Age estimation of 8- to 25-year-olds based on third molar calcification using the Demirjian method in an Indonesian population

Firdaus¹, R Puspitawati¹* and B Nehemia²

¹Department of Oral Biology, Faculty of Dentistry, Universitas Indonesia, Jakarta, 10430, Indonesia
²Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Universitas Indonesia, Jakarta, 10430, Indonesia

*Email: rpuspitawati2013@gmail.com

Abstract. Age estimation of adolescents and young adults is important both legally and medicolegally. During this age period, only the third molars are still in development. We aimed to determine the correlation between chronological age and third molar development in an Indonesian population using the Demirjian method. The sample consisted of 407 panoramic radiographics obtained from Indonesians aged between 8 and 25 years. Statistical analysis used a Pearson correlation test, and regression analysis was performed to obtain the regression formula to calculate the age estimation. The result of Pearson correlation test showed a strong correlation (p>0.75) between each third molar and age (p<0.05). Regression correlations obtained included the sum model of four third molars, three third molars, two third molars, and one third molar. There was a very strong correlation between chronological age and third molar development in the Indonesian population.

1. Introduction

In forensics, age estimation is often performed on living individuals as well as unidentified bodies. Identification of corpses is required in cases of massive disasters such as earthquakes, tsunamis, and the eruption of volcanoes such as Mount Merapi that claimed many victims. Unidentified corpses are also found in criminal cases such as terrorism, murder, and persecution. