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Relationship between dental age according to Demirjian and cervical vertebrae maturity in Polish children

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SUMMARY The purpose of the study was to investigate the relationship between Demirjian's method and the improved cervical vertebrae maturation (CVM) method. The material consisted of the clinical files and panoramic and lateral cephalometric radiographs of 718 children (431 girls and 287 boys) aged from 6 to 17 years, inhabitants of the Mazovia region (Central Poland). Dental age according to Demirjian was estimated using panoramic radiographs and the cervical stages (CS) of the CVM were evaluated on cephalometric radiographs. Descriptive statistics of the chronological and dental ages of the patients for a particular CS of skeletal maturity was calculated for girls and boys separately. Linear regression analysis and correlation (Pearson's r coefficient), as well as the Spearman rank correlation coefficient (R) were applied to measure the association between CS and dental calcification stages of all analysed teeth.

A consistently earlier occurrence (by about 6 months) for each CS was observed in females. A moderate, but statistically significant, correlation between Demirjian's dental developmental stages and CS was determined. The level of the correlation was different for individual teeth: the teeth showing the highest relationship with CVM were the second premolars and canines (in female and male subjects, respectively). The central incisor demonstrated the poorest correlation in both genders. The findings confirmed that both dental and skeletal maturity should be assessed if the maturity stage of a growing child is to be relevant to clinical practice. The results indicate the usefulness of dental calcification stages as a simple first-level diagnostic test to determine the skeletal maturity status of a subject.

Introduction

Precise evaluation of the developmental stage is an integral part of both diagnosis and treatment of paediatric patients. Considerable variations in development among children of the same chronological or calendar age have led to the introduction of the concept of developmental or physiological age based upon the degree of maturation of different tissues and systems. Developmental age reflects continuity and integrity of the biological processes. It expresses a stage of development of a child as a proportion of chronological age. Various biological ages, such as skeletal, morphological, and secondary sexual characteristics, as well as dental age, have been proposed for this purpose. These criteria can be applied separately or collectively in order to assess the degree of physiological maturity of a growing child (Green, 1961; Grave and Brown, 1976; Tanner, 1978; Fishman, 1979).

Interrelationships between skeletal, somatic, and sexual maturity have been shown in many studies (Grave and Brown, 1976; Fishman, 1979; Demirjian *et al.*, 1985). Association with dental maturation, especially the relationship between skeletal and dental maturity, remains inconsistent (Bambha and Van Natta, 1959; Green, 1961; Grøn, 1962; Engström *et al.*, 1983; Demirjian *et al.*, 1985; Helm, 1990; Lewis, 1991; Midtbø and Halse, 1992; Coutinho *et al.*, 1993; Nadler, 1998; Krailassiri *et al.*, 2002; Şahin Sağlam and Gazileri, 2002; Flores-Mir *et al.*, 2005; Uysal *et al.*, 2005). The lack of concordance among the results of previous studies may be due, at least to a certain extent, to different methods of assessing skeletal and dental maturity or existing racial variations of the examined groups (Sierra, 1987; Mappes *et al.*, 1992).

Skeletal maturation assessed on hand–wrist radiographs is considered the best indicator of skeletal maturity because of the availability of different types of bones in this area (Krailassiri *et al.*, 2002; Şahin Sağlam and Gazileri, 2002; Uysal *et al.*, 2005). However, recently, modifications in the size and shape of the cervical vertebrae in growing subjects have gained increasing interest as a biological indicator of individual skeletal maturity (Baccetti *et al.*, 2002, 2005; San Roman *et al.*, 2002). One of the main reasons for the increasing popularity of the method is that analysis of cervical vertebrae maturation (CVM) is performed on lateral cephalographs, a radiograph often used in orthodontic diagnosis. Therefore, this method of assessment of skeletal maturity does not require extra radiation exposure for the patient. Currently, the improved CVM method, consisting of six maturational stages determined on the basis of cervical vertebrae morphology (C2, C3, and C4), is the most widely used method of evaluation for this purpose (Baccetti *et al.*, 2002, 2005).

Among radiological methods for dental age estimation in children, Demirjian's method is widely used, although original standards elaborated for the French Canadian population are mostly not suitable for other populations and require modifications (Davis and Hägg, 1994; Różyło-Kalinowska *et al.*, 2008). In order to estimate dental age using this method, each tooth is given a mark indicating a developmental stage (ranging from A to H; there is also an additional stage 0, meaning no signs of mineralization). Each stage is assigned a given numeric value taken from tables prepared separately for boys and girls. Summing of the obtained values indicates the dental age of the patient, which is derived from standard tables or centile charts (Demirjian *et al.*, 1973; Demirjian and Goldstein, 1976).

Although comparative studies of skeletal maturity and dental age have been carried out, no direct comparison between Demirjian's method and the improved CVM method was found in literature. Therefore, the purpose of this study was to investigate the relationship between dental age evaluated using Demirjian's method and skeletal maturity determined by the CVM method.

Materials and methods

The material comprised the clinical files and panoramic and lateral cephalometric radiographs of 718 children (431 girls and 287 boys) aged from 6 to 17 years, inhabitants of the Mazovia region (Central Poland), followed up or treated for dental anomalies in the Department of Orthodontics at Warsaw Regional Dental Centre in the years 1994–2006.

