ORIGINAL ARTICLE

CHRONOLOGICAL AGE, DENTAL AGE AND SKELETAL AGE IN ORTHODONTIC PATIENTS

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ABSTRACT

Aim and objectives. The assessment of dental age and skeletal age by various methods is of utmost importance in many domains related or unrelated to dental medicine. The main objective of this paper was to investigate the accuracy of a well-known method used for the estimation of dental age and another one used for the estimation of skeletal age. Another objective was to make correlations between chronological age, dental age and skeletal age. **Material and methods.** 99 patients with ages between 7 and 15 years, all residing in the Bihor county, were included in the study and their panoramic radiographs and lateral cephalograms were assessed for the estimation of dental age and, respectively, skeletal age. **Results.** The Demirjian method tends to overestimate the dental age when compared to chronological age. Most of the children included in the study showed an advance in dental development. Dental age shows and advance when compared to the skeletal age for most of the age groups investigated, the results being statistically significant for most of the values obtained. Finally, comparing skeletal age with chronological age, an advance of skeletal age was observed in some age categories, while in others an advance of the chronological age was noted. **Conclusions.** Altough, Demirjian´s method for establishing the dental age and the CVM method for assessing the skeletal maturation are useful tools, the results obtained, indicate that they should be adapted for the investigated population. The study should be extended to larger samples.

Keywords: dental age, skeletal age, Demirjian, Cervical Vertebrae Maturation.

INTRODUCTION

The possibility of accurate estimation of dental age is beneficial in various fields such as pediatric dentistry, orthodontics, paleontology, archeology and forensic medicine [1]. In order for the assessment of the dental age to be as accurate as possible, a validated dental age estimation method should be used. Several methods have been proposed over the years. Among the best known methods developed for assessing dental age are: the "Nolla method", the "Demirjian method" and the "Cameriere method" [2,3,4]. All these techniques use radiographic examinations of the oral cavity based on which different stages of dental develoment are established for each tooth investigated. Each method has its own specific stages and evaluation criteria [2,3,4].

Despite the great number of methods that have been developed, the most widely used for the assessment of dental age has been and remains, the "Demirjian method", mainly due to the simplicity with which it can be applied. It requires a panoramic radiography of the child patient. The seven permanent teeth situated on the left mandibular arch are evaluated and are asigned a specific developmental stage. The third permanent molar is not taken into consideration [3].

The assessment of skeletal maturation is crucial in pediatric dentistry and orthodontics, because it influences the proper timing of treatment initiation, as well as the choice of the optimal treatment method [5]. Hand and wrist radiographs can be used to determine skeletal age, but they are not considered routine investigation methods in the conduct of the orthodontic treatment, the child patient needing, therefore, an additional X-ray exposure [5,6]. A much easier approach using the method initially developed by Franchi et al. and later improved by Baccetti et al., known as the Cervical Vertebral Maturation method or the CVM method [7,8]. The method no longer requires additional radiography of the wrist, but uses lateral cepaholgrams to determine skeletal age. The lateral cephalogram is a complementary examination, compulsory for the establishing of the correct diagnosis in orthodontics, but also for configuring the treatment plan [7,8]. It involves the examination of cervical vertebrae C2, C3 and C4, which will subsequently be placed in a developmental stage, depending on certain morphological aspects described by the authors of the technique [7,8].

Skeletal age and dental age can be correlated to each other, or may be correlated to the chronological age. When dental age and skeletal age do not coincide, a discrepancy in the rhytm of the dental eruption occurs [9,10]. Under normal circumstances, all three ages must correspond [9]. Left uninvestigated, undiagnosed and untreated, these eruption discrepancies can lead to

dental malpositions and can have a negative impact on the smile, but also on other functions of the oral cavity. The patient's mental health and the positive perception of one´s own image are other elements that will be potentially affected [10,11].

Aim and objectives

The main objective of this paper was to confirm or refute the accuracy of the application of the "Demirjian method" and the "Baccetti method", for assessing the dental age, and, respectively, the skeletal age for a group of children from Bihor county. A second objective was to make correlations between chronological age, dental age and skeletal age and to diagnose possible dental eruption discrepancies.

MATERIAL AND METHODS

The retrospective study was conducted in agreement with the World Medical Association Declaration of Helsinki-Ethical Principles for Medical Research Involving Human Subjects. The sample consisted of 99 sets of radiographs, belonging to 99 children, both boys and girls, all requiring orthodontic treatment, with ages between 7 and 15 years. Each radiographic set consisted of a panoramic radiography and a lateral cephalogram. Only radiographs of children residing in the Bihor county were taken into consideration.

