Comparison of age estimation between 15–25 years using a modified form of Demirjian's ten stage method and two teeth regression formula

Amiroh, M Priaminiarti* and S I Syahraini

Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Universitas Indonesia, Jakarta, Indonesia

*E-mail: menikneidy@yahoo.com

Abstract. Age estimation of individuals, both dead and living, is important for victim identification and legal certainty. The Demirjian method uses the third molar for age estimation of individuals above 15 years old. The aim is to compare age estimation between 15–25 years using two Demirjian methods. Development stage of third molars in panoramic radiographs of 50 male and female samples were assessed by two observers using Demirjian's ten stages and two teeth regression formula. Reliability was calculated using Cohen's kappa coefficient and the significance of the observations was obtained from Wilcoxon tests. Deviations of age estimation were calculated using various methods. The deviation of age estimation with the two teeth regression formula was ±1.090 years; with ten stages, it was ±1.191 years. The deviation of age estimation using the two teeth regression formula was less than with the ten stages method. The age estimations using the two teeth regression formula or the ten stages method are significantly different until the age of 25, but they can be applied up to the age of 22.

1. Introduction

Indonesia is prone to both natural disasters and human-caused disasters. Disasters that occur in Indonesia often cause a large number of fatalities [1]. People who die in a disaster are often found in unrecognizable circumstances. In Law No. 36, Year of 2009, Article 118, Clause 1 on Health, it was mentioned that the government and society should make efforts to identify unidentified corpses [2-3]. One important part of the process of individual identification is age estimation. Age estimation is performed not only on individuals who have died but also in living individuals. In Indonesian law, the age of the living individual is very important to identify because it could affect a person's status before the law. Within the age range of 15 to 25 years are limits affecting the status of citizens in Indonesian law in areas such as marriage law, the juvenile justice system, age restrictions of athletes who can participate in national sport competitions, and many more. Some of the body parts that can be identified for the age estimation are teeth and skeletal samples.

Age estimation using teeth can be done biochemically, histologically, clinically, and radiographically. In the radiographic method, information about the root resorption stage of a deciduous tooth, tooth calcification, and permanent dental eruption can be obtained; therefore, dental age can be predicted either through development from dental eruption or with scores of crown development and root of the tooth in radiograph [4-5]. Panoramic radiographs are the most commonly used radiographs in age estimation. Through panoramic radiographs, the stage of development of teeth can be obtained, from

the initiation or crypt stage until the teeth are formed perfectly (root apical closed). Not only that, panoramic radiographs are often used to examine third molars for consideration of whether they should be removed or not [6]. In forensic dentistry, there are two age estimation techniques with radiographic methods: atlas technique and scoring technique. Estimation of age with atlas techniques uses a radiograph that shows dental development, which is then compared with a published standard. In the scoring technique, the development of the tooth is divided into various stages, which are then converted into scores that are evaluated with statistical analysis [7]. The estimation of age by scoring techniques is done with the Demirjian method, found by Demirjian *et al.* (1973).

Initially, the Demirjian method was not performed using third molar teeth, but using eight stages (A-H) of development of seven mandibular left teeth (Demirjian *et al.*, 1973). In 1993 it was recommended by the American Board of Forensic Odontologists (ABFO) (Mincer *et al.*, 1993) and applied in many studies that used third molars [8]. In the study, it was mentioned that root formation in men progressed earlier than women, and the use of two upper and lower third molars resulted in a more accurate age estimation than only one tooth. The third molars are the teeth that still develop in adolescents and young adults. By an average age of 15 and 16 years, all permanent teeth have been completed except the third molar. The third molar teeth begin to grow their buds at the age of ±9 months, start to erupt at the age of 17–21 years, and no longer develop past the age of 25 years [9].