All panoramic radiographs were taken using a Planmeca Proline PM unit (Helsinki, Finland). The radiographic films used were Foton XR-1N (15 × 30 cm) (Foton S.A., Warsaw, Poland), the exposure time was 15 seconds and the films were developed with Retina X Ray (Fotochemische Werke GmbH, Berlin, Germany). When taking the radiographs, the ratio of enlargement was constant (1:2). Lateral cephalographs were taken with the same equipment with the aid of a cephalostat (collimation 4) using Kodak Green radiographic films (18 × 24 cm) (Eastman Kodak Company, Rochester, New York, USA). The exposure time was 0.4–0.6 seconds.

In total, 1436 radiographic images of the patients, who were in good general health, without general developmental impairments, were evaluated. At the start of the study, the chronological ages of the patients were established based on the time from the child's birth to the day the panoramic radiograph was taken. The obtained values were rounded down and noted in years and decimal points. The collected data enabled comparison of the chronological age of a patient with the dental age resulting from the standard tables of Demirjian. The development of the seven left permanent mandibular teeth was then assessed on the panoramic radiographs by means of the eight-grade scale according to Demirjian's system (Demirjian *et al.*, 1973; Demirjian and Goldstein, 1976).

In order to evaluate dental age using Demirjian's method, each panoramic radiograph was assessed twice by the same author (AKR) in order to minimize evaluation error. The first evaluation was carried out using a light box and the determined developmental stages of the teeth were entered into tables in a computer database. The images were then scanned and stored in a computer database and the evaluation of calcification was carried out on the computer screen. This method enabled magnification of selected regions of interest in order to achieve more accurate assessment of the developmental stages. The results of the second reading were compared with those of the first trial. The differences between the first and second evaluation for any given tooth did not exceed one developmental stage. When disparities occurred, a lower developmental stage was always chosen.

The evaluated teeth included the central incisor, lateral incisor, canine, first and second premolars, and first and second molars. An eight-grade scale was used and each tooth was assigned an appropriate value representing the developmental stage. Using standard tables (separate for boys and girls aged from 3 to 16 years), each evaluated stage was then assigned an appropriate numeric value. The values were then summed, and the obtained total score indicated the dental age derived from standard tables.

In the next step, cervical vertebrae (C2, C3, and C4) outlines traced from the lateral cephalometric radiographs were visually analysed using the CVM method in order to determine the skeletal maturation stage (Baccetti *et al.*, 2002, 2005). The presence or absence of concavity at the lower border of C2–C4 as well as the shape of the vertebral bodies of C3 and C4 (trapezoidal, horizontal, square, and vertical) were analysed. Six developmental stages are described—from cervical stage (CS)1 to CS6. In order to increase the diagnostic efficiency of the method, its authors included information on prognosis of mandibular growth potential related to every stage of CVM.

In order to study any direct relationship between the CS and the seven stages of Demirjian's method (B, C, D, E, F, G, and H), percentage distribution of dental development stages in subsequent CS stages was calculated, taking gender into account.

Statistical analysis was performed using the Statistica software package for Windows (StatSoft Media, Tulsa, Oklahoma, USA). Descriptive statistics (mean values and standard deviations) of the chronological and dental ages of the patients for the particular CS of skeletal maturity was calculated for girls and boys separately. Linear regression analysis and correlation (Pearson's r coefficient) was used to study the association between dental and chronological age for girls and boys separately, as well as for the whole group. The Spearman rank correlation coefficient (R) was applied to measure the association between the CS and dental calcification stages of all analysed teeth.

Results

The number and percentage of patients in the CVM stages, regarding gender, are presented in Table 1. A consistently earlier occurrence (about 6 months) for each skeletal maturation stage was observed in females (Figure 1a and 1c) but not in the males (Figure 1b and 1d).

Table 2 shows the chronological and dental ages corresponding to all CS stages in females and males. It was confirmed that CS increased together with increasing chronological age as well as with dental age (Figure 2a and 2b). Dental age was accelerated when compared with chronological age by 0.99 ± 1.25 years in males and 1.10 ± 1.18 years in females for all CS.

Chronological and dental ages showed an overall high correlation [(r = 0.77, P = 0.00 in females (Figure 3a) and 0.79 in males (Figure 3b, P = 0.00)] (Table 3). When the CS were evaluated separately, for females all correlations were statistically significant, while in males, CS5 stage lacked statistical significance (P = 0.3). The strongest correlation was observed between chronological and dental age in patients with CS1—both in females (r = 0.77, P = 0.00) as well as in males (r = 0.81, P = 0.00). The lowest correlation was for CS2 in females (r = 0.51, P = 0.00) and CS5 in males (r = 0.29, P = 0.3) (Table 3).

Spearman rank correlation coefficient revealed relationships between the dental calcification stages of all examined teeth and skeletal maturity stages (Table 4): R = 0.18–0.52 in male and R = 0.14–0.59 in female subjects.

The teeth showing the strongest relationship with CVM were the second premolar in females (R = 0.59) and the canine in males (R = 0.52). The lowest correlation, independent of gender, was noted for the central incisor (R = 0.14 in females and R = 0.18 in males).

Table 1 Number and percentage of patients in each cervical stage (CS) regarding gender.

