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Assessment of the Dental Age of Children in the Polish Population with Comparison of the Demirjian and the Willems Methods

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Background: Dental age is less affected than the bone age by nutritional and hormonal factors. The assessment of dental age in children is of value in clinical and forensic practice. The aims of this study were to compare the Demirjian method and the Willems method in the assessment of dental age in children in Poland and to consider the need to standardize dental age assessment.

Material/Methods: Polish children of Caucasian ethnicity (n=1,002) who were treated at a single orthodontic center between 1994–2016 included girls (n-540) and boys (n=462) aged between 4–17 years, and 1,002 panoramic radiographs were reviewed. Dental age was assessed using the Demirjian method and the Willems method, the findings of the two methods were compared with the chronological age of the study participants.

Results: Following statistical analysis, both the Demirjian method and the Willems method overestimated the dental age of the younger study participants, and underestimated the dental age of the older study participants. Both the Demirjian method and the Willems method had similar accuracy in estimating the chronological and dental age in the Polish population.

Conclusions: In the assessment of dental age in Polish children from panoramic radiographs, both the Demirjian method and the Willems method were accurate and should still be used as a method of choice. However, it seems reasonable to create international standards for the assessment of dentition maturity for this population to obtain a more acceptable range of error values between the dental age and chronological age.

MeSH Keywords: Age Determination by Teeth • Dentistry • Poland

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Background

The accurate assessment of the chronological age, or real age, is important in the evaluation of the normal development of children and adolescents and is also used in forensic identification. However, chronological age does not always reflect the developmental maturity of the child or adolescent and it may be necessary to use several developmental indices, including bone age, dental age, assessment of secondary sex characteristics, morphological age, and mental age [1]. Using several indices in a given patient will allow for precise determination of their chronological age [2]. The development of permanent dentition (dental age) is less affected by environmental factors, such as nutrition and hormone metabolism, compared to the skeletal development, or bone age [3]. Therefore accurate methods of assessment of dental age are useful in everyday clinical practice.

Also, for children and adolescents with an unknown date of birth, international adoption agencies have regarded the assessment of dental age as one of the most reliable methods to determine chronological age [4,5]. Assessment of dental age can also be used by international organizations to identify subjects who are illegal immigrants to a given country [6]. Dental age is used to determine the age of subjects at death, and is of particular importance in forensic medicine and anthropology to determine the chronological age of human remains [7–10].

In children who are being treated for endocrinological disorders that affect development, dental age is an important element in the diagnosis and the evaluation of treatment outcome [11]. Dental age is one of the indices of chronological or biological age and is used by orthodontists when planning treatment of young patients. Knowledge of the correct dental age, particularly when the patient is expected to undergo a growth spurt, allows treatment planning to include the optimum time to begin treatment, or to schedule surgical correction of skeletal defects.

There are many methods to assess dental age, and the majority of methods are based on the evaluation of the stage of mineralization of the tooth root, determined by panoramic radiographs. The Demirjian method is widely used because it is easy to conduct, reproducible, and panoramic radiographs required in this method are available in most orthodontic practices [12,13]. However, there have been reports in the literature indicating that the chronological age calculated with the Demirjian method is overestimated, due to the acceleration of tooth development in some cases, and because ethnic or geographic differences may be present. For example, there has been a wide range of studies in different geographical groups [13–21] that have criticized the current recommended standards of dental age evaluation, as the original Demirjian methods were based on French-Canadian standards in children in the 1970's [12,13]. An alternative method is the Willems method, a modified version of the Demirjian method, prepared for the Caucasian Belgian population in 2001 [22]. Several published studies have reported that the Willems method effectively assesses the dental age in their respective populations due to the more advanced dental maturation of the different study populations [17–19,22–28]. Previous studies have also shown that maturity of dentition varies between ethnic groups [14,29–32]. There is increasing support for the development of new standards for the assessment of dental age that are applicable and relevant for specific populations.

Therefore, the aims of this study were to compare the Demirjian method and the Willems method in the assessment of dental age in children in Poland, to determine which method was more applicable to the Polish population, and to consider the need to standardize dental age assessment methods according to the patient population being evaluated.

