4.49(54)	< 0.001
		Willems		13.88 ± 0.63	−0.52 ± 0.57	−0.67	−0.37	0.58 ± 0.50	−6.81(54)	< 0.001

A pairedt-test between DA and CA; DA-CA—difference between dental and chronological age; L—lower interval and U—upper interval of 95% Confidence Interval of DA-CA ; MAE—mean absolute error between dental and chronological age; SD—standard deviation; df—degrees of freedom; * significant if $p < 0.05$.

reconstructions of the developing teeth, with small effective doses of the radiation, is a perfect tool for the evaluation and analysis of developing teeth [47,48]. During children's growth and development, the dental maturity better correlate to age than to the skeletal maturity, [49–51]. Several concepts have been presented for evaluation of dental maturity: an analysis of the eruption of the teeth in the mouth, morphological changes or mineralization that can be seen on dental X-rays [52]. Using the X-ray examination for the dental maturity was

Table 7
A comparisons of chronological age (CA) and dental age (DA) (years) calculated using Demirjian's, Chaillet's and Willems' methods across different age groups in females.

Age groups	N	Method	CA ± SD	DA ± SD	(DA-CA) ± SD	L	U	MAE ± SD[b]	t(df)	P[a]
5.0–5.9	12	Dem73	5.48 ± 0.30	6.48 ± 0.92	1.00 ± 0.88	0.44	1.56	1.11 ± 0.73	3.91(11)	0.002
		Dem76		6.10 ± 0.85	0.61 ± 0.86	0.07	1.16	0.79 ± 0.67	2.47(11)	0.031
		$Dem76PM_1$		6.28 ± 0.85	0.80 ± 0.89	0.23	1.36	0.87 ± 0.80	3.11(11)	0.010
		$Dem76IN_2$,		6.61 ± 1.00	0.16 ± 0.77	0.20	1.44	1.0 ± 0.77	2.91(11)	0.014
		Chaillet		5.65 ± 0.73	0.16 ± 0.77	−0.33	0.65	0.56 ± 0.52	0.73(11)	0.480
		Willems		5.66 ± 0.99	0.17 ± 1.07	−0.51	0.85	0.92 ± 0.49	0.55(11)	0.590
6.0–6.9	38	Dem73	6.50 ± 0.28	7.37 ± 0.52	0.86 ± 0.46	0.71	1.01	0.90 ± 0.37	11.57(37)	< 0.001
		Dem76		7.04 ± 0.65	0.54 ± 0.57	0.35	0.73	0.69 ± 0.37	5.79(37)	< 0.001
		$Dem76PM_1$		7.37 ± 0.63	0.87 ± 0.56	0.69	1.06	0.95 ± 0.42	9.53(37)	< 0.001
		$Dem76IN_2$,		7.34 ± 0.78	0.84 ± 0.71	0.61	1.07	1.00 ± 0.45	7.36(37)	< 0.001
