A MODIFICATION OF THE DEMIRJIAN METHOD FOR AGE ESTIMATION IN CHILDREN

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ABSTRACT

The Demirjian method for age estimation in children by means of dental development is widely used and forms a basis on which a universal dental maturity score can be calculated. This score is then translated into a chronological age with aid of tables specific for each population. Such tables are, however, available for only a few populations and usually not where age estimations are needed. In several studies on age estimation in children it has been found that the original studies by Demirjian and co-workers do not give enough information to allow the construction of corresponding tables for other populations. The main reason for this is that the regression lines in the original graphs were obtained by manual smoothing to combine the individual plots and the tables were thereafter compiled from these graphs. In an attempt to avoid manual, and more or less subjective, construction of the regression line, an attempt was made to fit the plots into a regression line by a series of predefined functions. The aim was to find a model with the best possible explanation factor of the correlation between dental maturity score and chronological age. A cubic function was found to give a good fit to the plots with an R^2 of about 0.95. This modification of the original Demirjian method for age estimation of children is therefore recommended for the construction of population-specific tables. The use of a mathematical function also makes it possible to calculate confidence intervals to be used to describe the accuracy of an individual estimation. **(J Forensic Odontostomatol 2001;19:26-30)**

Keywords: Age determination, children, dental development

INTRODUCTION

The most common method for age estimation in children using dental development was first published by Demirjian *et al.*,[1] and a few years later subjected to a major revision.[2] This method is based on a sample of 4,756 Canadian children of French descent and describes a universal method to calculate a dental maturity score, which can subsequently be entered into a table allowing transformation to a chronological age. The maturity score is a measure of the dental development and the corresponding chronological age can be used to estimate the age of a child with missing or uncertain birth data. As populations may differ in maturity rate, the usefulness of the method in populations other than the French-Canadian one[2] depends on the availability of tables specific for the population in question. Such tables are still rare, and if absent the best estimation is made using tables from a genetically close population.

During attempts to compile transformation tables for some other populations, it was found that the original reports by Demirjian and co-workers[1,2] do not contain enough information on how the tables and graphs were obtained. After personal contact with, and kind help from, two of the authors (Demirjian[3] and Goldstein[4]) it was established that the tables were derived from regression lines, which had been produced as the best fit of the individual plots by manual smoothing. The lines for the confidence intervals were also manually fitted. It was therefore not possible to reproduce the original results or to produce new population-specific tables exactly equivalent to the original ones. Consequently, the few studies aimed at compiling population-specific tables do not describe how the tables and regression curves were produced.[5,6]

The aim of this study was to find a simple mathematical function of the relationship between maturity score and chronological age, and finally, to compare the resulting regression line with that of the French-Canadian population as presented by Demirjian *et al.*[1,2]

Table 1:

CORRELATIONS BETWEEN MATURITY SCORE (sumscore) AND AGE (age)

Gender: GIRLS

Independent Variable: Age

Dependent Variable	Method	Rsq	d.f.	F	Sigf	b 0	b 1	b 2	b 3
sumscr	LIN	.703	240	568.93	.000	34.9922	5.0952		
sumscr	LOG	.855	240	1416.57	.000	-25.278	49.5312		
sumscr	INV	.904	240	2251.34	.000	128.021	-370.27		
sumscr	QUA	.935	239	1716.40	.000	-32.995	20.1730	-.7538	
sumscr	CUB	.944	238	1336.79	.000	-63.683	31.2842	-1.9534	.0396
sumscr	COM	.579	240	329.46	.000	38.0001	1.0808		
sumscr	POW	.766	240	784.32	.000	14.0896	.7877		
sumscr	S	.902	240	2210.80	.000	5.1205	-6.2170		
sumscr	GRO	.579	240	329.46	.000	3.6376	.077		
sumscr	EXP	.579	240	329.46	.000	38.0001	.0777		
sumscr	LGS	.579	240	329.46	.000	.0263	.9253		