CS	Gender	*n* (%)
1	Female	67 (45.27)
	Male	81 (54.73)
	Total	148 (100.00)
2	Female	44 (44.44)
	Male	55 (55.56)
	Total	99 (100.00)
3	Female	58 (48.74)
	Male	61 (51.26)
	Total	119 (100.00)
4	Female	86 (58.90)
	Male	60 (41.10)
	Total	146 (100.00)
5	Female	86 (85.15)
	Male	15 (14.85)
	Total	101 (100.00)
6	Female	90 (85.71)
	Male	15 (14.29)
	Total	105 (100.00)

The sequence of teeth regarding increasing correlation with CVM in males was the central incisor (R = 0.18), lateral incisor (R = 0.27), first molar (R = 0.31), second molar (R = 0.48), first premolar (R = 0.49), second premolar (R = 0.49), and canine (R = 0.52). The sequence was slightly different for females: central incisor (R = 0.14), lateral incisor (R = 0.2), first molar (R = 0.29), canine (R = 0.48), first premolar (R = 0.54), second molar (R = 0.57), and first premolar (R = 0.59).

The percentage distribution of dental development stages was calculated for the canines, first and second premolars, as well as the second molars (Table 5). The central and lateral incisors as well as the first molars were excluded from this analysis due to the weakest correlations with CVM in the present study. In CS1, the most frequently observed dental development stage was G for the second molar (55.22 per cent) and the canine (50.75 per cent) in females and G for the canine in males (59.26 per cent). The CS2 maturity of the cervical vertebrae was accompanied by stage G of the second molar both in females (61.36 per cent) and males (58.18 per cent). In females, the H stage for the canines was also frequently observed (56.82 per cent) and the G stage for the canines in males (56.36 per cent). The G stage of the second molars occurred in 87.93 per cent of females and 70.49 per cent of males in the CS3 period. In the same CVM stage, in almost 75 per cent of females, development of the canines was complete (stage H), while in over one-half of males, the development of these teeth was incomplete (stage G). The development of the majority of canines and first premolars reached the final stage in CS4, both in females (84.88 and 79.09 per cent, respectively) and in males (65 and 76.67 per cent, respectively). The second molars still presented mainly the G stage of development (females 69.77 per cent and males 78.33 per cent). In CS5 dental development stage H was found for the majority of the canines and premolars. For the second molars, the final stage of dental development was observed only in 18.6 per cent of females and in 40 per cent of males. The last stage of development of the canines and the first and second premolars was reached in over 90 per cent of patients in CS6. The distribution of the G and H stages for the second premolars was almost balanced. In the first stages of skeletal development, there was advancement of dental development in females, in particular of the canines. In CS5 and 6, males were more advanced in dental development (especially the second molars).

Discussion

It is generally accepted that a strong relationship exists between skeletal, sexual, and somatic maturation (Green, 1961; Fishman, 1979; Grave and Brown, 1976; Demirjian *et al.*, 1985), but contributions to the correlation between dental age and skeletal maturity are inconclusive (Bambha and Van Natta, 1959; Green, 1961; Grøn, 1962; Engström *et al.*,

