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Evaluation of The Relationship Between Dental and Cervical Vertebrae Maturation in Terms of Age Determination

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ABSTRACT

Aim: Age determination is a very important issue in anthropology, forensic science, and dentistry. Today, the most commonly used methods for age determination are the methods in which tooth and bone development are evaluated. This study aims to evaluate the relationship between gender, chronological age, dental maturation, and cervical vertebral maturation in individuals aged 8-25 years.
Material and Method: Digital panoramic, lateral cephalometric radiographs of 500 patients aged 8-25 years were used in this study. Cervical vertebra maturation was evaluated using the dental maturation-modified Demirjian classification system of Baccetti et al. Means, minimum, maximum, and standard deviations were calculated and analyzed as descriptive statistics. Kolmogorov-Smirnov, Kappa, Kruskal-Wallis, Chi-Square, Linear Regression, and Spearman Correlation tests were used for statistical analysis.
Results: There was a statistically significant difference between chronological age and dental maturation and cervical vertebral maturation levels ($p < 0.01$). While dental maturation levels did not differ significantly according to gender ($p > 0.05$), cervical vertebra maturation was statistically different ($p < 0.01$). There was a positive correlation between chronological age and dental maturation, and cervical vertebral maturation levels ($p < 0.01$). There was a strong correlation between dental maturation and cervical vertebral maturation levels ($p < 0.01$).
Conclusion: The findings of this study showed that skeletal maturity increased with the increase in chronological and dental age for both genders. The earlier formation was consistently observed for each stage of skeletal maturation in females. All correlations between skeletal and dental maturations were statistically significant.

Dental ve Servikal Vertebra Olgunlaşması Arasındaki İlişkinin Yaş Tayini Açısından Değerlendirilmesi

Makale Bilgisi

Makale Geçmişi

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Olgunlaşma,
Yaş Tayini.

ÖZET

Amaç: Yaş tayini antropoloji, adli bilimler ve diş hekimliğinde çok önemli bir konudur. Günümüzde yaş tayini için en sık kullanılan yöntemler diş ve kemik gelişiminin değerlendirildiği yöntemlerdir. Bu çalışmada 8-25 yaş arası bireylerde cinsiyet, kronolojik yaş, dental maturasyon ve servikal vertebral maturasyon arasındaki ilişkinin değerlendirilmesi amaçlanmıştır.
Gereç ve Yöntem: Bu çalışmada 8-25 yaş arası 500 hastanın dijital panoramik, lateral sefalometrik radyografileri kullanıldı. Servikal vertebra maturasyonu Baccetti ve arkadaşlarının dental maturasyon-modifiye Demirjian sınıflandırma sistemi kullanılarak değerlendirildi. Ortalama, minimum, maksimum ve standart sapmalar hesaplandı ve tanımlayıcı istatistikler olarak analiz edildi. İstatistiksel analiz için Kolmogorov-Smirnov, Kappa, Kruskal-Wallis, Ki-Kare, Lineer Regresyon ve Spearman Korelasyon testleri kullanıldı.
Bulgular: Kronolojik yaş ile dental olgunlaşma ve servikal vertebral olgunlaşma seviyeleri arasında istatistiksel olarak anlamlı bir fark vardı ($p<0,01$). Dental olgunlaşma düzeyleri cinsiyete göre anlamlı farklılık göstermezken ($p>0,05$), servikal vertebra olgunlaşması istatistiksel olarak farklıydı ($p<0,01$). Kronolojik yaş ile dental olgunlaşma ve servikal vertebral olgunlaşma seviyeleri arasında pozitif bir korelasyon vardı ($p <0,01$). Dental olgunlaşma ile servikal vertebral olgunlaşma seviyeleri arasında güçlü bir korelasyon vardı ($p <0,01$).
Sonuç: Bu çalışmanın bulguları, iskelet olgunluğunun her iki cinsiyet için de kronolojik ve dental yaşın artmasıyla birlikte arttığını göstermiştir. Kadınlarda iskelet olgunlaşmasının her aşaması için tutarlı bir şekilde daha erken oluşum gözlenmiştir. İskelet ve diş olgunlaşmaları arasındaki tüm korelasyonlar istatistiksel olarak anlamlıydı.

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INTRODUCTION

The human growth and development trend is often expressed in chronological age. However, studies have shown that individuals of the same chronological age show developmental differences. In particular, the growth and development stages of individuals are important in orthodontic diagnosis and treatment planning and forensic sciences. For this reason, it has become increasingly popular to determine growth and development according to the maturation stage of the body's hard tissues and organs.[1,2]

Age determination according to bone development is one of the most commonly used methods. Many factors such as endocrine disorders, congenital disorders, nutritional disorders, congenital syndromes, systemic disorders such as growth retardation, and environmental and geographical factors affect bone development. Due to their hard structure and low metabolic rate, teeth are less affected by these factors than other structures in the organism.[3] For this reason, data from teeth can give more accurate results compared to other tissues.[3]

Radiological examination plays a crucial role in the diagnosis of dental or forensic issues in dentistry.[4] The radiological methods used to determine the growth and development period are classified as panoramic, cephalometric, and hand-wrist radiographs.[5] Since the changes in teeth and bones belonging to each period can be easily observed in radiological images, this method is preferred more than other growth, development, and age determination applications[6]. In addition, radiological examinations are superior to biochemical and histological examinations because they are not invasive and do not damage the integrity of the material.[7] Recently, cone-beam computed tomography (CBCT) has allowed for the acquisition of sagittal, coronal, and axial images, furnishing dentists with valuable insights into the anatomical structure and developmental stages.[8-10] However, considering the radiation dose, it has been stated that 2-dimensional diagnostic radiographs can also provide necessary information.[11-13]

Studies have shown that growth and development differ according to ethnic groups. For this reason, researchers emphasized the importance of using data according to populations in age determination.[14] Therefore, this study aims to reveal the relationship between dental age and skeletal age using panoramic radiography. The goal is to determine the optimal timing for initiating orthodontic treatment, to assist in age determination in forensic sciences, to minimize time loss, and to avoid additional radiation exposure from procedures like cephalometric radiography.

MATERIAL AND METHOD

Ethical approval was obtained for this study from the Necmettin Erbakan University Faculty of Dentistry Review Board (2022/190) and the study was conducted according to the criteria specified by the Helsinki Declaration.[15]

In this retrospective investigation, lateral cephalometric and panoramic radiographs from the radiology archive of Necmettin Erbakan University Faculty of Dentistry, Department of Oral and Maxillofacial Radiology in Konya, Türkiye, were utilized. The study involved a total of 500 patients, comprising 304 females and 196 males, within the age range of 8 to 25 years, who were selected randomly.

The inclusion criteria for the study were as follows: participants should not have any systemic diseases, conditions affecting bone development, or malnutrition, and should exhibit normal growth and development, as evidenced by quality radiographs. Radiographs of individuals who had orthodontic treatment before and any anatomical deformation in their cephalometric radiographs were not included in the study. Birth dates, radiography and sex of all selected lateral cephalograms were recorded. The chronological age of each individual was obtained by subtracting the date of birth from the date the image was taken.

Lateral cephalometric and panoramic x-rays were consistently captured using a uniform method on the same device (Morita Veraviewepocs 3D R100-P, J Morita MFG Corp., Kyoto, Japan), operating at settings of 65 kVp, 7mA, and a duration of 7.4 seconds. These images were saved in the TIFF format, and anonymized to obscure the subjects' age and gender from evaluators. An experienced observer (G.M.), with a background of twelve years in the field, reviewed a set of 50 radiographs twice, spaced one month apart, using a computer equipped with an Intel® Xeon® i5 processor, 2.5 GHz; NVIDIA Quadro 2000; a display resolution of 1366 x 768 pixels, 4 GB of RAM, and running on Microsoft Windows 10.

The CVM stages 1 to 6 on cephalometric X-rays, based on Baccetti et al.'s [16] system. This focuses on the shape and concavity of the lower borders of the second to fourth cervical vertebrae (C2-C4). Briefly, stages 1 and 2 feature flat and concave lower borders in C2-C4 with trapezoidal C3 and C4. In stages 3 and 4, concavities appear in C2-C4, with varying shapes from trapezoidal to rectangular. Stages 5 and 6 show concavities in all vertebrae, with C3 or C4 being either square or rectangular.

In the evaluation of radiographs, based on the classical method published by Demirjian et al.[17] in 1973, which is divided into 8 stages from A to H (stages A-D, crown development, E-H root development, stages 0 and 1 are added. The modified Demirjian method was used.[18]

For the statistical evaluation, various methods were employed, including Descriptive Statistics, Cohen's Kappa, the Kolmogorov-Smirnov test, the Chi-square test, the Mann-Whitney U test, and Linear Regression analysis. The analyses were conducted using SPSS version 22.0 by IBM, located in Armonk, NY, USA. A significance threshold was established at a p-value of 0.05.