Gender: BOYS

Independent Variable: Age

Dependent Variable	Method	Rsq	d.f.	F	Sigf	b 0	b 1	b 2	b 3
sumscr	LIN	.772	241	815.45	.000	25.3275	5.6715		
sumscr	LOG	.894	241	2022.24	.000	-35.163	52.5303		
sumscr	INV	.898	241	2120.81	.000	125.245	-371.94		
sumscr	QUA	.944	240	2024.95	.000	-34.355	19.5170	-.7035	
sumscr	CUB	.946	239	1401.23	.000	-49.486	25.11161	-1.3161	.0204
sumscr	COM	.659	241	365.94	.000	31.9618	1.0934		
sumscr	POW	.828	241	1160.15	.000	11.4343	.8617		
sumscr	S	.923	241	2895.65	.000	5.1077	-6.4261		
sumscr	GRO	.659	241	465.94	.000	3.4645	.0893		
sumscr	EXP	.659	241	465.94	.000	31.9618	.0893		
sumscr	LGS	.659	241	465.94	.000	.0313	.9146		

MATERIAL AND METHODS

Dental panoramic radiographs were obtained from 485 Swedish children, 242 girls (mean age 10.0 yrs., range 2.6 – 17.2 yrs.) and 243 boys (mean age 9.6 yrs., range 2.8 – 17.2 yrs.), living in various parts of the country. Part of the sample (197 individuals aged 5, 6, 9 and 12 yrs., all within a range of ± one month) came from the files of a number of specialist clinics for orthodontics or paedodontics and has been described in detail previously,[7,8] including studies of intra- and interexaminer variations.[9] The other part of the sample was collected from the files of the Department of Oral Radiology at the Dental School, Huddinge, Sweden and was evenly distributed between the age ranges. Both subsamples were drawn sequentially from the files, provided the child had a typical Swedish name, thus ensuring genetic homogeneity. All children were healthy and had a full set of permanent mandibular teeth. The chronological ages were rounded to the first decimal place of a year (Fig.1).

The radiographs were examined on a light table with the aid of a magnifying glass and a pair of callipers. The dental development, as seen in the radiographs, of each individual tooth was compared with the radiographic images, drawings and descriptions given by Demirjian *et al.*,[1] and given a score of A through H. Each of these alphanumeric scores was then translated into a numerical "self-weighted score for dental development" according to the tables in the updated report.[2] The scores for the seven mandibular teeth were then added and a dental "maturity score" was derived.

With the aid of the SPSS statistical program,[10] the original scores, A through H, were processed and transformed by running batch files containing the constants given in the paper by Demirjian and Goldstein.[2] The calculated sum of the individual scores, the maturity score, was then used to correlate with the chronological age.

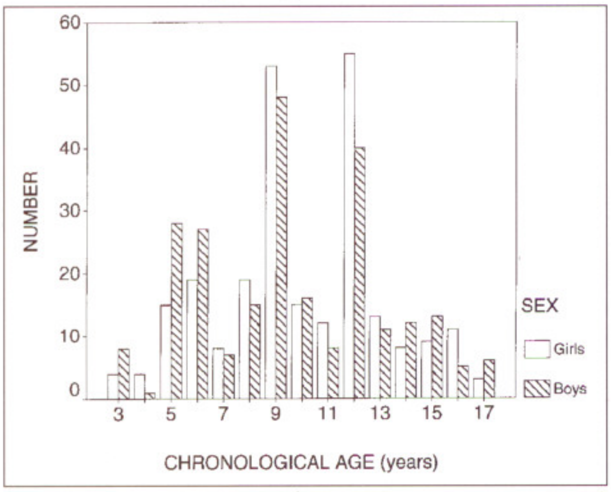

Fig.1: *Age and gender distribution of the material. (242 girls and 243 boys, mean age 9.8 years, range 2.6 - 17.2 years).*

Since the maturity scores corresponding to the revised data[2] are not tabulated, the maturity scores of the Canadian population were obtained from the tables in Demirjian *et al.*[1]

The maturity score was plotted against chronological age, and the best fitting regression line was tested with a series of curve estimation models (linear, logarithmic, inverse, quadratic, cubic, compound,

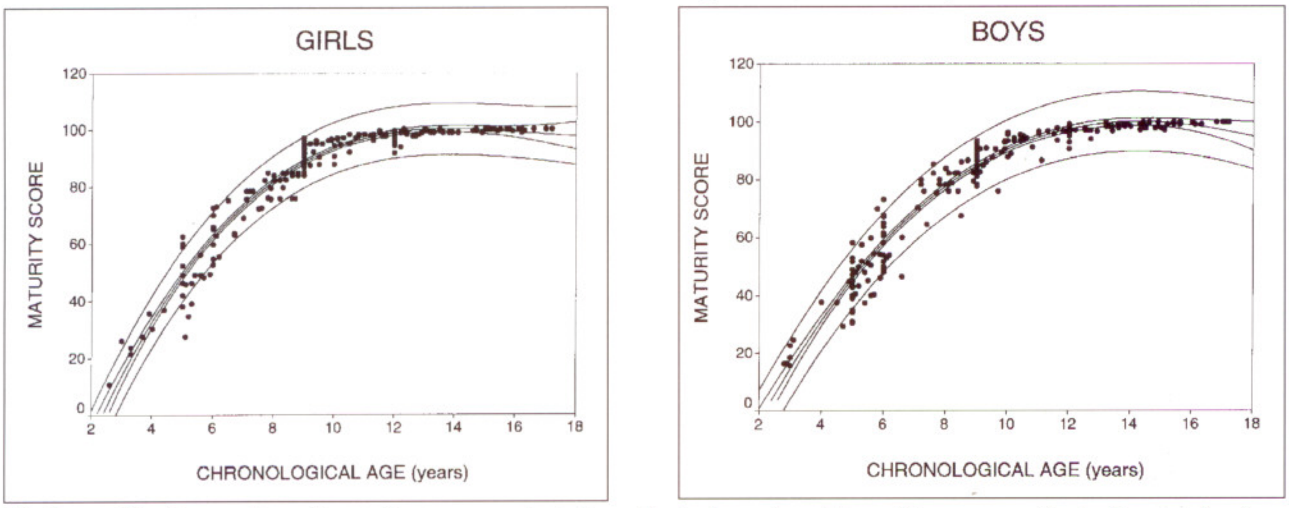

Fig.2 a and b: *Scatterplots of maturity score against chronological age for girls and boys, respectively. Inner pair of lines denotes, mean regression prediction and the outer pair, individual regression prediction at a confidence interval of 95%*

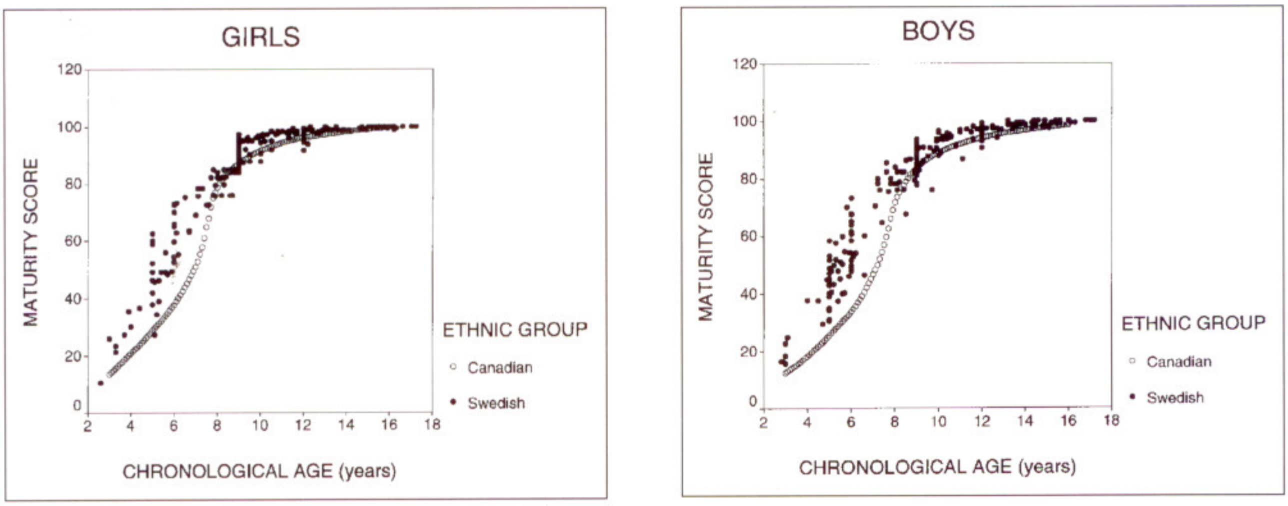

Fig.3 a and b: *Comparison of scatterplot of maturity score against chronological age for girls and boys, respectively. Filled plots Swedish children and open plots Canadian children. The Canadian data compiled from Demirjian et al. (1973)*

power, S, growth, exponential and logistic), available in the SPSS statistical package.