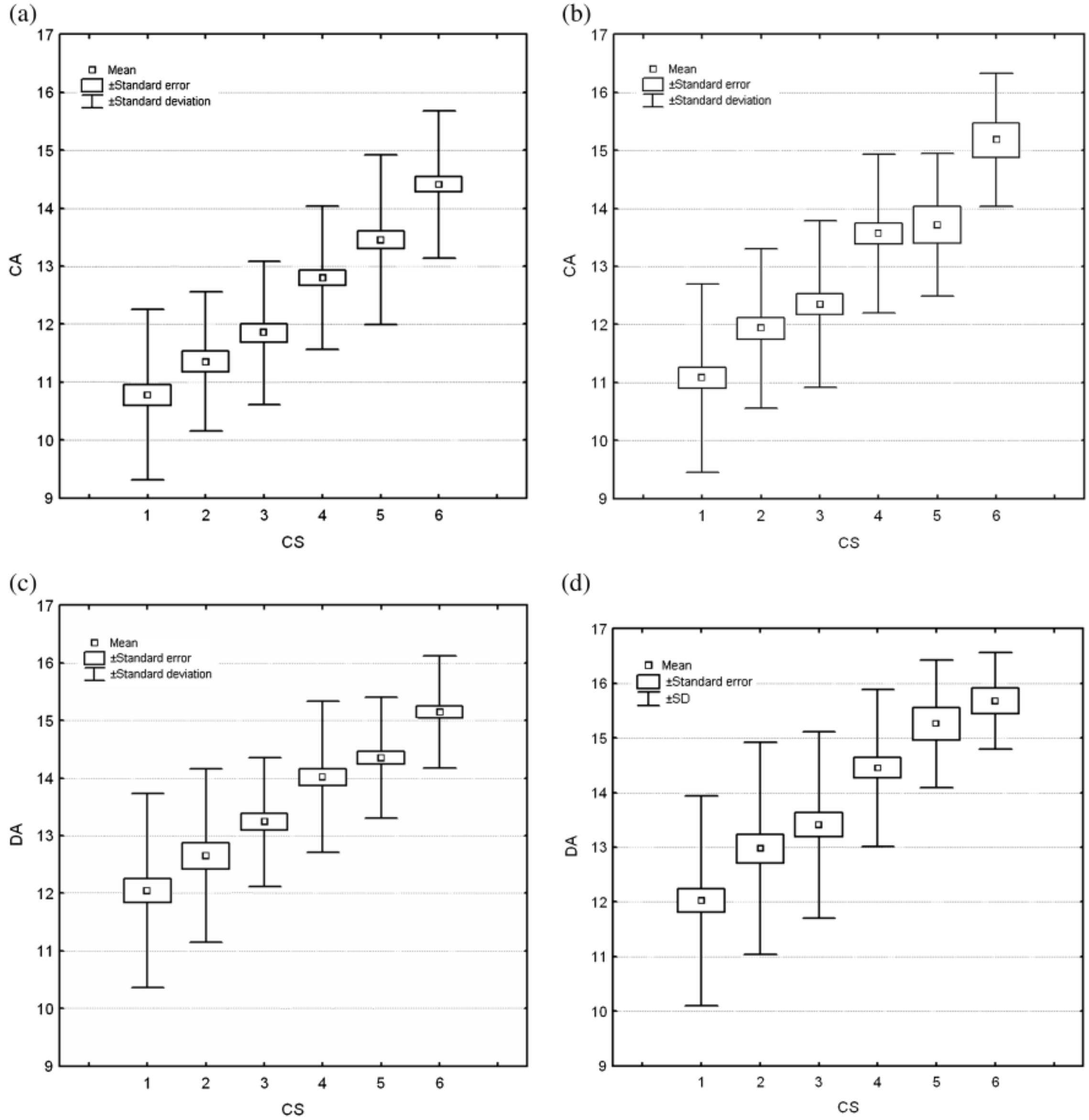


Figure 1 Chronological age (CA) in females (a) and males (b) as well as dental age (DA) in females (c) and males (d) related to cervical stage (CS).

1983; Demirjian *et al.*, 1985; Sierra, 1987; Helm, 1990; Lewis, 1991; Midtbø and Halse, 1992; Coutinho *et al.*, 1993; Nadler, 1998; Krailassiri *et al.*, 2002; Şahin Sağlam and Gazileri, 2002; Flores-Mir *et al.*, 2005; Uysal *et al.*, 2005). Lack of concordance may result, at least in part, from differences in evaluation methods of dental and skeletal maturity. Discrepancies in the number, age, and racial background of the studied subjects conditioned by ethnic origin, climate, nutrition, socio-economic status, and industrialization are the main reasons for variability of the results in many studies (Sierra, 1987; Mappes *et al.*, 1992).

Panoramic radiographs are routinely available in orthodontic clinics and the method of dental age determination described by Demirjian is based on the calcification stage of the seven left mandibular teeth, which are clearly visible on such radiographs. The criteria of the method comprise the shape and proportion of root length (using the relative value to crown height rather than absolute tooth length) and thus the influence of radiographic projection is minimal (Krailassiri *et al.*, 2002).

In the majority of available studies, skeletal maturity was assessed by means of hand wrist radiographs (no matter which method of radiograph evaluation was used) due to the presence of different types of bones in this anatomical region (Green, 1961; Grøn, 1962; Engström *et al.*, 1983; Demirjian *et al.*, 1985; Sierra, 1987; Helm, 1990; Lewis, 1991; Midtbø and Halse, 1992; Coutinho *et al.*, 1993; Nadler, 1998; Krailassiri *et al.*, 2002; Şahin Sağlam and Gazileri, 2002; Flores-Mir *et al.*, 2005; Uysal *et al.*, 2005). However, recently, there has been growing interest in the

Table 2 Chronological age (CA) and dental age (DA) corresponding to all cervical stages (CS) regarding gender.

CS	Females				Males			
	n	CA	DA	Difference	*n*	CA	DA	Difference
1	67	10.78 ± 1.47	12.04 ± 1.69	1.26 ± 1.10	81	11.08 ± 1.62	12.02 ± 1.92	0.94 ± 1.12
2	44	11.35 ± 1.20	12.65 ± 1.51	1.30 ± 1.37	55	11.93 ± 1.37	12.97 ± 1.94	1.04 ± 1.40
3	58	11.85 ± 1.24	13.24 ± 1.12	1.39 ± 1.07	61	12.35 ± 1.44	13.41 ± 1.70	1.06 ± 1.18
4	86	12.80 ± 1.23	14.02 ± 1.31	1.22 ± 1.14	60	13.57 ± 1.36	14.45 ± 1.43	0.89 ± 1.37
5	86	13.46 ± 1.47	14.35 ± 1.05	0.91 ± 1.21	15	13.71 ± 1.23	15.26 ± 1.17	1.55 ± 1.43
6	90	14.41 ± 1.27	15.15 ± 0.97	0.75 ± 1.12	15	15.18 ± 1.15	15.68 ± 0.89	0.58 ± 0.87
Total	431	12.68 ± 1.82	13.77 ± 1.64	1.10 ± 1.18	287	12.39 ± 1.83	13.37 ± 2.04	0.99 ± 1.25

stages of the maturity of the cervical vertebrae as a biological index of individual skeletal maturity (Baccetti *et al.*, 2002, 2005; Chen *et al.*, 2004; Flores-Mir *et al.*, 2006). One of the main reasons for the increasing popularity of this method is avoidance of additional radiation exposure to the patient, as cervical vertebrae can be assessed on cephalometric radiographs, frequently used in orthodontic diagnostics. The current CVM method, consisting of six maturity stages defined by means of visual evaluation of morphology of three cervical vertebrae (C2, C3, and C4), is that most frequently used for this purpose (Baccetti *et al.*, 2002, 2005; Flores-Mir *et al.*, 2006). Validity of the method, irrespective of the approach or the studied population, had been confirmed by comparisons with skeletal age estimated by means of hand and wrist radiographs (Flores-Mir *et al.*, 2006; Gandini *et al.*, 2006; Kamal and Goyal, 2006). In the present study, it was shown that cervical vertebrae maturity increased together with the increases in chronological and dental age.