		Chaillet		6.65 ± 0.73	0.14 ± 0.63	−0.06	0.35	0.53 ± 0.35	1.41(37)	0.167
		Willems		6.78 ± 0.60	0.27 ± 0.54	0.10	0.45	0.50 ± 0.34	3.15(37)	0.003
7.0–7.9	52	Dem73	7.58 ± 0.28	7.92 ± 0.74	0.34 ± 0.70	0.15	0.53	0.47 ± 0.62	3.51(51)	0.001
		Dem76		7.70 ± 0.85	0.12 ± 0.78	−0.10	0.34	0.52 ± 0.59	1.12(51)	0.268
		$Dem76PM_1$		7.77 ± 0.86	0.20 ± 0.76	−0.02	0.41	0.54 ± 0.57	1.86(51)	0.069
		$Dem76IN_2$		7.85 ± 0.86	0.27 ± 0.75	0.06	0.48	0.58 ± 0.54	2.63(51)	0.011
		Chaillet		7.42 ± 0.88	−0.15 ± 0.81	−0.38	0.07	0.64 ± 0.51	−1.37(51)	01.76
		Willems		7.38 ± 0.68	−0.19 ± 0.62	−0.37	−0.02	0.48 ± 0.43	−2.25(51)	0.029
8.0–8.9	57	Dem73	8.53 ± 0.28	8.99 ± 0.75	0.47 ± 0.64	0.30	0.64	0.59 ± 0.53	5.50(56)	< 0.001
		Dem76		8.92 ± 0.74	0.39 ± 0.63	0.22	0.56	0.55 ± 0.49	4.70(56)	< 0.001
		$Dem76PM_1$		8.98 ± 0.73	0.46 ± 0.63	0.29	0.62	0.59 ± 0.50	5.53(56)	< 0.001
		$Dem76IN_2$,		8.93 ± 0.67	0.41 ± 0.60	0.25	0.57	0.52 ± 0.50	5.14(56)	< 0.001
		Chaillet		8.59 ± 0.70	0.07 ± 0.57	−0.08	0.22	0.43 ± 0.37	0.88(56)	0.383
		Willems		8.34 ± 0.63	−0.18 ± 0.54	−0.33	−0.04	0.45 ± 0.34	−2.58(56)	0.013
9.0–9.9	65	Dem73	9.58 ± 0.28	10.21 ± 0.72	0.63 ± 0.65	0.30	0.47	0.74 ± 0.52	7.80(64)	< 0.001
		Dem76		10.07 ± 0.66	0.49 ± 0.60	0.22	0.34	0.64 ± 0.44	6.53(64)	< 0.001
		$Dem76PM_1$		9.93 ± 0.64	0.35 ± 0.61	0.20	0.50	0.57 ± 0.41	4.65(64)	< 0.001
		$Dem76IN_2$,		9.83 ± 0.77	0.25 ± 0.72	0.07	0.43	0.62 ± 0.44	2.74(64)	0.008
		Chaillet		9.48 ± 0.43	−0.10 ± 0.40	−0.08	−0.20	0.30 ± 0.28	−2.03(64)	0.046
		Willems		9.22 ± 0.64	−0.36 ± 0.60	−0.33	−0.51	0.58 ± 0.38	−4.92(64)	< 0.001
10.0–10.9	65	Dem73	10.58 ± 0.27	11.27 ± 0.79	0.69 ± 0.73	0.51	0.87	0.78 ± 0.62	7.61(64)	< 0.001
		Dem76		11.13 ± 0.81	0.55 ± 0.75	0.36	0.73	0.70 ± 0.60	5.89(64)	< 0.001
		$Dem76PM_1$		11.15 ± 0.96	0.57 ± 0.89	0.35	0.79	0.80 ± 0.68	5.18(64)	< 0.001
		$Dem76IN_2$,		11.19 ± 0.95	0.62 ± 0.87	0.40	0.83	0.86 ± 0.61	5.72(64)	0.209
		Chaillet		10.25 ± 0.63	−0.33 ± 0.58	−0.47	−0.19	0.56 ± 0.36	−4.60(64)	< 0.001