Later, modifications of the Demirjian stages were also developed by various investigators, including Solari and Abramovitch. In 2002, Solari and Abramovitch added the final stages of development that were F1 and G1, so there were ten Demirjian stages [10]. In Indonesia, there has not been much research on the accuracy of modified Demirjian methods as a tool for age estimation. Previous research has been done by Firdaus on the Indonesian population, estimated ages 8–25 years, based on the stage of calcification of third molars. The result obtained was a regression relationship modeling the addition of four third molars, three third molars, two third molars, and one third molar for the estimated age of the Indonesian population [11]. The purpose of this study was threefold: to compare age estimation in the 15–25 year range using modification of the Demirjian ten stages and two teeth regression formula; to know the magnitude of deviations of the results of age estimation in the 15–25 year range using both methods; and to know the difference in age estimation between men and women in individuals with an age range of 15–25 years**.**

2. Materials and Methods

This study used 100 panoramic radiographs, consisting of 50 panoramic radiographs from male patients and 50 from female patients. The panoramic radiographs were derived from patients at the Teaching Hospital Faculty of Dentistry Universitas Indonesia with an age range of 15–25 years. Inclusion criteria were good quality radiographs, at least two third molar teeth on one side (right or left), and records of the patient's date of birth and sex and the date of the radiograph's manufacture. Panoramic radiographs with images of three superimposition molars, with rotated third molars, and with the presence of anomalies or other abnormalities in third molars were not selected for this study. The design of this research was analytical cross-sectional study. Independent variables in this study were the modification method of the Demirjian ten stages and two teeth regression formula, while the dependent variable was age.

Research samples were selected from the medical records of Teaching Hospital Faculty of Dentistry Universitas Indonesia. Samples were then grouped by age and gender, which were known from the medical record data. For the next step, panoramic radiographs were scanned using a UMAX PowerLook 1120 scanner (maximum resolution 9600 dpi). Determination of developmental stages of third molars by comparing eight stages of development of third molars (two teeth regression formulas) with ten stages of Demirjian (as modified by Solari and Abramovitch) was performed from the scanned images by two observers using the Microsoft Office 2010 program. From the observation results between two observers, the Cohen's kappa coefficient test was done; a kappa value of >0.81 showed agreement between observers. The observations were then placed into the age estimation calculations using both methods, and the results were then compared with chronological age. A Kolmogorov-Smirnov test and

Saphiro Wilk test were performed to determine the normality of data distribution. To see whether or not there was a significant difference between chronological age and chronological age estimation, a paired t test was used for normal data distribution, whereas if abnormal data distribution was found, the Wilcoxon test would be used.

3. Results and Discussion

3.1 Results

The distribution of age and gender from the radiographs' sample is shown on Table 1. The kappa score of the intraobserver reliability test for determination with eight stages of third molar development was 0.830, while the one for ten stages was 0.907. The kappa score of the interobserver reliability test for determination with eight stages of third molar development was 0.869, while the one for ten stages was 0.863. All kappa scores were above 0.81, so it was concluded that interrater agreement was good (Table 2). Results from Kolmogorov-Smirnov normality test of chronological age data from 15–25 years showed abnormal data distribution, so the later statistical analysis was used with a nonparametric test, which was the Wilcoxon test.

Table 1. Distribution of samples' age and gender

Age	Gender		Total
	Male	Female	
15	6	8	14
16	2	2	4
17	2	2	4
18	3	6	9
19	7	4	11
20	2	4	6
21	3	5	8
22	6	7	13
23	13	4	17
24	4	4	8
25	2	4	6
Total	50	50	100

Table 2. Kappa scores of intra- and interobserver tests for third molar developmental stages with Demirjian method

Stages	Kappa *Intraobserver* score	Kappa *Interobserver* score
Eight stages	0.830	0.869
Ten stages	0.907	0.863

Table 3. Nonparametric Wilcoxon test results (chronological age 15–25 years)

Wilcoxon test	p-value
CA vs EA M8	0.008
CA vs EA F8	0.031
CA vs EA MF8	0.001
CA vs EA M10	0.016
CA vs EA F10	0.024
CA vs EA MF10	0.001

CA: Chronological Age, EA: Estimated Age, M: Male, F: Female, 8: third molar developmental stages — 8 stages, 10: third molar developmental stages — 10 stages