Studies on the correlation of dental maturity described on the basis of dental eruption or mineralization of the entire dentition, usually produced low or no correlation coefficients between dental and skeletal age, regardless of the method of skeletal age assessment (Bambha and Van Natta, 1959; Grøn, 1962; Demirjian *et al.*, 1985; Helm, 1990; Midtbø and Halse, 1992).

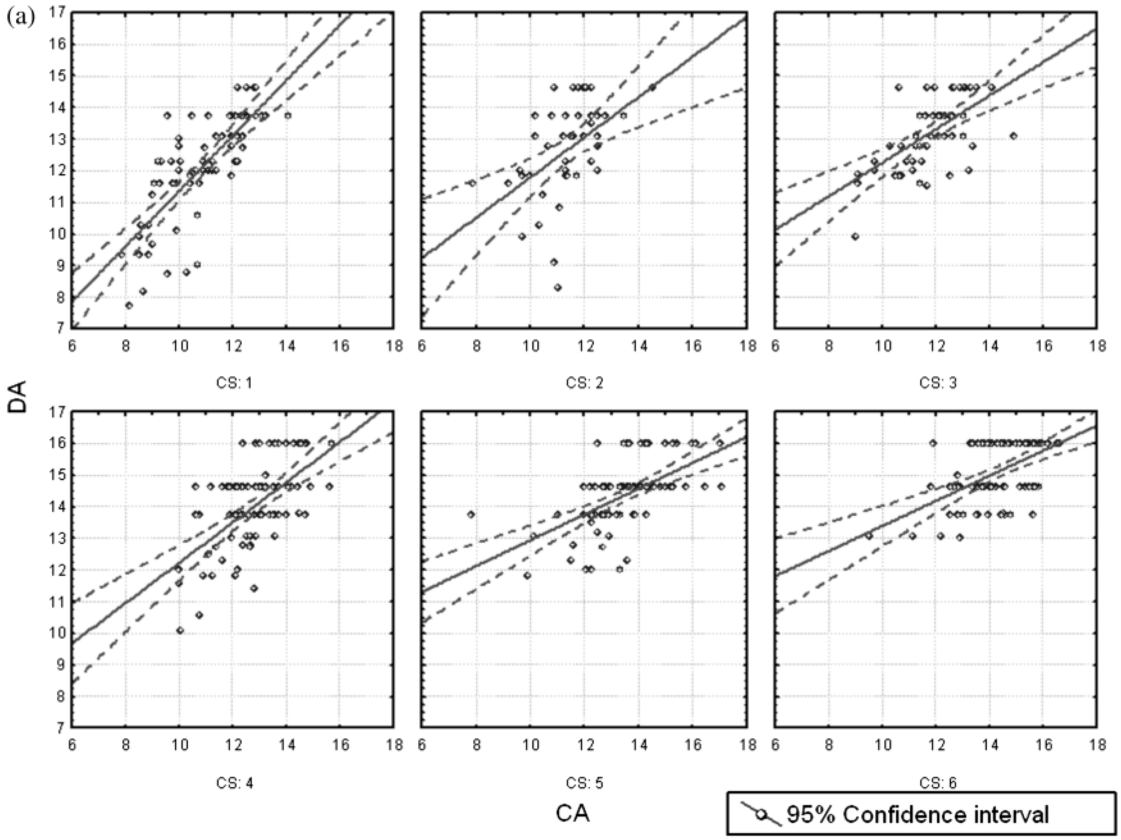
For example, Demirjian *et al.* (1985) carried out a comparison of five maturity indices: the date of menarche, peak height velocity (PHV), 75 per cent of skeletal maturity, presence of thumb sesamoid bone (Tanner–Whitehouse method) (Tanner *et al.*, 1983), and 90 per cent dental maturity in 50 French Canadian girls aged 6–15 years. The mean age of occurrence of the indices was statistically inconsistent ($P < 0.01$). No significant correlation was found between the age of occurrence of 90 per cent dental maturity and other variables (skeletal age: $R = 0.17$, thumb sesamoid bone: $R = -0.03$, age of PHV: $R = -0.16$, and age of menarche: $R = -0.10$).

Lack of a relationship between skeletal age determined by means of the atlas method according to Greulich and Pyle (1959) as well as the development of the roots of permanent maxillary incisors and mandibular teeth (apart from the third molars) during eruption of individual teeth was noted by Grøn (1962).

When bone age according to Greulich and Pyle (1959) was compared with dental age determined on antero-posterior and lateral cephalometric radiographs of the skull according to the Bolton standards, the differences in skeletal and dental age obtained by Lewis (1991) in a group of 694 American children reached 36 months. This probably reflects the fact that skeletal and dental maturation are separate processes (Lewis, 1991). These observations are supported by Helm (1990) and Bambha and Van Natta (1959), who used the phenomenon of eruption for determination of dental age. However, this approach is generally considered less accurate than analysis of mineralization of teeth for assessment of a child's dental maturity.