		Willems		10.35 ± 0.87	−0.23 ± 0.81	−0.43	−0.03	0.69 ± 0.47	−2.25(64)	0.028
11.0–11.9	64	Dem73	11.48 ± 0.29	11.96 ± 0.96	0.48 ± 0.88	0.26	0.70	0.74 ± 0.67	4.34(63)	< 0.001
		Dem76		11.77 ± 1.02	0.29 ± 0.94	0.06	0.53	0.76 ± 0.62	2.50(63)	0.015
		$Dem76PM_1$		11.66 ± 1.09	0.18 ± 1.02	−0.07	0.44	0.82 ± 0.63	1.43(63)	0.159
		$Dem76IN_2$,		11.68 ± 1.09	0.20 ± 1.02	−0.05	0.45	0.82 ± 0.63	1.57(63)	0.121
		Chaillet		10.83 ± 0.87	−0.65 ± 0.79	−0.85	−0.45	0.89 ± 0.50	−6.61(63)	< 0.001
		Willems		11.07 ± 1.01	−0.41 ± 0.93	−0.64	−0.18	0.87 ± 0.53	−3.50(63)	0.001
12.0–12.9	63	Dem73	12.50 ± 0.29	13.26 ± 0.97	0.76 ± 0.86	0.55	0.98	0.94 ± 0.66	7.09(62)	< 0.001
		Dem76		13.17 ± 1.09	0.68 ± 0.98	0.43	0.92	0.95 ± 0.72	5.47(62)	< 0.001
		$Dem76PM_1$		13.13 ± 1.21	0.63 ± 1.12	0.35	0.92	1.09 ± 0.67	4.47(62)	0.
		$Dem76IN_2$,		13.19 ± 1.21	0.69 ± 1.12	0.41	0.97	1.08 ± 0.74	4.91(62)	0.
		Chaillet		12.04 ± 1.01	−0.46 ± 0.90	−0.69	−0.23	0.83 ± 0.58	−4.01(62)	< 0.001
		Willems		12.40 ± 1.06	−0.09 ± 0.97	−0.34	0.15	0.77 ± 0.58	−0.76(62)	0.451
13.0–13.9	64	Dem73	13.48 ± 0.30	14.02 ± 0.56	0.54 ± 0.55	0.40	0.67	0.60 ± 0.47	7.85(63)	< 0.001
		Dem76		14.04 ± 0.71	0.56 ± 0.68	0.38	0.73	0.68 ± 0.56	6.50(63)	< 0.001
		$Dem76PM_1$		14.08 ± 0.70	0.60 ± 0.64	0.44	0.76	0.75 ± 0.45	7.76(63)	0.0
		$Dem76IN_2$,		14.12 ± 0.76	0.64 ± 0.69	0.47	0.82	0.81 ± 0.48	7.43(63)	0.0
		Chaillet		12.85 ± 0.62	−0.63 ± 0.60	−0.78	−0.48	0.72 ± 0.48	−8.42(63)	< 0.001
		Willems		13.22 ± 0.63	−0.26 ± 0.60	−0.41	−0.11	0.54 ± 0.36	−3.48(63)	0.001
14.0–14.9	44	Dem73	14.39 ± 0.32	14.42 ± 0.37	0.03 ± 0.34	−0.08	0.13	0.29 ± 0.18	0.50(43)	0.619
		Dem76		14.55 ± 0.49	0.16 ± 0.43	0.03	0.29	0.39 ± 0.24	2.55(43)	0.014
		$Dem76PM_1$		14.54 ± 0.33	0.15 ± 0.32	0.05	0.24	0.28 ± 0.21	3.02(43)	0.004
		$Dem76IN_2$,		14.62 ± 0.37	0.23 ± 0.34	0.12	0.33	0.32 ± 0.25	4.35(43)	0.0
		Chaillet		13.30 ± 0.40	−1.09 ± 0.36	−1.20	−0.98	1.09 ± 0.36	−19.83(43)	< 0.001
		Willems		13.64 ± 0.39	−0.75 ± 0.36	−0.86	−0.64	0.75 ± 0.36	−13.77(43)	< 0.001