RESULTS

The correlation between the maturation score and chronological age is shown in Table 1 and in Figs. 2a and b. Table 1 shows the squared correlation coefficients (R^2) and some selected statistical factors and constants. The highest degrees of explanation (R^2) were obtained by the models using the cubic ($R^2 = 0.94$ for girls and $R^2 = 0.95$ for boys), quadratic ($R^2 = 0.94$ for both genders) and S ($R^2 = 0.90$ and 0.92) functions. By comparing the cubic and quadratic models with an F test, the cubic function proved to be the better model ($p < 0.005$). The cubic function also gave an apparently good fit of the individual plots, and this function was therefore chosen for the subsequent studies. Figs. 2a and b demonstrate the correlation and the fitting with the aid of the cubic function for girls and boys, respectively. Figs. 3a and b show the corresponding scatter plots together with the data from the Canadian population as extracted from the tables in Demirjian *et al.*[1]

The cubic function of the best fitting lines in Figs. 2a and b were:

Girls: maturity score = $- 63.7 + 31.3 * (\text{age}) - 1.95 * (\text{age})^2 + 0.0396 * (\text{age})^3$

Boys: maturity score = $- 49.5 + 25.1 * (\text{age}) - 1.32 * (\text{age})^2 + 0.0204 * (\text{age})^3$

It appears from Figs. 3a and b that the shape of the plots from the Swedish and Canadian populations differs. The Swedish population follows a cubic function better than the Canadian population, which is more S-shaped.

DISCUSSION

The method by Demirjian and co-workers[1,2] for age estimation of children with uncertain or unknown date of birth was a break-through when published almost 30 years ago. An important feature of the Demirjian method is its applicability to transform the universal maturity score into a chronological age. However, as also expressed by the original authors, each population then needs its own transformation table to obtain a chronological age since there appear to be differences in maturation rates of the dentitions in different populations.[3,5,9-11] Another important disadvantage with the original method is that modern forensic methods aim not only at an accurate estimated age, but also need some quantification of the dispersion around the estimate. In the original articles the dispersions were expressed as percentiles, which do not allow advanced statistical calculations.

It has been repeatedly shown that the Scandinavian population is up to one year ahead of its French-Canadian counterparts, as described in the original articles,[1,2] in its dental development when the Demirjian method has been used to compare the populations.[5,6,7,11] There could be many reasons for this difference, one being a genuine genetic difference but this seems unlikely since the genetic distance between the two populations is otherwise not especially pronounced. Other studies on more genetically distant populations[12,13] have also shown that the French-Canadian children seem to consistently lag behind when compared with the Demirjian method.

It appears from graphs in Figs. 3a and b that the plots from the Swedish population follow a cubic function although there is a tendency towards an S-shape, which however is much less pronounced than that seen in the Canadian population. The scale of the maturity score in Figs. 3a and b is linear, in contrast to the logarithmic scale in the original studies,[1,2] and the graphs can therefore not be directly compared. It could be that the manual fitting and the logarithmic scale have caused the S-shaped relationship to be exaggerated, which will give an over-estimate in those ages where the S displays the most vertical orientation, that is at the ages of 6 - 10 years, which unfortunately is when age estimations are often done.

The fitting with a cubic function is however also an approximation as there appear to be some deviations from the curve, which are especially pronounced in the lowest and highest age groups. At the ages above 15 years the downward deviation of the function is, however, of no practical importance since the method cannot in any case be used at these ages.

There also seems to be a deviation from the cubic function curve at the ages around 5 years, especially among girls, where the plots line up somewhat S-shaped, possibly causing a slight under-estimation at this age.

It is quite clear that the relationship between the maturity score and chronological age does not follow a simple mathematical function. Attempts were therefore also made to use an advanced analysis of regression with the aid of the maximum-likelihood method, with three different regression functions, linear up to the age of seven, quadratic between the ages of seven and 11 and a section of hyperbola for ages above 11 years. This method, however, does not give a better adaptation and it is not possible to carry out the calculations without a computer. The cubic function on the other hand can easily be utilised with the aid of a simple pocket calculator. The use of a modification of the original Demirjian method with the objective cubic function instead of the manual fitting is therefore recommended, and it has three major advantages. First, it makes it possible to describe a confidence interval around an estimated age, second, it makes possible the comparison of different populations, and third, it is possible to construct population specific tables out of even a small sample once the model is known.

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