The above results testify almost unequivocally to a poor or even a lacking relationship between these maturity processes. On the other hand, a detailed literature review leads to an observation that authors studying selected teeth rather than the dentition as a whole obtained higher correlation coefficients between dental and skeletal maturity (Engström *et al.*, 1983; Coutinho *et al.*, 1993; Krailassiri *et al.*, 2002; Şahin Sağlam and Gazileri, 2002; Uysal *et al.*, 2005) than those who assessed dental maturity of the entire dentition (Demirjian *et al.*, 1985; Grøn, 1962; Lewis, 1991; Midtbø and Halse, 1992). Moreover, according to Kataja *et al.* (1989), the use of several chosen teeth results in a decrease of the probability of accidental errors. Therefore, in the present research apart from correlation between dental age and cervical maturation stages, correlations between development of individual teeth and skeletal maturity stages were calculated.

A statistically significant correlation was observed between maturity stages of the examined teeth and skeletal maturity stages for both genders. The differences in the correlation coefficients in comparison with the results of other authors may, at least in part, result from discrepancies in the number, age, and racial background of the studied subjects as well as methods of selection of the teeth.



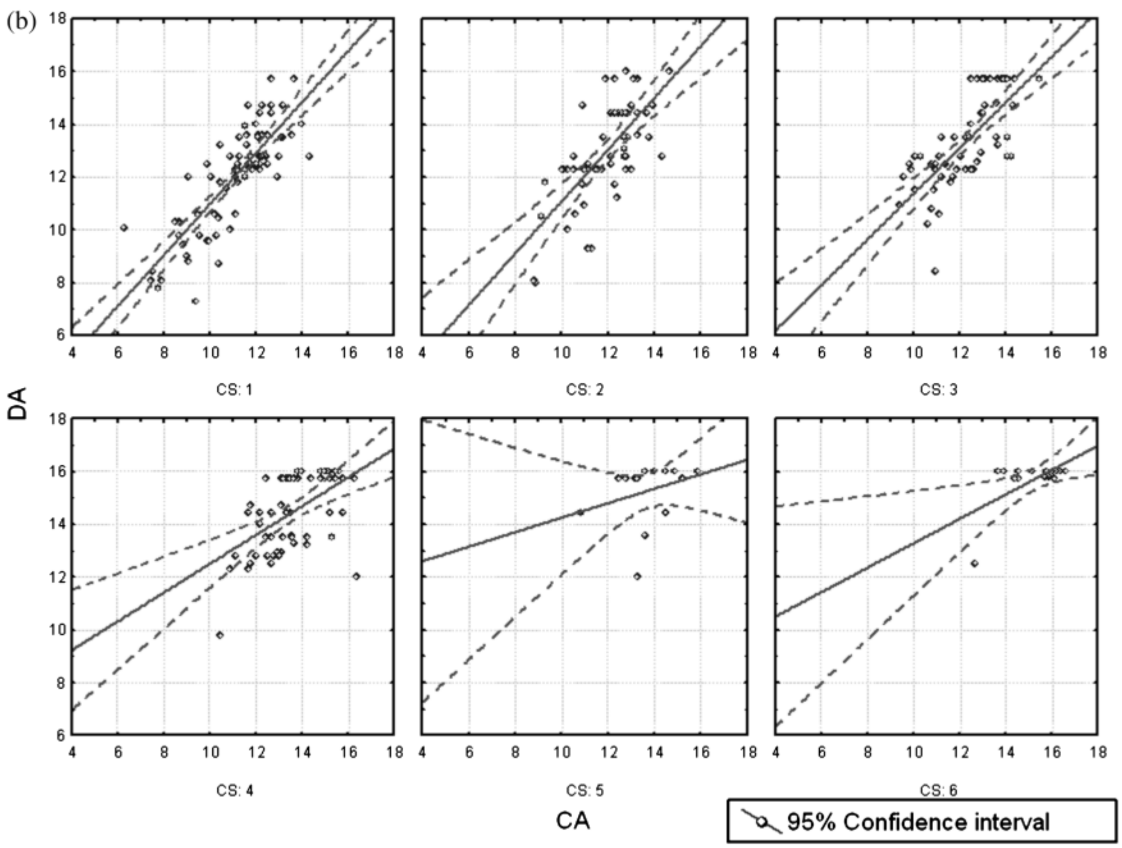


Figure 2 Chronological age (CA) versus dental age (DA) for each cervical stage (CS) in females (a) and males (b).