A pairedt-test between DA and CA; DA-CA—difference between dental and chronological age; L—lower interval and U—upper interval of 95% Confidence Interval of DA-CA ; MAE—mean absolute error between dental and chronological age; SD—standard deviation; df—degrees of freedom; * significant if $p < 0.05$.

recommended by the previous studies of different diagnostic procedures [53]. Demirjian's maturity standards, based on the staging assigned by following the specific criteria for each stage and by comparing each tooth with the diagrams and X-ray pictures, was suggested because of acceptable reproducibility of mineralization stages [27,33,35,37,54].

This study, with the cross-section sample, was the first study in Kosovo that simultaneously compare four different Demirjian methods

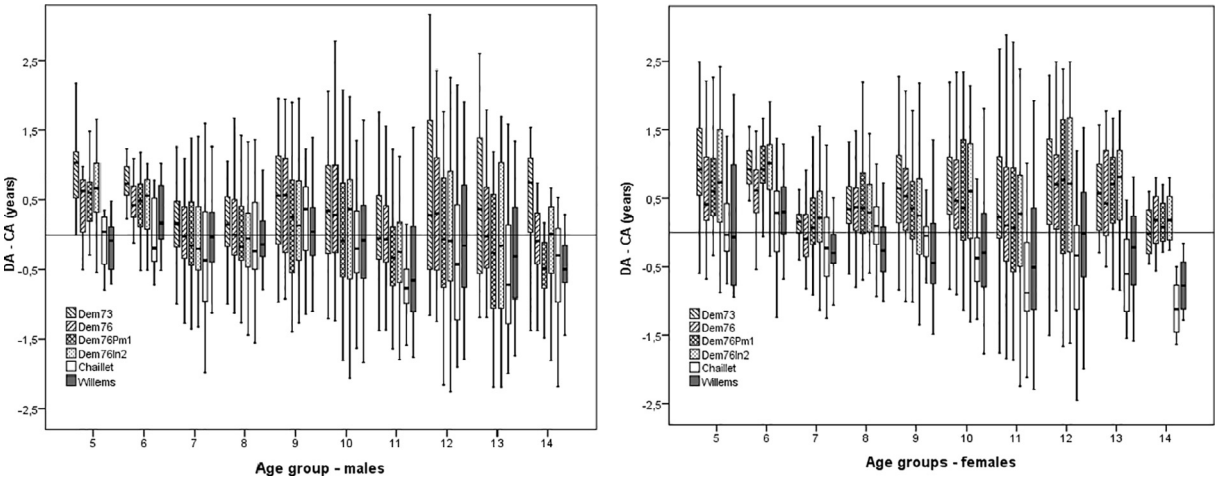

Fig. 2. Boxplots of the relationship between age groups age and difference between dental age according to four Demirjian, Chaillet and Willems methods and chronological age (DA-CA) for males and females. Boxplot shows median and inter-quartile ranges, while whiskers are lines extending from box to highest and lowest values, excluding outliers.

and two modification, Chaillet's international standards, and Willems' method. The study tested the precision and accuracy of the six-listed method for possible application in age estimation procedures and clinical cases. The previous study tested the applicability of the third molar maturity index for indicating adult age in Kosovar population, an ethnic Albanians, with the results in line with other population from the geographic region [55–58]. The Kosovo war in 1998–1999 was the final part of the breaking of the Yugoslav federation. The war led to the displacement of 850,000 Kosovars (ethnic Albanians) to Albania, Montenegro and the former Yugoslav Republic of Macedonia and then by the Humanitarian Evacuation Program to other European countries or overseas [59]. Many Kosovars applied for asylum during the war, mostly in Germany, Switzerland, United Kingdom and Belgium [59]. In 2008, Kosovo's Parliament declared independence. The 2011 census noted over 1.7 million inhabitants in Kosovo. The most significant ethnic group and the absolute majority are Albanians, following Serbs, Bosniaks, Turks, and others. A few studies tested age estimation methods on teeth in Albanians. There is no broad consensus on whether ethnicity in some ways affects the development of the tooth. From the forensic view, the validation of scientific age estimation methods in a representative sample from the specific population can provide the expert with the knowledge for the best evaluation of a particular case. Next, alternative possibilities and methods on a specific set of teeth, in cases with missing teeth, could be decisive. Especially this applies to criminal or judicial proceedings of the investigated person. Our presented results of six methods and the recommendations obtained from the published meta-analyses proved the necessity of the evaluation of scientific age estimation methods on a Kosovars or any new population-specific sample [28].

5. Conclusion

The mineralization of the mandibular teeth was ahead in females in most stages. The Willems method is the most accurate for estimating a dental age if all seven teeth are available for analysis. We found the similar accuracy of $Dem76PM_1$ and $Dem76IN_2$ methods; therefore we may encourage their use for age estimation in the children from Kosovo.

6. Declaration

The authors declare no conflict of interest.

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