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Original Article

Assessment of the Relationship between Skeletal Maturity and the Calcifications Stages of Permanent Canines and Second Premolars

Emel Oncan[1], Seden Akan[2]

[1]Oral and Dental Health Program, Vocational School of Health Services, Altınbaş University, Istanbul, Turkey
[2]Department of Orthodontics, Faculty of Dentistry, Altınbaş University, Istanbul, Turkey

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Main points:

- Evaluation of tooth calcification stages is an alternative approach for identifying individual skeletal maturity.
- The calcification stages of permanent canines and second premolars show satisfactory demonstrative performance of assessing the pre-pubertal phase.
- The subjects of this study showed precocious puberty.

ABSTRACT

Objective: This study aimed to evaluate the relationship between the calcification stages of permanent maxillary and mandibular canines and second premolars and skeletal maturity in both sexes.

Methods: This study included 138 patients (82 females, 56 males) who were treated in the Department of Orthodontics, Altınbaş University. The mean age of the patients was 12.31±1.76 years, ranging from 7.8 years to 15.8 years. Dental maturity stages of canines and second premolars were evaluated according to the Demirjian index on digital panoramic radiograph. The skeletal maturation stage was determined using the cervical vertebral maturation (CVM) index. The Pearson correlation analysis was performed to assess the association among CVM stages and calcification stages of canines, second premolars, sex, and chronological ages.

Results: A statistically significant correlation was found between CVM and the calcification stages of the canines and second premolars ($p<0.05$). The calcification stages of the canines and second premolars had the highest distribution of Stage F and Stage G at CVM2 ($p<0.01$). For the canines and second premolars, Stage H corresponded to CVM3 in female patients and a high percentage of Stage G corresponded to CVM3 in the male group.

Conclusion: A significant correlation was found between the calcification stages of maxillary and mandibular canines, second premolars, and skeletal maturity in both sexes. It was observed that calcification stages and cervical maturations were advanced in female subjects compared with male subjects.

Keywords: Tooth calcification stages, digital panoramic radiography, skeletal maturity

INTRODUCTION

Skeletal maturity plays a key role in orthodontics and dentofacial orthopedics when treating growing orthodontic patients. In various malocclusions, optimal treatment time is critical. For instance, early Class III treatment using protraction facemasks with skeletal expansion is more efficiently performed at the pre-pubertal period, whereas the functional appliances for Class II treatment are more efficient at the growth peak stage when incorporated in the treatment. Nevertheless, as there are notable variations regarding the development among children of the same age, the role of chronological age in the evaluation of skeletal maturation does not matter (1). Discrepancies between chronological and biological ages showed a need for maturity indicators, such as morphological age, skeletal age, sexual age, and dental age (2). The most commonly used

Address for Correspondence: Seden Akan, Department of Orthodontics, Faculty of Dentistry, Altınbaş University, Istanbul, Turkey
E-mail: sedenakandt@hotmail.com

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techniques for growth evaluation are physical indicators, which are based on the overall body changes, such as the appearance of sexual characteristics and the evaluation of the hand-wrist radiographs, lateral cephalometric radiographs, or digital panoramic radiographs (3-6).

Numerous researchers have evaluated the cervical vertebral maturation (CVM) index, which determines the growth stage according to morphological shapes of the second, third, and fourth cervical vertebrae in lateral cephalometric radiographs (7, 8). Similarly, hand-wrist radiographic evaluation is an important diagnostic tool used in ascertaining whether pubertal growth has started, is still occurring, or has finished (9). Tooth calcification is a more dependable indicator of dental maturity than tooth eruption because it is not influenced by factors such as early loss of primary teeth, missing spaces, maturation, caries, ankyloses, and malocclusions, in addition to genetic control (10).

The most widely used method for estimating dental maturation or dental age was described in 1973 by Demirjian et al. (10). This method is based on the development of 7 left permanent mandibular teeth. Most of the studies using Demirjian's method have reported overestimation (11, 12). For Turkish population, there are studies that have shown both overestimation and convenience (13-15).

The CVM method is accepted as a precise method for evaluating the growth stage; however, it requires a lateral cephalogram to be taken from every patient, which is currently controversial (16, 17). In recent research, lateral cephalometric radiographs have not been taken routinely. Instead, digital panoramic radiographs are routinely obtained in orthodontic practice and are beneficial for evaluating dental maturity. It could be said that the evaluation of dental maturity is an alternative to the CVM method (18-20).