The results of the Wilcoxon test in Table 3 showed that there was a significant difference between chronological age and estimated age of male, female, and combined sex groups, using either eight stages or ten stages of development of third molars, due to p-value < 0.05. Because the results were significantly different for the chronological ages of 15–25 years at eight and ten stages of development of third molars, the researchers tried to do a Wilcoxon test on the data for subjects with chronological ages only up to 22 years. A normality test was done beforehand for data related to subjects aged 15–22 years. Kolmogorov-Smirnov and Saphiro Wilk normality test result from all chronological age data in the 15–22 year range still showed data that was not normal, so for this data a nonparametric Wilcoxon test was performed.

Table 4. Wilcoxon nonparametric test result (chronological age 15–22 years)

Wilcoxon test	p-value
CA vs EA M 8	0.153
CA vs EA F 8	0.602
CA vs EA MF 8	0.126
CA vs EA M10	0.290
CA vs EA F 10	0.627
CA vs EA MF 10	0.176

CA: Chronological Age, EA: Estimated Age, M: Male, F: Female, 8: third molar developmental stages — 8 stages, 10: third molar developmental stages — 10 stages

Table 4 showed that there was no significant difference between chronological age and estimated age of male, female, or combined sex groups using either eight stages or ten stages of development of third molars because the p-value > 0.05.

3.1.1. Comparison of Estimated Age Deviation with the Eight Stages and Ten Stages of Third Molar Development (Two Teeth Regression Formula).
To compare the age estimation results between the two methods, a calculation of deviations from the age estimation results was done by finding the difference or delta (Δ) of each of the eight stages or ten stages age estimates.

Table 5. Comparison of estimated age deviation using demirjian method with eight stages and ten stages (Chronological Age 15–25 years)

	Third Molar Developmental Stages	
	Eight stages	Ten stages
Mean Deviation	±1.090	±1.191

Table 6. Comparison of estimated age deviation between male and female samples using demirjian method with eight stages and ten stages (chronological age 15–25 years)

	Mean Deviation	
	Male	Female
Eight stages	±1.328	±0.852
Ten stages	±1.247	±1.135

In Table 5, the calculation result showed the mean deviation using eight stages was ±1.090 years and using ten stages was ±1.191 years. The final result of the calculation of the deviation in male subjects was ±1.328 years for eight stages and ±1.247 years for ten stages, while in female subjects the deviation was ±0.852 years for eight stages and ±1.135 years for ten stages, as shown in Table 6.

3.2 Discussion

To test the accuracy of the data in studies using radiographs, interobserver agreement testing was always done. In this study, the assessment of the development of third molars on the panoramic radiograph was performed by two observers during two different time spans. Later, reliability testing using Cohen's kappa coefficient test was done to find both intra- and interobserver agreement. The kappa test result for intraobserver testing of eight stages of development of molar three using the Demirjian method was 0.830, and for ten stages it was 0.907. Meanwhile on the interobserver test, the kappa value for the eight stages of third molar development was 0.869, and for ten stages it was 0.863. In this study, all of the kappa values were more than 0.81, leading to the conclusion that the agreement between the observers was very good.

After kappa tests were performed, a Kolmogorov-Smirnov normality test was done to see the distribution of data. In the normality test with chronological age data of 15–25 years using either eight stages or ten stages, all data had p-value <0.05, so the data distribution was not normal. Because the data was not normally distributed, a nonparametric test was performed, which was the Wilcoxon test [12]. As shown in Table 4, the significance value obtained from the Wilcoxon test on the age estimation from eight stages of third molar development was 0.008 in the males, 0.031 in females, and 0.001 on the combined data of both male and female. This showed that there was significant difference between chronological age and estimated age from assessment of eight stages of third molar development in the male, female, and sex-mixed subjects. The significance value obtained from the Wilcoxon test results on the estimated age from ten stages of third molar development was 0.016 in males, 0.024 in females, and 0.001 in the combined subjects. Based on these results, there was significant difference between chronological age and estimated age from assessment of ten stages of third molar development in each sex or in the combined data.