RESULTS

Table I presents the average chronological and dental ages of patients at each stage of CVM, broken down by gender. Additionally, this table includes the distribution frequency of patients across the various CVM stages. Notably, the largest concentration of patients was observed in stages CVM5 and CVM6.

While DM levels did not differ statistically by gender (p>0.05) (Figure 1), CVM was statistically different (p<0.01) (Figure 2). The frequency of CVM 3, 5, and 6 was more predominant in females (Figure 2).

Figure 1. The distribution of Demirjian dental maturation levels according to gender and age.

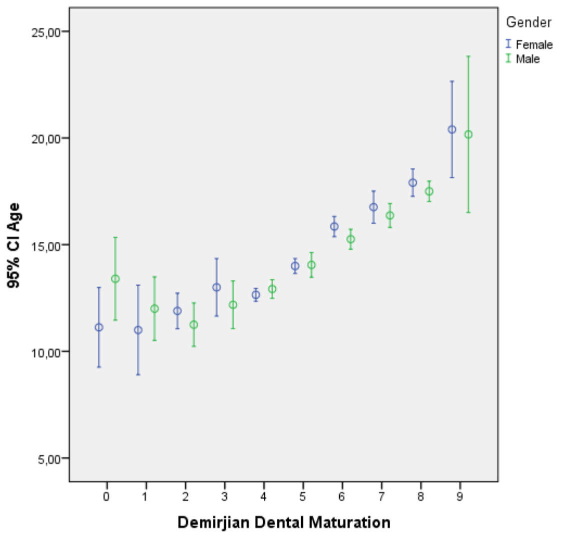

Figure 2. The distribution of cervical vertebrae maturation levels according to gender and age

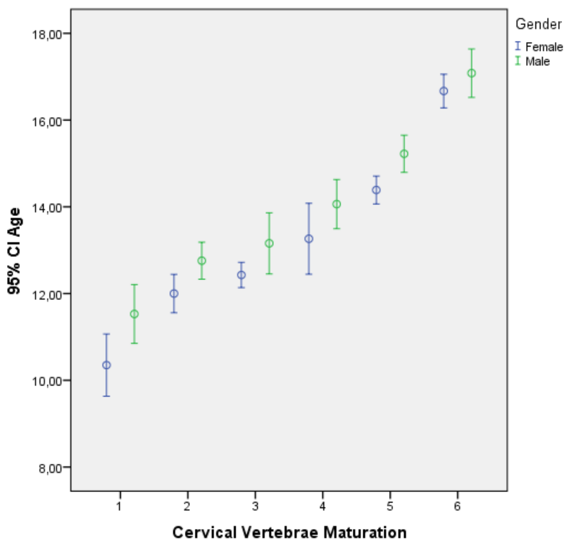

Table 1. The mean chronological age and dental age of patients at each cervical vertebra maturation (CVM) stage separately for females and males

CVM		Female		Male		Total	
		Number	Mean	Number	Mean	Number	Mean
CVM1	Chronological age	20(37.0%)	10.35±1.53	34(63.0%)	11.52±1.94	54(100.0%)	11.09±1.87
	Dental age		12.00±1.69		12.35±1.47		12.22±1.55
	Difference of chronological and dental age		0.14±0.051		0.13±0.044		0.13±0.047
CVM2	Chronological age	29(46.8%)	12.00±1.16	33(53.2%)	12.76±1.20	62(100.0%)	12.40±1.23
	Dental age		13.46±1.22		13.44±1.18		13.44±1.19
	Difference of chronological and dental age		0.101±0.02		0.10±0.02		0.101±0.02
CVM3	Chronological age	35(64.8%)	12.42±0.85	19(35.2%)	13.15±1.46	54(100.0%)	12.68±1.14
	Dental age		13.33±1.25		13.81±1.22		13.50±1.25
	Difference of chronological and dental age		0.10±0.038		0.09±0.023		0.10±0.033
CVM4	Chronological age	19(54.3%)	13.26±1.69	16(45.7%)	14.06±1.06	35(100.0%)	13.62±1.47
	Dental age		14.05±1.11		13.63±1.89		13.86±1.51
	Difference of chronological and dental age		0.09±0.017		0.11±0.048		0.10±0.035
CVM5	Chronological age	98(68.5%)	14.38±1.60	45(31.5%)	15.22±1.42	143(100.0%)	14.65±1.59
	Dental age		14.36±1.29		14.85±1.66		14.52±1.43
	Difference of chronological and dental age		0.09±0.024		0.10±0.036		0.09±0.029
CVM6	Chronological age	103(67.8%)	16.66±1.98	49(32.2%)	17.08±1.94	152(100.0%)	16.80±1.97
	Dental age		15.62±1.29		16.00±1.75		15.74±1.46
	Difference of chronological and dental age		0.11±0.031		0.12±0.037		0.11±0.034
Total	Chronological age	304(60.8%)	14.37±2.56	196(39.2%)	14.33±2.56	500(100.0%)	14.35±2.56
	Dental age		14.41±1.66		14.27±2.00		14.35±1.80
	Difference of chronological and dental age		0.10±0.033		0.11±0.039		0.10±0.035

As shown in Table I, dental age was higher than chronological age between CVM 1 and 4 in females, while CVM was higher between 1 and 3 in males. The largest difference between chronological age and dental age in males and females was recorded in CVM1.

Table 2 shows the relationship between age, CVM, and DM levels as assessed by the Spearman correlation test. According to this test, correlations between all parameters were statistically significant ($p<0.01$). As shown in Table II, the highest correlation was found between CVM and chronological age. The correlation coefficient between CVM and DM was also found to be 0.659. In addition, the correlation coefficient of the relationship between chronological age and DM was 0.744.

While there was a very high correlation (0.814) between CVM and chronological age in males, this value was 0.794 in females. Correlations between CVM and dental age were high in both genders (Table 2).

Table 2. The relationship between age, cervical vertebra maturation (CVM), and dental maturation (DM) levels as assessed by the Spearman correlation test

CVM		CVM	Dental Age	Chronological age
Spearman's rho	Correlation coefficient	1,000	0.659**	0.786**
	Number	500	500	500
Female	Correlation coefficient	1,000	0.636**	0.794**
	Number	304	304	304
Male	Correlation coefficient	1,000	0.695**	0.814**
	Number	196	196	196

The correlations between dental age and chronological age according to CVM stages for males and females separately are shown in Table 3. Accordingly, the strongest correlation was seen in the CVM2 stage (0.617) in males. In females, the strongest correlation was in CVM 4 stage (0.633). The correlation between dental age and chronological age in males was weakest (0.115) at CVM4, while it was weakest at CVM3 (0.097) in females.

Table 3. The correlations between dental age and chronological age according to cervical vertebra maturation (CVM) stages for males and females separately

				Dental Age
Female	CVM1	Chronological age	Spearman's correlation	0.503*
			Number	20
	CVM2	Chronological age	Spearman's correlation	0,252
			Number	29
	CVM3	Chronological age	Spearman's correlation	0,097
			Number	35
	CVM4	Chronological age	Spearman's correlation	0.633**
			Number	19
	CVM5	Chronological age	Spearman's correlation	0.580**
			Number	98
	CVM6	Chronological age	Spearman's correlation	0.629**
			Number	103
Male	CVM1	Chronological age	Spearman's correlation	0,252
			Number	34
	CVM2	Chronological age	Spearman's correlation	0.617**
			Number	33
	CVM3	Chronological age	Spearman's correlation	0.476*
			Number	19
	CVM4	Chronological age	Spearman's correlation	0,115
			Number	16
	CVM5	Chronological age	Spearman's correlation	0.471**
			Number	45
	CVM6	Chronological age	Spearman's correlation	0.574**
			Number	49

DISCUSSION

Various research has been carried out globally to identify growth, development, and age estimation. A significant correlation has been observed between skeletal, sexual, and somatic growth stages. However, there is a lack of studies that link dental maturity (DM) with skeletal development.[17] This prompted our investigation into the connection between CVM and DM stages within the Turkish population.

Panoramic radiographs are a common tool in dental practices. The DM assessment technique, as proposed by Demirjian[17], focuses on the teeth's calcification stages, examining the shape and proportion of the teeth's root length. This approach minimizes the impact of radiographic projection. On the other hand, cephalometric radiographs, essential for CVM assessment, are not typically used due to the additional radiation exposure they entail. Thus, understanding the relationship between CVM and DM becomes crucial. Should a positive correlation be established, patients could potentially use a single, routinely conducted panoramic radiograph for predicting skeletal maturation stages. This would serve as a safer alternative to other methods that involve higher radiation exposure.