Material and Methods

Study design

Polish children of Caucasian ethnicity (n=1,002) who were treated at the Orthodontic Clinic, Warsaw Medical University between 1994–2016 included girls (n-540) and boys (n=462), who had 1,002 panoramic radiographs available to review. The study group was divided into 13 age groups. The subjects in the study groups in the initially devised Demirjian method were aged between 2.5–17.0 years [12,13], and in the Willems method, the study group was aged between 3–18 years [13,22]. However, using the available clinical database, the age of the subjects in the present study included children and adolescents aged between 4–17 years. Dental age was assessed using the Demirjian method and the Willems method. The findings of the two methods were compared with the chronological (real) age of the study participants.

Inclusion and exclusion criteria

The eligibility criteria included healthy, Caucasian Polish boys and girls without development impairment, all with permanent tooth roots, a confirmed date of birth, and who had good quality panoramic radiographs available for review.

The exclusion criteria for this study were based on the published evidence of conditions that affect tooth development. Systemic diseases, premature birth, congenital anomalies, and malnutrition may have an influence on tooth development, the stage of periodontitis, secondary dentin deposition, and premature tooth loss [33–36]. Tooth agenesis delays dental

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age [37]. Therefore, children and adolescents with these medical conditions were excluded from this study.

Orthodontic panoramic radiographs and evaluation of dental age

Panoramic radiographs were analyzed by one expert who did not know the chronological age of the patients in the study. The dental age was determined using the Demirjian method and the Willems method. In both methods, the permanent teeth of the mandible on the left were assessed, excluding for the third molars. The developmental stage of the tooth root (bud) was assessed according to eight stages (0–7), starting from the initial signs of mineralization to the complete closure of the apical foramen. Stage 0 indicated no sign of mineralization. In the Demirjian method, each stage was assigned with a maturity score according to standard tables for men and women. Points were assigned to each stage for seven analyzed teeth. Based on the sum of points obtained, the dental age was read using conversion tables or percentile charts (50^{th} percentile). Percentile standards from ages 2.5 years to 17.0 years were evaluated.

In the Willems method, each stage was assigned a maturity score according to standard tables for men and women. The sum of the maturity points obtained made it possible to determine the dental age directly. The chronological age was determined as the difference between the date of birth and the date of a panoramic radiograph.

Statistical analysis

A randomly selected 100 panoramic radiographs were first assessed twice during an interval of two weeks, with repeat evaluation by another examiner. The intra-observer and inter-observer agreement were tested using Cohen's Kappa statistic, or coefficient (κ). The intra-examiner and inter-examiner values were calculated as 0.953 and 0.952 respectively, which were considered to represent high reproducibility.

Data on the variables in the study were analyzed using the mean ± standard deviation (SD). Comparison of means was performed with the Student's t-test for dependent (paired) variables. Correlation between the chronological age and the estimated age were determined using simple linear regression and the Pearson correlation coefficient. Statistical analysis was performed using the Statistica 10 and the Excel calculation spreadsheet.

Results

The study included 540 female 462 male children and adolescents, divided into 13 age groups. Data were analyzed separately for girls, boys, and for both genders together. The mean chronological age of the study group was 10.417 years for girls, 9.943 years for boys, and 10.198 years for the whole study group. The lowest number of patients were in the youngest age groups between 4.00–5.00 years and 5.00–6.0 years, as there are only a few indications to perform panoramic radiographs at this age.

Table 1 shows the data on the number of study participants in each age group, the mean values of the chronological (real) age, the dental age calculated with the Demirjian method and the Willems method, the differences between the chronological age and estimated dental age, the standard deviation (SD) values for the chronological age, the methods used to analyze the data and the p-values for the methods used to assess the dental age. The results were presented for both genders because the results were similar.

The Demirjian method underestimated the chronological age by 0.317 years. The Student's t-test showed a lack of statistically significant differences between errors for girls and boys and showed similar efficacy using the Demirjian method for both sexes (p=0.936). The standard deviation (SD) was 2.497 for the whole study population. The Willems method underestimated the calendar age by 0.383 years for the whole population. The Student's t-test showed similar efficacy of the Willems method for sexes (p=0.835). The standard deviation was 2.494 in the whole study population.