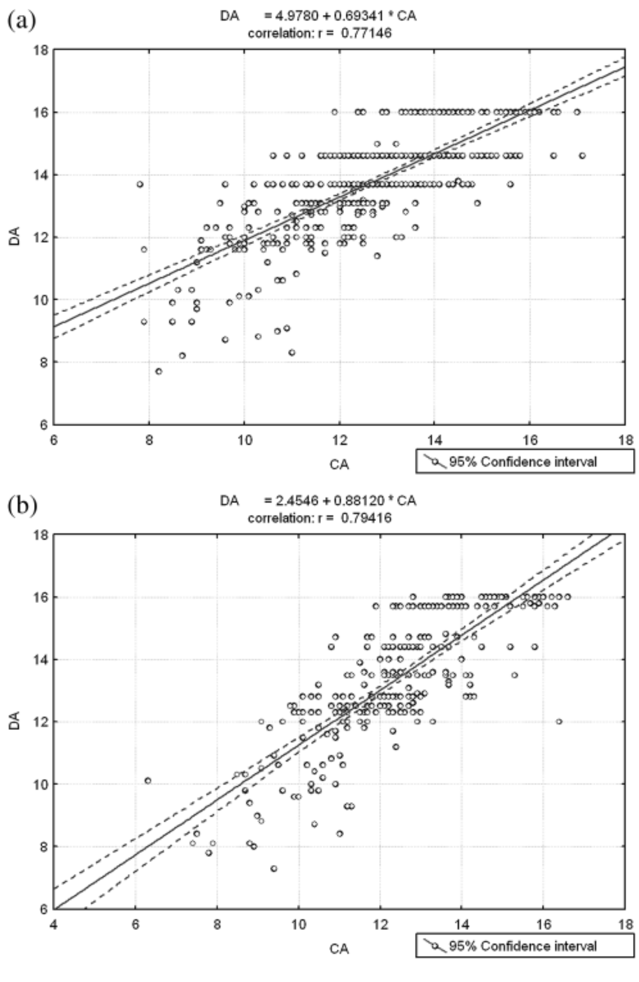


Figure 3 Correlation of chronological age (CA) and dental age (DA) in females (a) and males (b).

Krailassiri *et al.* (2002), in a study of Thai children, determined the development of teeth using Demirjian's method and skeletal maturity by means of hand wrist radiographs analysis (Greulich and Pyle atlas, Fishman system). Those authors analysed development of the left mandibular canines, first and second premolars, and second and third molars. The relationship between development of individual teeth with skeletal development was the strongest for the second premolar, as in the present study. The obtained correlation coefficients for the second premolar was R = 0.66 in boys and R = 0.69 in girls (Krailassiri *et al.*, 2002). The lowest correlation was found for the third molar in both genders, R = 0.47 in boys and R = 0.31 in girls, but the relationship of this tooth with skeletal maturity is uncertain. Uysal *et al.* (2005) found low or no correlation for these teeth. The level of statistically significant correlations between dental and skeletal maturity stages in a group of 500 Turkish young subjects aged 7 to 20 years obtained by Uysal *et al.* (2005) was from 0.490 to 0.826 in girls and from 0.414 to 0.706 in boys ($P < 0.01$). These findings are similar to those obtained by Krailassiri *et al.* (2002), higher than those in the present research (R = 0.14–0.59), but at the same time show considerable variance. The observed differences, independent of gender, might have resulted from the lowest Spearman rank coefficients for the central and lateral incisors as well as the first molars, which were also included in the evaluation (from R = 0.14 to R = 0.31). In the Turkish population, the second molar presented the highest relationship with skeletal maturity (boys: R = 0.826 and girls: R = 0.706). The lowest correlation was noted for the third molar, both in girls (R = 0.49) and boys (R = 0.414). Uysal *et al.* (2005) also analysed the mean chronological age related to all skeletal maturity stages and an earlier occurrence of all, but the last stage (Ru), was noted in girls. This observation is in concordance with the comparison of chronological age with CS maturity stages in the current study. Earlier skeletal maturation (approximately 6 months) was observed in females, which is in agreement with the results of Coutinho *et al.* (1993) and Krailassiri *et al.* (2002). On the other hand, acceleration of dental age was observed in children of Mazovia (Central Poland) (Różyło-Kalinowska *et al.*, 2008). This finding was confirmed in the current study.

Table 3 Correlation coefficients between chronological age and dental age in all cervical stages (CS).

CS	Correlation coefficients			
	Females		Males	
	r	*P*	*r*	*P*
1	0.7664	0.0000 < 0.01	0.8148	0.0000 < 0.01
2	0.5066	0.0004 < 0.01	0.6915	0.0000 < 0.01
3	0.5885	0.0000 < 0.01	0.7305	0.0000 < 0.01
4	0.6008	0.0000 < 0.01	0.5188	0.0000 < 0.01
5	0.5711	0.0000 < 0.01	0.2883	0.2974 > 0.05
6	0.5190	0.0000 < 0.01	0.5985	0.0184 < 0.05
Total	0.7715	0.0000 < 0.01	0.7942	0.0000 < 0.01

r, Pearson's correlation coefficient.
P, probability of the test.

Table 4 Spearman rank coefficients (R) between dental development stages and cervical stage (CS) in males and females together with probability of the test (P).

Dental developmental stages	Females		Males	
	R	*P*	*R*	*P*
Stage 7	0.5654	0.0000 < 0.01	0.4835	0.0000 < 0.01
Stage 6	0.2583	0.0000 < 0.01	0.3103	0.0000 < 0.01
Stage 5	0.5849	0.0000 < 0.01	0.4864	0.0000 < 0.01
Stage 4	0.5413	0.0000 < 0.01	0.4855	0.0000 < 0.01
Stage 3	0.4768	0.0000 < 0.01	0.5213	0.0000 < 0.01
Stage 2	0.1967	0.0000 < 0.01	0.2691	0.0000 < 0.01
Stage 1	0.1439	0.0028 < 0.01	0.1827	0.0019 < 0.01

Table 5 Percentage distribution of dental development stages according to Demirjian's method for subsequent cervical stages (CS).