An established link between permanent tooth calcification stages and CVM may assist in ascertaining the skeletal maturity of the patient on the digital panoramic radiograph. Numerous studies have been performed using a similar method (18-22). Permanent canines have primary roles in determining functional occlusion and disturbances of normal development and its eruption may have major consequences (23).

This study aimed to evaluate the correlation between calcification stages of permanent canines and second premolars and skeletal maturity to assess whether this correlation among those teeth may be used as a reliable diagnostic tool for skeletal maturity assessment. The null hypothesis of the study is that no correlation exists between calcification stages of the permanent canines, second premolars, and CVM.

METHODS

The protocol of this retrospective research was evaluated and approved by the clinical sciences ethical board of Altınbaş University (2020/6). Signed informed consents of the patients treated at the Department of Orthodontics at Altınbaş University between December 2018 and January 2020 were obtained. The study group included 138 Caucasian orthodontic patients (82 females, 56 males) treated in the Department of Orthodontics, Altınbaş University. To determine whether the correlation between the calcification stages of the canines and premolars and skeletal maturity, power analysis was performed with G*Power Ver. 3.1.9.7 (Franz Faul, Universität Kiel, Germany) software (with the two-tailed hypothesis, α=0.05, f=0.30, power=0.95). The mean age of the patients was 12.31±1.76 years, ranging from 7.8 years to 15.8 years. The mean age of the female and male patients was 12.32±1.72 and 12.35±1.83 years, respectively. The minimum age of the patients was 7.8 years and maximum age was 15.6 years. The exclusion criteria were as follows: presence of any congenital anomalies, no congenitally missing mandibular second premolar, development/systemic disorders, nutritional deficiencies, and prolonged illnesses and patients who were undergoing or had previously undergone orthodontic treatment. An experienced orthodontist analyzed pretreatment digital panoramic radiographs and lateral cephalometric radiographs of the patients, which were taken according to the standard technique for evaluating cranial structures, using a NewTom-Giano Imaging System machine (CeflaGroup, Verona, Italy) by the same technician.

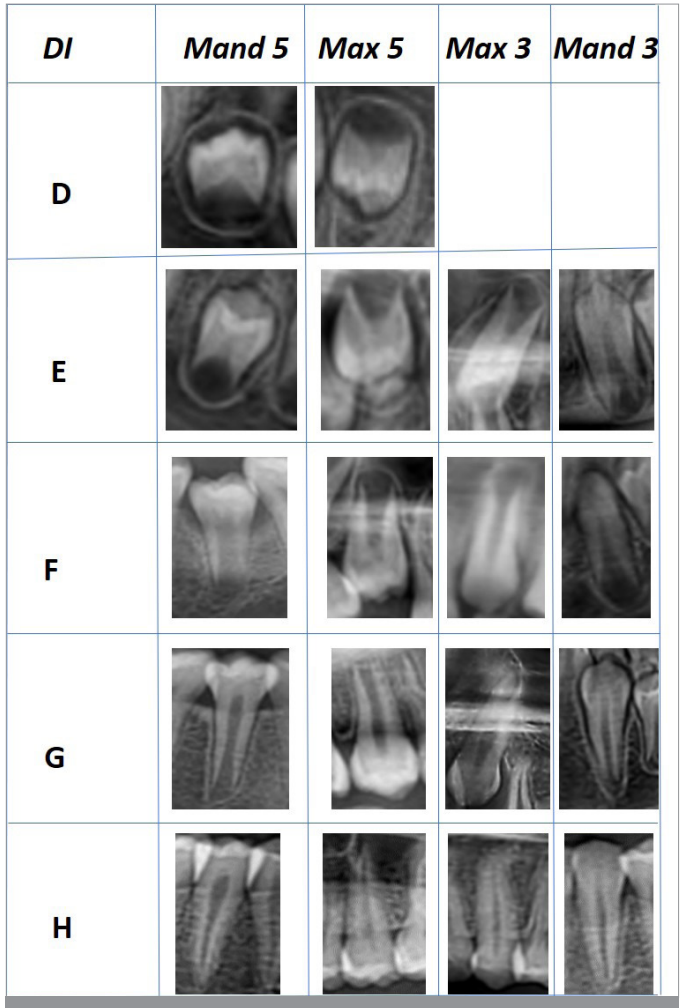

Figure 1. Classification of the dental maturation stages used in this study according to the Demirjian index method (10)

The calcification stages of canines and second premolars were evaluated. We chose canines and second premolars because, usually, these teeth are the last erupted teeth. The maxillary canine should erupt at the same time as the second premolar (24).