Based on the results of the Wilcoxon test above, all methods using either eight stages or ten stages showed significantly different results, which means the accuracy of the use of the Demirjian method for eight stages and ten stages in the age range 15–25 years was still low. This was in accordance with the results of Solari and Abramovitch's research in 2002 in Hispanic populations, which stated that the age estimate could not be done after the teeth have reached stage H and the apex has been closed, and the average age of stage H is 20.5 years with a standard deviation of ±1.5 years. As a consequence, the maximum recommended age was not more than 22 years [12]. This was also in accordance with results obtained in this study in samples with chronological age over 22 years; on average, they were all already in stage H, which means the root canal had been completely closed. Based on previous research, the average third molar growth of Indonesians ended at ages of 22 and 23 years, and the highest limit of estimation obtained in the two teeth regression formula was 22.334 years and in the Demirjian ten stages was 21.7 years with the standard deviation 1.8 years, while more of the data in this study came from subjects with ages above 22 years [10-11]. Therefore, the researchers did the calculation once more by limiting the chronological age range to only 15–22 years. The normality test was done beforehand using Kolmogorov-Smirnov and Shapiro Wilk tests. Normality test results of all the sexes on the eight-stage or ten-stage data also had p-value <0.05, which means the distribution of data was not normal.

In the Wilcoxon test results (Table 6), the significance values obtained at the estimated age with eight stages of third molar development was 0.153 in males, 0.602 in females, and 0.126 in the combined data. From these results, it could be seen that there was no significant difference between chronological age and estimated age of development of an eight-stage third molars in all sexes and combined data. The significance value obtained from the Wilcoxon test results on the estimated age of development of third molars with ten stages is 0.290 in males, 0.627 in females, and 0.176 in the combined data. Based on these results, it could be seen that there was no significant difference between chronological age and the estimated age from ten stages of development of third molars in all sexes and combined data, and it can be concluded that the accuracy of the Demirjian method for eight stages and ten stages was preferred at the age limit of 22 years.

Furthermore, calculations of deviation in all methods, either eight stages or ten stages, were done and then compared with each other. The result of age estimation using the Demirjian method was obtained; the mean deviation using eight stages was ±1.090 years and using ten stages was ±1.191 years. Based on these calculations, it can be concluded that the deviation of age estimation with ten stages was smaller than the eight stages' deviation. However, the difference of deviation between eight stages and ten stages was not much, only ±0.101 years. So, for its application in Indonesia, it was suggested to use a two tooth regression formula (with eight stages of development of third molars), since the usage was simple and deviation value was quite low.

In its application, the 1-year chronological age difference is very significant for laws requiring the determination of the age limit for adults and children, for example in Law No. 11, Year of 2012, Article 1, Clause 3 about the criminal justice system. Therefore, regarding the value of deviation, in determining age estimation more than one method should be used, to add confidence in legal certainty. Based on Willems *et al.*, an important aspect in age estimation was that investigators should use several different techniques and take repeated measurements to improve the reproducibility and reliability of estimated age [13]. Further research is needed with larger sample sizes in each age range and also for the accuracy of age estimation using the Demirjian method which compares panoramic radiographs and periapical radiographs.

4. Conclusion

In this research, the deviation of age estimation using the eight stages Demirjian method (two teeth regression formula) was smaller than with ten stages. The deviation value of female samples is less than male, using either the two teeth regression formula or ten stages. In this study, it can also be concluded that the result's accuracy for samples over the age of 22 years was low in both methods. Estimated ages within the range of 15–25 years were significantly different from chronological age, while age estimation within the range of 15-22 years was not significantly different statistically. So, it can be concluded that the two teeth regression Demirjian method and the ten stages method could be primarily used in samples with estimated ages of 15-22 years. It can also be concluded that the eight stages two teeth regression Demirjian method was preferred because it is simpler and has lower deviation, although further research has to be done with larger sample sizes.

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