According to the CVM method, it was stated that the pubertal growth spurt occurred between CVM3 and CVM4.[16] At the CVM3 stage in this study, the mean chronological age was 12.42 ± 0.85 in girls and 13.15 ± 1.46 in boys. These findings were consistent with the age of onset of pubertal growth spurt for adolescents in the literature.[19-21] The mean chronological age in girls was lower at each CVM stage. This indicates that, within the measured age range and the preferred vertebral framework, girls are more mature than boys. These findings are consistent with previous studies that found differences in skeletal maturation by gender.[19,21] Consistent with our previous study[22], no significant difference was found between DM and gender in this study ($p<0.05$).

In the present study, we observed significant correlation coefficients between CVM and chronological age, with values of 0.814 for males and 0.794 for females. These findings suggest a potential variance between skeletal maturity and chronological age. Notably, in females, the link between skeletal and chronological ages was more pronounced than the correlation between skeletal age and dental age. Literature typically reports positive correlations among chronological age, dental age, and skeletal age. In a study which conducted in 2006[23] conducted on a similar population to ours indicated a lower correlation coefficient of 0.720 between chronological age and CVM, compared to our finding of 0.786. Contrastingly, the study by Al-Balbeesi et al.[24] highlighted a stronger relationship between chronological age and CVM, especially in females. However, current study found a more significant correlation in males.

The literature contains few studies that examine the connection between the maturation of third molars and skeletal development stages. Cho and Hwang[25] observed a marginally stronger association between skeletal maturation and the Demirjian index (with a correlation coefficient of 0.640) compared to the correlation between CVM and DM, which was 0.590. This is in line with the findings of Chertkow and Fatti[26], Engstrom et al.[27], and Krailassiri et al.[28]. However, this differs from the results of Uysal et al.[23], who identified a weak link between the development of the third molar and skeletal maturation. In a 2016 study involving Indian individuals aged 9 to 14, researchers found correlations of 0.683 in males and 0.704 in females between dental and skeletal ages.[29] In agreement with these findings, our study also recorded a high correlation between CVM and DM, with a correlation coefficient of 0.659.

In present study, a stronger relationship was observed between dental age and chronological age at the CVM2 stage for males and at the CVM4 stage for females. Rozylo-Kalinowska et al.[19] identified the highest correlation between dental and chronological ages at the CVM1 stage for both genders. Litsas and Lucchese[30], in 2016, noted the strongest link between chronological and dental ages for both males and females at the CVM4 stage. Conversely, Mollabashi et al.[31]. discovered a more pronounced correlation at the CVM5 stage for males and the CVM4 stage for females. The variability in these results across different studies could potentially be attributed to ethnic variations.

Consistent with our results, the literature shows a strong correlation between DM and CA.[32-35] The correlation coefficient was 0.744. In a study that included Hispanic individuals aged 4-13 in 2020, a very high correlation was found between dental age and chronological age ($r = 0.86$).[36] In a study evaluating the third molar teeth of 832 Turkish individuals aged 6-16 years in 2013 [37], a correlation coefficient of 0.63 and 0.61 was found between DM and age in males and females, respectively. In another study conducted in a Turkish population[38], a correlation coefficient of 0.77 in males and 0.69 in females was found between age and DM.

The limitations of the study are that factors such as climate, environment, ethnic diversity, socioeconomic status, genetics, and hormones, which are effective on the growth of children, were not evaluated in this study. Another limitation is that this study was conducted in only one subpopulation of Türkiye. Therefore, further research on a larger sample with new population groups is needed. Additionally, a limitation that can be added is that the radiographic images included in the study were obtained from a single brand of device.

CONCLUSION

The findings of this study showed that skeletal maturity increased with the increase in chronological and dental age for both genders. Earlier formation was consistently observed for each stage of skeletal maturation in females. All correlations between skeletal and dental maturations were statistically significant. Although a strong relationship between skeletal and dental age has been reported, it cannot be considered the only reliable indicator for evaluating growth. However, dental calcification stages can be useful in addition to skeletal maturity in assessing an individual's growth. More research is needed to reach stronger results.

Acknowledgment

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Ethical Approval

The required ethical approval for this study was received by Necmettin Erbakan University Non-Pharmaceutical and Medical Device ethics committee (2022/190).

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Conflict of Interest

The authors declare that they have no competing interests.

Author Contributions

Design: GM, Data collection or data entry: GM, Analyzing and interpreting: GM, Literature review: GM, Writing: GM.

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