The calcification stages of the canines and second premolars were evaluated according to the Demirjian method (DI), in which 1 of the 8 stages of calcification (A to H) was assigned to the tooth (10) (Figure 1).

Evaluation of skeletal maturity was carried out using CVM index, and, the method proposed by Baccetti et al. (7), lateral cephalograms. The second, third, and fourth cervical vertebrae (C2, C3, and C4) were examined according to their shapes and grouped into 1 of the 6 stages in CVM (Figure 2).

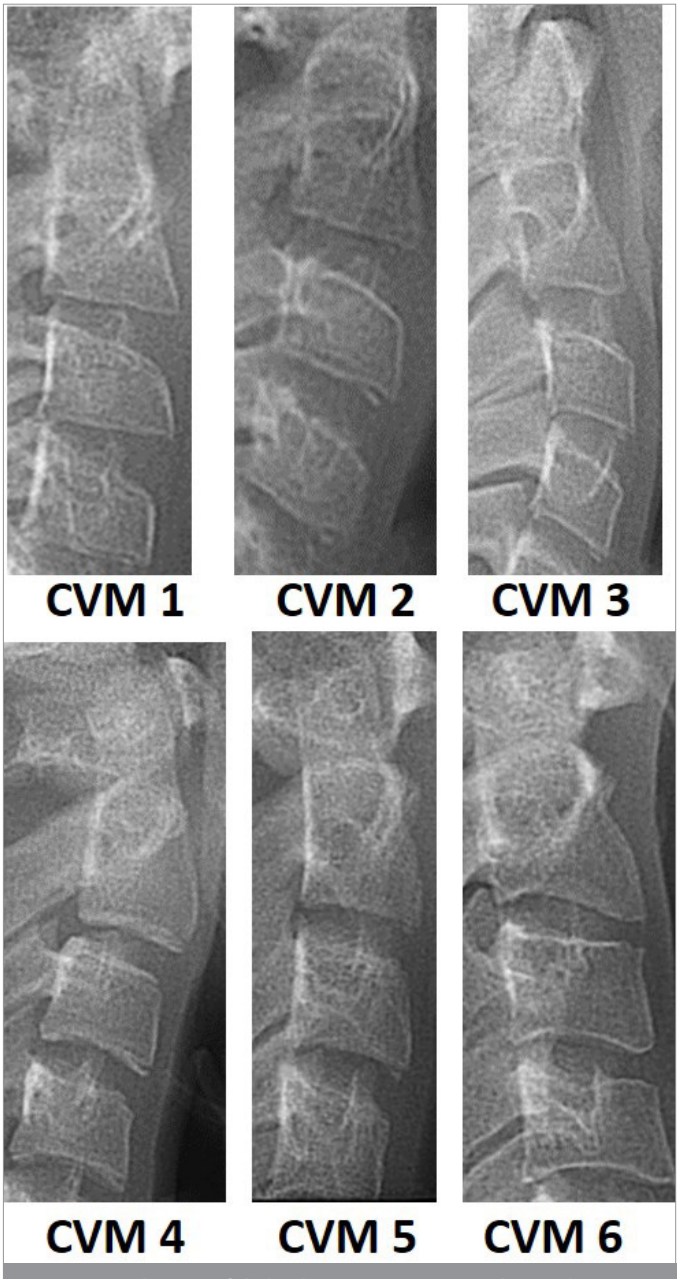

Figure 2. Evaluation of skeletal maturity stages used according to the method described by Baccetti et al. (7)

Statistical Analysis

Analysis of the data was conducted using the package program Statistical Package for the Social Sciences (SPSS) version 16 (SPSS for Windows, SPSS Inc., Chicago, IL, USA). The mean, standard deviation, frequency, and percentage of the DI stages and CVM were calculated, and the Shapiro–Wilk normality test was applied to the data. The Pearson correlation analysis was adopted to assess the association among CVM stages of canines, second premolars, sex, and chronological ages., evaluation of randomly selected. The lateral cephalometric and digital panoramic radiographs of 10 randomly selected patients were re-evaluated at an interval of 15 days to determine intra-rater reliability, and Pearson correlation coefficients were calculated as being in the range of 0.780–0.864. Statistical significance was set at $p<0.05$.