The chronological age was determined by substracting the date of birth from the date the radiographs were taken. The chronological age was expressed in years and months.

The "Demirjian method", that is based on the usage of panoramic radiographs, was utilized to estimate the dental age. The method establishes the existence of 8 stages of development for each of the 7 permanent teeth situated on the lower left dental arch. The stages are assessed with letters from A to H. After determining the right stage for each of the 7 permanent teeth of the lower left dental arch, they are converted into numerical scores. After all scores are added together, a final value is obtained, representing the Dental Maturity Score. The Dental Maturity Score will be transformed into dental age, according to gender, based on the tables proposed by Demirjian et al. [3].

Lateral cephalograms were used to estimate the skeletal age, based on which the Cervical Vertebral Maturation method, developed by Baccetti et al., was applied. The method surveys the morphology of the C2, C3 and C4 cervical vertebrae. Based on their morphology, the maturational stage of the child is established. The method describes 6 different stages of development, from CS1 to CS6. Depending on the stage obtained, the skeletal age is assessed based on the indicative tables produced by Baccetti et al. [8,12]. The "CVM Stage Guide App", an application developed by Dr. Pavam Kumar (NXS Inc), for educational purposes, was used to quickly estimate the Cervical Vertebral Maturation stage.

In order to decide which radiographs will be analyzed, the following inclusion criteria were applied: high quality radiographs, available in a digital format; radiographs that had the patients´ gender and date of birth imprinted; radiographs belonging to non-syndromic children; radiographs that belonged to children without congenital oral anomalies; radiographs of children who had all the permanent teeth in the lower left dental arch. Patients were divided into the following age categories, expressed in years: 7 – 8.9; 9 – 10.9; 11 – 12.9; 13 – 14.9; 15 – 15.9. Patients in each main category were divided into sub-groups of boys and girls. All radiographs were analyzed by a single examiner (MAE), in order to avoid inter-operators bias.

The data was analyzed with the IBM Statistical Package for the Social Sciences (SPSS) ver. 20. Quantitative variables were written as averages with or without standard deviations, while categorical variables were written as counts or percentages. A paired sample t-test was used to compare the mean chronological age with the mean dental age, the mean dental age with the mean skeletal age and, utlimately, the mean chronological age with the mean skeletal age. Microsoft Excel for Mac 2011 programme was used for designing tables and graphics.

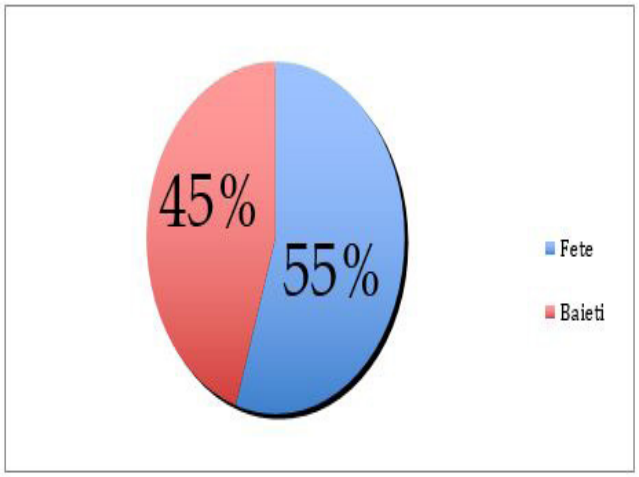
RESULTS

Table 1 illustrates the number and percentages of boys and girls included in the study. Graphic 1 highlights the percentage of boys and girls investigated. As such, the sample consisted of 99 sets of radiographs, of which 45 (45%) belonged to male patients and 54 (55%) belonged to female patients.

Gender	No.	Percentage
Boys	45	45%
Girls	54	55%

Table I.
Number and percentages of boys and girls included in the study

Table 2 illustrates the number of patients included in each age group according to their gender, as well as the total number and percentages of patients included in each age group.



Graphic 1.
Percentages of boys and girls included in the study

Age groups (years)	Girls	Boys	Total number	Percentage
7 – 8.90	10	9	19	19%
9 – 10.90	10	5	15	15%
11 – 12.90	14	18	32	33%
13 – 14.90	15	12	27	27%
15 – 15.90	5	1	6	6%

Table 2.
Distribution of patients according to age group and gender

As such, 19 patients (19%) were included in the first age group, 15 patients (15%) were included in the second age group, 32 patients (33%) were included in the third age group, 27 patients (27%) were included in the fourth age group and, finally, 6 patients (6%) were included in the sixth age group.

A distribution of the various CVM stages in different age groups is shown in Table 3 and Table 4 for girls and boys. The most prevalent CVM stage for each age group was highlighted. In the girls´ sample, CS 1 is the most prevalent stage in the first age group, 50% of the girls showing a first stage skeletal maturation. CS 1 is the second most prevalent CVM stage in the second age group, the most prevalent being CS 3, accounting for a total of 40% of the girls´ sample of the second age group. The third age group has the CS 4 stage as the most prevalent stage, while in the last two age groups CS 5 stage prevails. As for the boys´ sample, the first age group, is predominantly situated in the first stage of skeletal maturation, CS 1 accounting for a total of 44% of the boys´ sample of the first group. CS 2 predominates in the second age group, while CS 4 prevails in the third (50%) and fourth (58%) age groups. The last age group consisted of only one radiograph, belonging to a boy showing a CS 6 stage, in terms of skeletal maturation.

Age groups (years)	CVM Stages			
7 – 8.9	***CS 1**	CS 2	CS 3	CS 4
	5	3	1	1
	50%	30%	10%	10%
9 – 10.9	CS 1	CS 2	***CS 3**	CS 4
	3	2	**4**	1
	30%	20%	**40%**	10%
11 – 12.9	CS 2	CS 3	***CS 4**	CS 5
	3	2	**6**	3
	21%	14%	**44%**	21%
13 – 14.9	CS 4	***CS 5**	CS 6	
	4	**10**	1	
	27%	**67%**	6%	
15 – 15.9	CS 4	***CS 5**		
	1	**4**		
	20%	**80%**		

*most prevalent CVM Stage for each age group.

Table 3.
Prevalence of various CVM Stages for girls

Age groups (years)	CVM Stages				
7 – 8.9	***CS 1**	CS 2	CS 3	CS 4	
	4	3	1	1	
	44%	34%	11%	11%	
9 – 10.9	CS 1	***CS 2**	CS 3	CS 4	
	1	**2**	1	1	
	20%	**40%**	20%	20%	
11 – 12.9	CS 1	CS 2	CS 3	***CS 4**	CS 5
	2	4	2	**9**	1
	11%	22%	11%	**50%**	6%
13 – 14.9	***CS 4**	CS 5			
	7	5			
	58%	42%			
15 – 15.9	***CS 6**				
	1				
	100%				

*most prevalent CVM Stage for each age group.

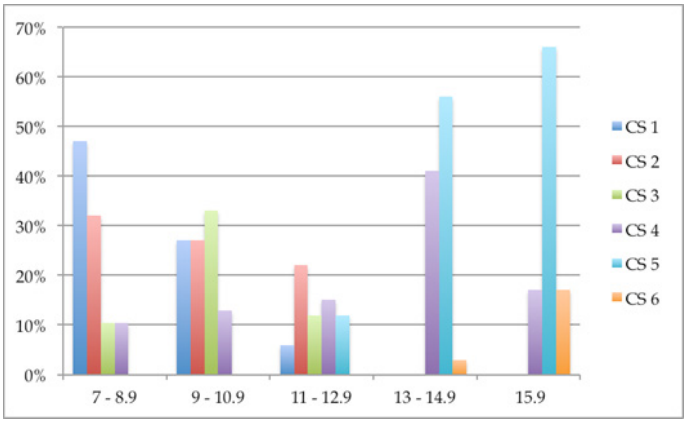
Table 4.
Prevalence of various CVM Stages for boys

Table 5 and Graphic 2 display the distribution of CVM stages in different age groups, for the entire sample. As shown, the first CVM stage is prevalent in the 7 – 8.9 age group, while the third CVM stage is prevalent in the 9 - 10.9 age group. 48% of the patients included in the 11 – 12.9 age group show a CS 4 stage. 56% of the patients included in the 13 – 14.9 age group and 66% of those included in the 15 – 15.9 age group, are situated in the CS 5 maturational stage, this being the most prevalent in the last two age groups.

Age groups	CVM Stages				
7 – 8.9	*CS 1	CS 2	CS 3	CS 4	
	9	6	2	2	
	47%	32%	10,5%	10,5%	
9 – 10.9	CS 1	CS 2	*CS 3	CS 4	
	4	4	5	2	
	27%	27%	33%	13%	
11 – 12.9	CS 1	CS 2	CS 3	*CS 4	CS 5
	2	7	4	15	4
	6%	22%	12%	48%	12%
13 – 14.9				CS 4	*CS 5	CS 6
				11	15	1
				41%	56%	3%
15 – 15.9				CS 4	*CS 5	CS 6
				1	4	1
				17%	66%	17%

*most prevalent CVM Stage for each age group.

Table 5.
Prevalence of various CVM Stages for the entire sample



Graphic 2.
Prevalence of various CVM Stages for the entire sample

Table 6 and Table 7 illustrate the mean chronological age, the mean dental age and the mean skeletal age with their standard deviation beneath, separately, for girls and boys. The important thing to note is the overestimation of dental age, using the Demirjian method, for both genders. It is a technique for assessing endothelial cell proliferation by introducing into the synthesis phase of DNA cellular replication measuring agents such as tritiated thymidine or bromodeoxyuridine. (6)

Table 8 and Table 9 compare the chronological age and dental age, dental age and skeletal age and, finally, chronological age and skeletal age, separately, for girls and boys.

Age groups (years)	CA (MA and SD)	DA (MA and SD)	SA (MA and SD)
7 – 8.9	8.09	10.16	9.30
	0.60	2.44	1.03
9 – 10.9	10.25	12.26	9.80
	0.47	0.92	1.05
11 – 12.9	12.11	13.75	11.14
	0.47	1.48	1.08
13 – 14.9	13.73	15.70	12.36
	0.49	0.81	0.51
15 – 15.9	15.82	16	12.30
	0.10	0	0.44

CA – Chronological age; DA – Dental age; SA – Skeletal age; MA – Mean value for age; SD – Standard deviation; all values are expressed in years.

Table 6.
Mean chronological age, dental age and skeletal age for girls

Age groups (years)	CA (MA and SD)	DA (MA and SD)	SA (MA and SD)
7 – 8.9	8.40	10.38	9.38
	0.51	1.29	1.05
9 – 10.9	9.82	12.14	9.90
	0.60	1.66	1.14
11 – 12.9	11.64	13.10	10.66
	0.49	1.71	1.20
13 – 14.9	13.77	15.73	11.91
	0.56	0.92	0.51
15 – 15.9	15.60	16	12.60

CA – Chronological age; DA – Dental age; SA – Skeletal age; MA – Mean value for age; SD – Standard deviation; all values are expressed in years.

Table 7.
Mean chronological age, dental age and skeletal age for boys

The mean result and their standard deviations are reported, as well as the value of "t" and "p", for each comparison. The paired sample t-test was used to analyze the comparisons between the various ages. When comparing chronological age and dental age, an overestimation of the latter is visible in both genders, the differences being statistically significant for all age groups and for both genders, with values of "p" varying from 0.000 to 0.050. Dental age shows and advance when compared to the skeletal age, for most of the age groups investigated, the results being statistically significant for most of the values obtained, with the exception of the girls´ first age group and the boys´ second age group, where the value of "p" is higher than 0.05 (p=0.218 and 0.118, respectively). The overestimation of the skeletal age was observed in the first girls´ age group and in the first boys´ age group.

Both results are statistically significant ($p<0.05$). An overestimation of the skeletal age was obtained in the second boys´ age group, but the results are not statistically significant ($p>0.05$). For all other age groups, the underestimation of the skeletal age was noticeable, all result being statistically significant ($p<0.005$).

Age groups (years)	CA-DA (Mean value ± SD in years)		DA-SA (Mean value ± SD in years)		CA-SA (Mean value ± SD in years)	
7 – 8.9	-2.07±2.45	*t=-2.662 **p=0.026	0.86±2.05	*t=1.323 **p=0.218	-2.21±1.27	*t=-2.991 **p=0.015
9 – 10.9	-2.01±1.13	*t=-5.616 **p=0.000	2.46±1.01	*t=7.701 **p=0.000	0.45±1.39	*t=1.022 **p=0.333
11 – 12.9	-1.63±1.59	*t=-3.829 **p=0.002	2.60±1.92	*t=5.063 **p=0.000	0.97±0.96	*t=3.779 **p=0.002
13 – 14.9	-1.97±0.78	*t=-9.701 **p=0.000	3.34±0.89	*t=14.414 **p=0.000	1.36±0.62	*t=8-496 **p=0.000
15 – 15.9	-1.80±0.10	*t=-3.674 **p=0.021	3.70±0.44	*t=18.500 **p=0.000	3.52±0.50	*t=15.670 **p=0.000

CA – Chronological age; DA – Dental age; SA – Skeletal age; SD – Standard deviation; *t value as obtained with the paired sample t-test; **p value as obtained with the paired sample t-test.

Table 8.

Comparisons between mean chronological age, dental age and skeletal age for girls

Age groups (years)	CA-DA (Mean value ± SD in years)		DA-SA (Mean value ± SD in years)		CA-SA (Mean value ± SD in years)	
7 – 8.9	-1.97±0.93	*t=-6.36 **p=0.000	1.00±1.10	*t=2.727 **p=0.026	-0.97±0.80	*t=-3.654 **p=0.006
9 – 10.9	-2.32±1.83	*t=-2.770 **p=0.050	2.24±2.52	*t=1.987 **p=0.118	-0.08±0.73	*t=-0.244 **p=0.819
11 – 12.9	-1.45±0.43	*t=-3.369 **p=0.004	2.43±1.92	*t=5.375 **p=0.000	0.97±1.16	*t=3.651 **p=0.002
13 – 14.9	-1.95±0.94	*t=-7.177 **p=0.000	3.81±0.93	*t=14.126 **p=0.000	1.85±0.77	*t=8.343 **p=0.000
15 – 15.9	-	-	-	-	-	-

CA – Chronological age; DA – Dental age; SA – Skeletal age; SD – Standard deviation; *t value as obtained with the paired sample t-test; **p value as obtained with the paired sample t-test.

Table 9.

Comparisons between mean chronological age, dental age and skeletal age for boys

DISCUSSIONS

The total number of patients included in the study was 99, of which 45 were boys and 54 were girls, gender distribution being relatively homogeneous. The distribution of patients according to the age category was variable. Most patients were distributed in the 11 - 12.90 years age group, while the last age group consists of the smallest number of patients. This distribution may be related to the moment most preffered by patients for the initiation of the orthodontic treatment and for the first orthodontic examination.

The distribution of different skeletal maturation stages by different age categories and by gender revealed various results. Safavi et al. investigated the correlation between CVM stages and chronological age in a group of female patients from Iran. The results of the study revealed that CS 1 most frequently corresponds to the age of 9 years, CS 2 most frequently corresponds to the age of 10 years, CS 3 corresponds to the age of 11 years, CS 4 corresponds to the age of 12 years, and CS 5 is the most common stage in 13- and 14-year-old patients [13]. The present study reveals similar results for the first three age categories, however, compared to the cited study, in the 11 - 12.9 years age category, CS 4 is the most common stage in the group of girls investigated. Stoilova-Totorova et al. compared skeletal maturation stage and chronological age in a group of patients from Bulgaria. The investigated patients had ages ranging from 9 to 17 years. The most common stage was CS 6, and the least common was CS 1 [14]. The differences from the cited studies are numerous, probably due to the different categorization of the investigated patients.

Discrepancies between chronological age, dental age and skeletal age are also of interest to the scientific community. The results of the current study are similar to those published by the author in the past. The previous study suggests that the "Demirjian method", used to estimate dental age, tends to overestimate the dental age [15]. The "Demirjian method´s" tendency to overestimate the dental age is also visible in the current study. However, Savin et al., in a study comparing skeletal maturation with dental and chronological age, on a group of patients from Iasi, concludes that the values obtained by the Demirjian method for dental age are close to chronological age [16]. Discrepancies between dental age, obtained by utilizing the "Demirjian method", and chronological age were also reported in other populations, suggesting, like the present study, the need to adapt the values in the Demirjian tables for the studied populations [17,18,19].

When it comes to comparing dental age and skeletal age, the current study reveals an advance of dental age over skeletal age, which may be due to the overestimation of dental age by the "Demirjian method". These results are similar to those of other published studies [10,20]. Finally, comparing skeletal age with chronological age, an advance of skeletal age was observed in some age categories, while in others an advance of the chronological age was noted. The results are comparable, to some extent, with those obtained by other authors. Thus, Calfee et al. , following a study investigating American adolescents, concluded that skeletal age is, in most cases, more advanced than chronological age. The method of determining skeletal age was, however, different from the present study [21]. Ramos et al. obtained similar results using hand-wrist radiographs to determine skeletal age [22].

This research highlights that many of the patients investigated show discrepancies between the chronological age and dental age. All groups investigated showed an overestimation of the dental age when compared to the chronological age. Discrepancies were found between dental age and skeletal age, as well as between chronological age and skeletal age, with different values for the different groups.

CONCLUSIONS

"Demirjian´s method" of dental age assessment is relatively easy to use, but adaptations of this method must be provided for the Romanian population, as it overestimated the dental age of the patients investigated. The improved and simplified CVM method is, also, easily applied on lateral cephalograms and an advance of skeletal age when compared to dental age or chronological age was discovered, for most of the age groups investigated. This indicates the existance of discrepancies between the the different ages examined. For more accurate results, the examination of larger samples should be considered.

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