Dental stages	Canines		First premolars		Second premolars		Second molars	
	Female (%)	Male (%)	Female (%)	Male (%)	Female (%)	Male (%)	Female (%)	Male (%)
CS1								
C	—	—	—	—	1.49	—	—	1.23
D	—	1.23	0	1.23	1.49	4.49	2.99	6.17
E	1.49	4.49	4.48	11.11	11.94	12.35	17.91	20.99
F	11.94	20.99	28.36	28.40	32.84	38.27	23.88	22.22
G	50.75	59.26	37.31	39.51	44.78	34.57	55.22	49.38
H	35.82	13.58	29.85	19.75	7.46	9.88	—	—
Total	100	100	100	100	100	100	100	100
CS2								
C	—	—	—	—	2.27	—	—	—
D	—	—	—	1.82	2.27	3.64	2.27	7.27
E	—	1.28	—	5.45	2.27	3.64	6.82	1.82
F	2.27	12.73	18.18	18.18	34.09	27.27	29.55	29.09
G	40.91	56.36	43.18	30.91	43.18	45.45	61.36	58.18
H	56.82	29.09	38.64	43.64	15.91	20	—	3.64
Total	100	100	100	100	100	100	100	100
CS3								
D	—	—	—	—	—	—	—	1.64
E	—	1.64	0	1.64	—	3.28	1.72	4.92
F	1.72	6.56	8.62	18.03	29.31	29.51	10.34	22.95
G	24.14	57.38	44.83	34.43	43.1	37.7	87.93	70.49
H	74.14	34.43	46.55	45.9	27.59	29.51	—	—
Total	100	100	100	100	100	100	100	100
CS4								
E	—	—	—	—	1.16	1.67	2.33	3.33
F	—	1.67	3.49	5	12.79	10	9.3	5
G	15.12	33.33	17.44	18.33	38.37	40	69.77	78.33
H	84.88	65	79.07	76.67	47.67	48.33	18.6	13.33
Total	100	100	100	100	100	100	100	100
CS5								
F	—	—	1.16	6.67	5.81	6.67	2.33	6.67
G	10.47	6.67	9.3	6.67	25.58	20	79.07	53.33
H	89.53	93.33	89.53	86.67	68.6	73.33	18.6	40
Total	100	100	100	100	100	100	100	100
CS6								
F	—	—	—	—	—	6.67	1.11	—
G	1.11	6.67	4.44	6.67	17.78	—	45.44	40
H	98.89	93.33	95.56	93.33	82.22	93.33	53.33	60
Total	100	100	100	100	100	100	100	100

Statistical analysis of the relationship between dental maturity (partly estimated according to Demirjian) and skeletal maturity (assessed by means of Fishman's system on conventional radiographs of the left hand) in a population of 422 generally healthy Turkish children aged 91–168 months (7.8–14 years) revealed the strongest correlation between skeletal maturity level and development of the first maxillary premolar in girls (R = 0.648) (Şahin Sağlam and Gazileri, 2002). In boys, the second mandibular molar strongly correlated with skeletal maturity (R = 0.550). The lowest correlation was found for the first mandibular premolar in girls (R = 0.558) and the maxillary canine in boys (R = 0.474) (Şahin Sağlam and Gazileri, 2002).

One tooth that constantly shows a stronger correlation with skeletal maturity level in comparison with other teeth is the mandibular canine (Sierra, 1987; Coutinho *et al.*, 1993; Flores-Mir *et al.*, 2005). The findings of the present study support this observation.

In the majority of the above studies, including the present research, a statistically significant correlation between dental and skeletal maturity was confirmed. Nevertheless, many authors still highlight the importance of parallel evaluation of both maturity indices in a growing child (Sierra, 1987; Coutinho *et al.*, 1993; Şahin Sağlam and Gazileri, 2002; Uysal *et al.*, 2005). However, the simplicity of the evaluation of the development of teeth as well as the widespread availability of intra- and extraoral radiographs is decisive in the application of the dental maturity method as a tool for initial assessment of the level of skeletal maturity of a child. It must be remembered that this tool cannot be used as the only measure of development, especially in atypically developing patients, such as those with endocrine disorders, congenital diseases, or other signs and symptoms of developmental disharmonies. In such subjects, full information on developmental age is relevant only when simultaneous estimation of several indices is performed (Sierra, 1987; Coutinho *et al.*, 1993; Uysal *et al.*, 2005).

The present results are preliminary due to the fact that it is the first study to compare the CVM method of skeletal maturity evaluation with dental development indices. Moreover, the material consisting of 718 patients (including 60 per cent of females) is not fully representative and for epidemiological purposes, the studied group should be larger and balanced regarding gender. Nevertheless, the results are a contribution to the still inconclusive discussion on interrelationships between the two most often applied measures of development—skeletal and dental maturity of growing patients.

Conclusions

In the studied group of children, a consistently earlier occurrence (approximately 6 months) of each skeletal maturation stage was found in females. A moderate, but statistically significant, correlation between Demirjian's dental developmental stages and the maturation stages of the cervical vertebrae was determined. The level of correlation was different for individual teeth: the teeth showing the highest relationship with CVM classification were the second premolars and canines (in female and male subjects, respectively). The central incisor demonstrated the poorest correlation in both genders. The results confirm that both dental maturity and skeletal maturity should be assessed if the maturity stage of a growing child is relevant to clinical practice. The findings also indicate the usefulness of dental calcification stages as a simple first-level diagnostic tests to determine skeletal maturity.

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