RESULTS

Table 1 shows chronological distribution of the CVM stages for the female and male groups. According to the results, maturation of the female group was earlier than that of the male group. In all the CVM stages, the average maturation age of the female group was lower than that of the male group.

Table 2 shows the distributions between the CVM stages and the calcification stage of the maxillary canines. Stage G DI showed the highest percentage distribution (50%) for female patients at CVM2 (pre-peak of pubertal growth spurt), whereas Stage F was observed in 66.67% of the male patients at CVM2. In the CVM3 (peak of pubertal growth spurt) stage calcification, Stage G was observed in 52.63% of the male patients, whereas Stage H was observed in 69% of the female patients. In contrast, the highest percentages were observed between the DI Stage H and CVM4 (deceleration of growth spurt), CVM5, and CVM6 stages (post-peak of pubertal growth spurt) in both male and female groups.

Table 1. Chronological distribution of CVM stages for female and male groups

			Ages (years)	
CVM Stages	**Sex**	**N**	**Mean**	**Standard deviation**
CVM1	Female	5	8.93	0.49
	Male	5	10.34	1.19
CVM2	Female	8	9.94	1.22
	Male	9	10.52	1.84
CVM3	Female	13	11.88	1.01
	Male	19	12.31	1.03
CVM4	Female	17	12.45	0.89
	Male	12	13.02	1.27
CVM5	Female	34	13.16	1.45
	Male	11	14.01	1.12
CVM6	Female	5	13.60	0.66
	Male	1	15.80	0.00

CVM: Cervical vertebral maturation; N: number of patients

Table 2. The distributions between CVM stages and calcification stages of maxillary canines; descriptive statistic was used

		Calcification stages, n (%)				
CVM stages		**E**	**F**	**G**	**H**	**Total**
CVM1	Female	4 (80)	1 (20)			5 (100)
	Male	1 (20)	1 (20)	3 (60)		5 (100)
CVM2	Female	1 (12)	3 (38)	4 (50)		8 (100)
	Male	1 (11.11)	6 (66.67)	2 (22.22)		9 (100)
CVM3	Female			4 (31)	9 (69)	13 (100)
	Male		3 (15.79)	10 (52.63)	6 (31.58)	19 (100)
CVM4	Female			3 (18)	14 (82)	17 (100)
	Male			3 (25)	9 (75)	12 (100)
CVM5	Female			3 (9)	31 (91)	34 (100)
	Male			1 (10%)	9 (90)	10 (100)
CVM6	Female				5 (100)	5 (100)
	Male				1 (100)	1 (100)
Total	Female	5	4	14	59	82
	Male	2	10	19	25	56

CVM: cervical vertebral maturation

Table 3. The distributions between CVM stages and calcification stages of mandibular canines; descriptive statistic was used

		Calcification stages, n (%)				
CVM stages		**E**	**F**	**G**	**H**	**Total**
CVM1	Female	2 (40)	3 (60)			5 (100)
	Male		3 (60)	2 (40)		5 (100)
CVM2	Female		4 (50)	3 (37.5)	1 (12.5)	8 (100)
	Male		4 (44.44)	5 (55.56)		9 (100)
CVM3	Female			6 (46.15)	7 (53.85)	13 (100)
	Male		1 (5.26)	11 (57.90)	7 (36.84)	19(100)
CVM4	Female			1 (5.88)	16 (94.12)	17 (100)
	Male		3 (25)	9 (75)	12 (100)	3 (25)
CVM5	Female			3 (8.83)	31 (91.17)	34 (100)
	Male				10 (100)	10 (100)
CVM6	Female			3 (8.83%)	31 (91.17)	34 (100)
	Male				1 (100)	1 (100)
Total	Female	2	7	13	60	82
	Male		8	21	27	56

CVM: Cervical vertebral maturation

Table 3 shows the percentage distributions between DI stages of mandibular canines and CVM stages. DI Stage F included the highest distribution (50%) at CVM2. Similar to the other CVM stages, Stage H was found in both sexes (male, 36.84%; female, 53.85%) for mandibular canine.

Tables 4 and 5 present the relations of the DI stages and CVM stages for mandibular and maxillary second premolars. Both tables show the DI Stage H at CVM4, CVM5, and CVM6 (from 76.47% to 100% for female and from 83.3% to 100% for male), while observing the differences at the CVM2 stage.

The correlations between the CVM stages, calcification stages of the canines and second premolars, sex, and chronological ages are shown in Table 6. A significant correlation was found between the calcification stages of the maxillary canine and the second premolar ($r=0.911$, $p\leq0.01$).

DISCUSSION

This study was performed to determine the relationship between the CVM stage and the calcification stages of permanent canine and second premolars and whether these stages can be used as indicators to determine the skeletal maturity of the CVM in both sexes.

Skeletal maturation exhibited fluctuation compared with chronological age**.** As a result, the effectiveness of chronological

Table 4. The distributions between CVM stages and calcification stages of maxillary premolars; descriptive statistic was used

		Calcification stages, n (%)					
CVM stages		**D**	**E**	**F**	**G**	**H**	**Total**
CVM1	Female	3 (60)	2 (40)				5 (100)
	Male	1 (20)	1 (20)	1 (20)	2 (40)		5 (100)
CVM2	Female		4 (50)	1 (12.5)	3 (37.5)		8 (100)
	Male	1 (11.11)	2 (22.22)	2 (22.22)	4 (44.44)		9 (100)
CVM3	Female			3 (23.08)	4 (30.77)	6 (46.15)	13 (100)
	Male		1 (5.26)	1 (5.26)	10 (54.6)	7 (36.84)	19 (100)
CVM4	Female				4 (25.53)	13 (76.47)	17 (100)
	Male				2 (16.67)	10 (83.33)	12 (100)
CVM 5	Female				5 (14.71)	29 (85.29)	34 (100)
	Male					10 (100)	10 (100)
CVM 6	Female					5 (100)	5 (100)
	Male					1 (100)	1 (100)
Total	Female	3	6	4	16	53	82
	Male	2	4	4	18	28	56

CVM: Cervical vertebral maturation

Table 5. The distributions between CVM stages and calcification stages of mandibular premolars; descriptive statistic was used

		Calcification stages, n (%)					
CVM stages		**D**	**E**	**F**	**G**	**H**	**Total**
CVM 1	Female	1 (20)	2 (40)	2 (40)			5 (100)
	Male	1 (20)		2 (40)	2 (40)		5 (100)
CVM 2	Female		2 (25)	4 (50)	2 (25)		8 (100)
	Male	1 (11.11)	3 (33.33)	2 (22.22)	3 (33.33)		9 (100)
CVM 3	Female		1 (7.69)	3 (23.08)	2 (15.39)	7 (53.85)	13 (100)
	Male		1 (5.26)	2 (10.52)	10 (52.64)	6 (31.58)	19 (100)
CVM 4	Female			1 (5.88)	8 (47.06)	8 (47.06)	17 (100)
	Male				7 (58.33)	5 (41.67)	12 (100)
CVM5	Female			1 (2.94%)	8 (23.53)	25 (73.53)	34 (100)
	Male				3 (30)	7 (70)	10 (100)
CVM6	Female					5 (100)	5 (100)
	Male					1 (100)	1 (100)
Total	Female	1	5	11	20	45	82
	Male	2	4	6	25	19	56

CVM: Cervical vertebral maturation

age regarding the assessment of the maturation status is ambiguous (25, 26).

Digital panoramic and cephalometric radiographs are used as routine diagnostic methods in orthodontic treatment. It is easy to assess dental maturation using digital panoramic radiographs (5, 18), and the DI could be used for evaluating the maturation of tooth calcifications (10). DI is based on shape criteria and the proportion of root length. In this study, DI stages of teeth were considered instead of eruption because calcification stages are anticipated as a more reliable criterion for assessing dental maturation (10).

The CVM method was used for evaluating skeletal maturity, as stated by Baccetti et al. (7), on lateral cephalograms. Researchers have found that CVM is an efficient method for assessing skeletal maturity (8, 18-21). In this study, skeletal maturation was evaluated using the method by Baccetti et al. (7) instead of the method by Hassel and Farman (8). The method by Baccetti et al. is the modified and refined version of the CVM and is valid for the appraisal of mandibular skeletal maturity in light of the findings of recent studies.