Statistically significant differences between the chronological age and the dental age using the Demirjian method were found in most age groups, except the age groups 4–5 years, 5–6 years, 10–11 years, and 11–12 years. Statistically significant differences between the chronological age and the dental age using the Willems method were found in most age groups, except the age groups 4–5 years, 5–6 years, 7–8 years, and 11–12 years. Both methods showed the greatest underestimation of chronological age below age the age of 13 years, with the mean difference between chronological and dental age that ranged from 0.904–1.87 years using the Demirjian method, and from 0.884–1,518 years in the Willems method.

Figure 1 shows the correlation between the chronological age and the dental age calculated with the Demirjian method, and Figure 2 shows the correlation between the chronological age and the dental age calculated with the Willems method. Table 1 shows the comparison of the dental age calculated with each study method (the Demirjian method and the Willems method) and the chronological age in the female study population. Table 2 shows the Pearson's correlation coefficient for both sexes in the study population. It is possible to determine correlations between the chronological age and the dental age estimated with both study methods. Regarding the youngest children in

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Table 1. Comparison of the dental age calculated with each study method (the Demirjian method and the Willems method) and the chronological age in the female study population. Mean values, differences between the chronological age, and the age calculated using two study methods (the Demirjian method and the Willems method) and p-values using the Student's t-test.

Real age in females (years)	N	Mean real age	Mean age Demirjian	Mean age Willems	Differences between the real age and Demirjian	p Value real age *vs.* Demirjian	Differences between the real age and Willems	p Value real age *vs.* Willems	SD real age	SD Demirjian	SD Willems
4–5	2	4.607	4.950	4.365	–0.343	**0.0191***	0.242	0.1417	0.056	0.071	0.021
5–6	7	5.684	6.100	6.110	–0.416	0.1794	–0.426	0.1606	0.229	0.768	0.737
6–7	28	6.665	7.139	7.223	–0.475	**0.0074**	–0.558	**0.0030**	0.243	0.864	0.919
7–8	74	7.476	7.545	7.633	–0.068	0.3954	–0.157	**0.0394**	0.304	0.746	0.717
8–9	97	8.490	8.120	8.128	0.370	**0.0000**	0.362	**0.0000**	0.279	0.736	0.739
9–10	69	9.457	9.125	8.973	0.332	**0.0213**	0.484	**0.0001**	0.298	1.162	0.954
10–11	61	10.456	10.344	9.982	0.112	0.5311	0.473	**0.0043**	0.269	1.393	1.255
11–12	51	11.618	11.851	11.474	–0.233	0.2187	0.144	0.4495	0.307	1.322	1.315
12–13	49	12.614	12.222	11.922	0.392	**0.0465**	0.692	**0.0002**	0.273	1.341	1.217
13–14	28	13.516	12.679	12.918	0.837	**0.0018**	0.598	**0.0096**	0.274	1.276	1.141
14–15	34	14.517	13.512	13.829	1.005	**0.0002**	0.688	**0.0065**	0.263	1.451	1.423
15–16	22	15.527	14.236	14.186	1.290	**0.0000**	1.340	**0.0000**	0.294	0.758	1.186
16–17	18	16.568	14.744	15.190	1.823	**0.0000**	1.378	**0.0000**	0.261	0.478	0.941
Total	540	10.417	10.102	10.040	0.315	**0.0000**	0.377	**0.0000**	2.768	2.618	2.616

* The **bold** indicates p<0.05, namely the fact that a difference between the age estimated with a given method and the real age is statistically significant.

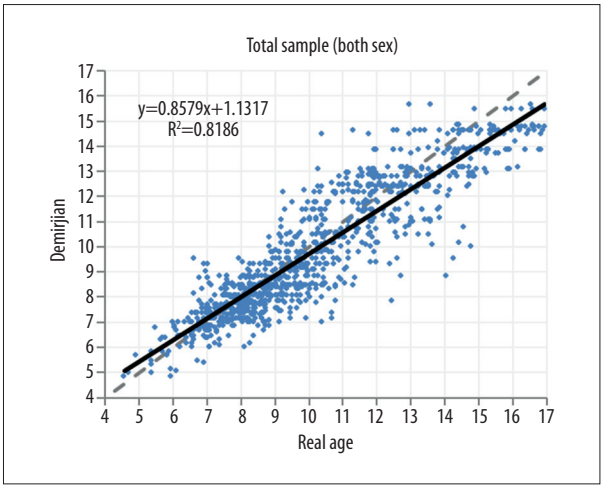

Figure 1. The correlation between the chronological age and the dental age calculated with the Demirjian method in the study group. Black – regression function; grey dotted – reference line.