Kumar et al. (20) have revealed that each cervical stage consistently appears earlier in females than in males. These findings are similar to those of this study. In contrast, the association between CVM and DI is examined separately for male and female patients. Previous studies have shown that DI stages in male patients tend to be earlier than cervical stages in female patients (5,

Table 6. Correlation between the CVM, calcification of maxillary canine and second premolar, sex, and ages; Pearson correlation coefficients were performed

		max canine	mand canine	max premolar	mand premolar	sex	age
CVM	Pearson correlation	0.724**	0.692**	0.709**	0.649**	-0.262**	0.688**
	Sig. (two-tailed)	0.01	0.01	0.01	0.01	0.002	0.01
max canine	Pearson correlation	1.000	0.886**	0.911**	0.826**	-0.084	0.673**
	Sig. (two-tailed)		0.01	0.01	0.01	0.326	0.01
mand canine	Pearson correlation	0.886**	1.000	0.875**	0.785**	-0.046	0.589**
	Sig. (two-tailed)	0.01		0.01	0.01	0.595	0.01
max premolar	Pearson correlation	0.911**	0.875**	1.000	0.866**	0.020	0.595**
	Sig. (two-tailed)	0.01	0.01		0.01	0.818	0.01
mand premolar	Pearson correlation	0.826**	0.785**	0.866**	1.000	-0.003	0.601**
	Sig. (two-tailed)	0.01	0.01	0.01		0.976	0.01
sex	Pearson correlation	-0.084	-0.046	0.020	-0.003	1.000	-0.028
	Sig. (two-tailed)	0.326	0.595	0.818	0.976		0.739
age	Pearson correlation	0.673**	0.589**	0.595**	0.601**	-0.028	1.000
	Sig. (two-tailed)	0.01	0.01	0.01	0.01	0.739	

CVM: Cervical vertebral maturation; ** p≤0.01

20, 27, 28). It was also discerned that at the same cervical stage, male patients had more advanced trends in DI than female patients in this study.

According to the recent studies, the associations between the CVM indicator and maxillary and mandibular canine and second molar calcification are acceptable for both female and male patients; these teeth could be indicators for growth stages (19, 20). This finding of the present study is consistent with previous studies. Canines and second premolars can be used as indicators of skeletal maturation.

Obvious correlations were observed between the DI of canines and second premolars. Kumar et al. (20) have assessed the maturation stages of maxillary canines. They found that the DI Stage E of maxillary canines was essentially distributed for CVM2 and was indicative of growth status in the early stages (pre-pubertal; Stage F). However, in our study, the DI stages of maxillary and mandibular canines were between Stages G and F at CVM2 in the female group. It was found that mandibular and maxillary second premolars were in DI Stage E by the time CVM2 was reached. The highest distribution of Stage F at CVM2 was revealed at the pre-peak phase of the mandibular growth spurt. In this study, the Stage F calcification of the mandibular canine and second premolar coincided well with the CVM Stage 2. Džemidžić et al. (21) and Mittal et al. (29) have reported similar results in their studies. This means that the Stage F calcification of mandibular canines and second premolars could be used for assessing the pre-pubertal phase.

Kamal et al. (13) have reported that mandibular canines are in the DI Stages G and H by the time CVM3 was reached. They also pointed out that the second premolars were found to be in Stages F and G with CVM3. Mittal et al. (29) have found that the second mandibular premolars, which were in Stage F of the DI, corresponded to CVM3. In our study, the Stage G calcification of the second mandibular premolar was observed at CVM3 in male patients. Moreover, a high percentage was found in Stage H at CVM3 in the female group, whereas the DI Stage G was at CVM3 in the male group for maxillary canines. However, for female patients, the Stage H calcification of the mandibular canine showed the highest percentage of distribution at CVM3. These results comply and are parallel to the results obtained by Džemidžić et al. (21). In contrast, the calcification stages, which are advanced in this study compared with those in the previous studies, revealed that Stage F corresponded to CVM3 (18, 20, 27, 29). According to the method described by Baccetti et al. (7), growth at CVM3 is still accelerating toward peak velocity, whereas at CVM4, adolescent growth begins to decelerate. In this study, canine and second premolar root formation was complete (Stage H) in the majority of female patients at CVM3. Observing Stages G and H in CVM3 in children aged 7-9 years may be the result of precocious puberty. It is presumable that the reason for such precocious puberty is exposure to pharmacological insecticides and, especially for females, the use of cosmetic products (30).

Stage H calcification of maxillary and mandibular canines coincided well with CVM4, CVM5, and CVM6 for both sexes in our study. The DI Stage H suggests insignificant or no remaining adolescent growth. These results are consistent with the results of other similar studies (20, 21).

Uysal et al. (31) have argued that the second molar teeth were the most correlated teeth with the skeletal maturity stage in terms of calcification stage. They showed that the highest correlation was in the third molar teeth. However, the authors have suggested that completion of the mandibular canine and the first premolar root formation can be used as an indicator of maturity for a pubertal growth spurt. Krailassiri et al. (28) have demonstrated that the second premolar was the tooth showing the highest correlation with skeletal maturity. Trakinienė et al. (19) have found that maxillary canines and mandibular second molars and third mo-

lars were good predictors of the growth phase. Our findings corresponded with the findings of other studies: the mineralization stages of canines and second premolars were a good predictor of skeletal maturity. In this study, a correlation was found between the calcification stages of canines and second premolars.

Determination of the pubertal growth stage is very important for planning orthopedic force application. Functional appliances could have a greater skeletal effect when they are used in this period, whereas they have greater dental changes after the growth has ended. In this study, canine maturation occurred earlier in female patients than in male subjects. In addition, studies have revealed that the relationship between the dental calcification stages and skeletal maturity indicators in patients with cleft lip palate may potentially allow determination of the stages of the pubertal growth period on panoramic radiograph; the findings of this study can be used in such patients in the future (32, 33).

Numerous studies have been performed to determine the reliability of the DI for Turkish children in different regions of Turkey. Özveren and Serindere (13) have studied in the Aegean region of Turkey; Sen Tunç and Koyutürk (34) have studied in Northern Turkey; and Çelikoğlu et al. (14) have studied Eastern Turkey; thus, they have stated that DI may not be suitable for Turkish children in the specific regions. However, Apaydın and Yaşar (15) have shown that DI is appropriate and recommended for Turkish children ranging in age from 5 to 15 years. Our study was conducted in Turkey's largest city; it is not representative of any ethnic regions.

This study was limited by a number of factors, including a small number of patients and the limitations owing to the nature of DI. The DI is based on the shape and proportion of root length, using its relative value to crown height rather than its absolute length. Thus, the panoramic distortions of the developing teeth will not affect the reliability of estimation. Another limitation of DI is the tendency toward overestimation of a patient's age (35). It can be recommended that periapical dental radiograph could be used for evaluation of DI in future studies.

CONCLUSION

A significant correlation was found between the calcification stages of maxillary and mandibular canines and second premolars and skeletal maturity in both sexes. The calcification stages of maxillary and mandibular canines and second premolars showed a satisfactory diagnostic performance to assess skeletal maturity. The evaluation of sexes showed that females reach skeletal maturity earlier than males do.

The calcification stages of canines and second premolars had the highest distribution of Stages F and G at CVM2. This means that Stage F calcification of mandibular canines and second premolars could be used for assessing the pre-pubertal phase.

It was found that Stage H corresponds to CVM3 in female patients and a high percentage of Stage G corresponds to CVM3 in the male group.

Observing the DI Stage H at CVM4 demonstrated the deceleration of the pubertal growth spurt; CVM5 and CVM6 represented post-peak pubertal growth spurts. For both sexes, canine root formation was complete (Stage H) in the majority of patients at CVM5 and CVM6. This means that the majority of patients in this study were at precocious puberty. The findings of this study indicate that the time to commence orthodontic treatment might be earlier in female than in male patients. In contrast, owing to precocious puberty, orthodontic treatment can be started at the beginning of CVM2.

Ethics Committee Approval: The study was approved by the Clinical Sciences Ethical Board of Altınbaş University (Approval No: 2020/6).

Informed Consent: Written informed consent was obtained from the patients who agreed to take part in the study.

Peer-review: Externally peer-reviewed.

Author Contributions: Supervision – E.O., S.A.; Design – E.O, S.A.; Supervision – E.O., S.A; Resources – E.O.; Materials – S.A.; Data Collection and/or Processing – S.A..; Analysis and/or Interpretation – E.O.; Literature Search – E.O, S.A.; Writing Manuscript – E.O; Critical Review – S.A.

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