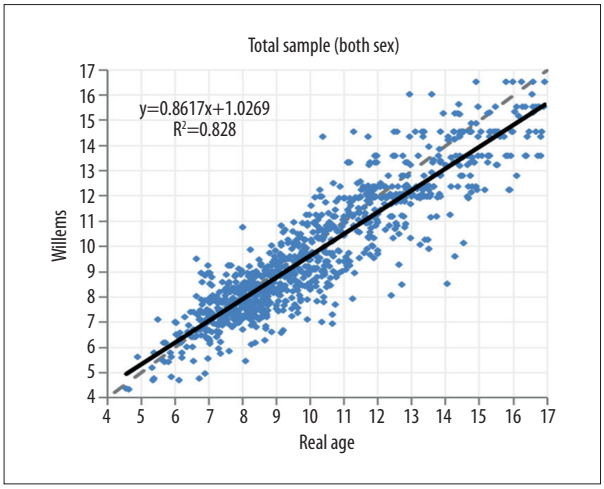

Figure 2. The correlation between the chronological age and the dental age calculated with Willems method in the study group. Black – regression function; grey dotted – reference line.

the study population, both methods tended to overestimate the age slightly, but in older groups, there was a tendency to underestimate the chronological age, which was observed for both methods and both sexes. The age limit below which each method overestimated the chronological age was about 8 years for the whole study population in the Demirjian method, and

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Table 2. Pearson's correlation coefficient for both sexes in the study population. The strength of the correlation between the chronological age and the age estimated using both study methods (the Demirjian method and the Willems method).

	Real age	Demirjian	Willems
Real age	1.000	0.905	0.910
Demirjian	0.905	1.000	0.978
Willems	0.910	0.978	1.000

about 7.5 years for the whole study population in the Willems method. The Demirjian method and the Willems method both showed a high degree of agreement between the chronological age and the dental age calculated with both study methods. The Pearson correlation coefficient was 0.905 for the Demirjian method and 0.910 for the Willems method for both sexes. Comparable correlation coefficients between the dental age and the chronological age for both methods showed a high degree of agreement.

Discussion

In 1973 Demirjian et al., described a method to assess the dental age, in the French-Canadian population, based on the assessment of mineralization stages of seven permanent teeth in the left mandible [12]. In 1976, the same author presented three methods to assess the dental age, with an updated seven tooth evaluation method, and two other methods based on the assessment of development of four permanent teeth of the left mandible, which according to Demirjian were indicated for patients with bilateral lack of teeth in the mandible or cases when it was not possible to assess all seven permanent teeth [13]. Among the many proposed methods of dental age assessment, the Demirjian method has been widely accepted. The clear criteria describing stages of tooth formation, illustrated by line diagrams and radiographic images, make the Demirjian method a reproducible and commonly used technique. Also, in Poland, the Demirjian method is commonly used in orthodontics, forensic medicine, anthropology, and pediatrics as the method of choice. However, according to the many previously published studies, the dental age calculated with the Demirjian method can be overestimated in relation to the chronological age, due to the acceleration of tooth development [13,15,19,27].

The Willems method is a modified version of the Demirjian method that was developed in 2001, based on studies in the Belgian Caucasian population. Therefore, the aim of the present study was to compare the Demirjian method of 1976 with the Willems method of 2001 in the Polish population of Caucasian ethnicity. According to the findings of this study, the Demirjian method overestimated the dental age in patients less than 8 years and underestimated the dental age in patients in older ages groups. The findings of the present study are supported by a study conducted in Germany by Frucht et al., which showed that the Demirjian method overestimated the dental age in relation to the calendar age in patients below the age of 8 years, and in older age groups, the dental age was underestimated [37]. As further support of the findings of the present study, Liversidge et al. suggested most radiographic age determination methods, in children aged between 3–15 years, overestimated dental age in younger age groups, and underestimated dental age in older ages [38].

The findings of the present study showed that the Demirjian method had the greatest accuracy for determining dental age in the age group between 6–12 years in both genders. According to Corral et al. the Demirjian method had the greatest accuracy in the age group between 5–12 years [39]. Hegde et al. also showed that the Demirjian method showed the greatest accuracy for the detection of dental age in the age group between 6–12 years in both genders [40]. In 2007, in the Polish population, Różyło-Kalinowska et al. evaluated the Demirjian method and dental age in a study group that included 994 patients aged between 6–16 years in which the authors concluded that the Demirjian method was inappropriate and that it was necessary to create standards for the Polish population [16]. However, in contrast to our findings, Różyło-Kalinowska et al. reported that the Demirjian method overestimated the dental age by 0.317 years and 0.300 years in girls and boys, respectively [16]. The greatest difference between the dental age and chronological age was observed in 11-year-old and 12-year-old girls (1.5 and 1.1 years, respectively) and in 13-year-old boys (1.4 years); the least difference between the dental age and chronological age was found in the oldest age group of 15-year-olds (0.2 years in girls and 0.4 years in boys) [16].

From the findings of the presented studies, the greatest discrepancies between values of the dental age and calendar age occur in age groups above 13 years the Demirjian method and the Willems method, which has also been confirmed by Livesidge et al. [38]. Livesidge et al. showed that in the study population age groups above 13 years, the number of children with complete mineralization of the tooth root (buds) (apart from third molars) were increased, which led to a lack

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of precision and reliability of the methods to assess the dental age [41,42]. In older children, it has recently been recommended to assess the dental age based on the assessment of the development stage of the third molars or the bone age [25,40,43,44]. The trend for earlier dental maturation of children may be due to increased availability and better quality of food, improved social conditions and access to health care [1]. Differences in the results of the studies on the topic of dental age may also be affected by factors, including the size of the study population, the distribution of the age and sex of the study population, the selected age groups, the statistical methods used, the study methodology and experience of the assessor [45]. There have been reports in the literature that the Willems method more effectively assessed the dental age in various populations [27,28]. Although the present study has shown similar efficacy for both the Demirjian method and the Willems method in the assessment of dental age in children, it is clear that controversy still exists, which can only be resolved by future large-scale, controlled studies for clearly identified populations.

In forensic medicine, an accepted range of error values between the estimated dental age and chronological age for patients in the developmental age group is between 0.5 years to up 1.00 year [17,46]. According to the findings of the present study, the Demirjian method and the Willems method met these criteria in the majority of age groups [17,46]. However, from the present study, the Demirjian method and the Willems method are not suitable for dental assessment for age groups above the age of 14 years in the Polish population. According to some studies conducted in other populations, the Demirjian method has not been recommended to estimate the dental age [13–21]. Conversely, the Willems method has been considered acceptable and is recommended in some study populations [5,28,47]. Several authors support that it is necessary to verify the precision of methods to assess the dental age and to create standards for a given population [14,29–32]. For example, Chaillet et al. created percentile charts and tables to determine the dental age in children of unknown background, based on the analysis of panoramic radiographs of patients in the developmental age of eight nationalities [48]. However, these authors concluded that the use of pre-prepared charts and tables is reasonable to use only if there are no such standards available for a given nationality or ethnic group [48].

Conclusions

The Demirjian method and the Willems method, that use panoramic radiographs to assess dental age, were used in a study population in children in Poland to assess the degree of correlation with chronological age. Both methods were considered as reliable methods for the assessment of dental age in the Polish population in all the age groups of boys and girls below the age of 14 years, and that the Demirjian method was highly accurate when applied to Polish children. The development of dentition in children and adolescents is affected by environmental factors that vary in individual populations. Also, due to an accelerated tooth eruption process and the varied course in the development of occlusion, standards used to determine dental age should be regularly updated, developed for specific populations such as the Polish population, and a more acceptable range of error values between the estimated dental age and chronological age should be defined.

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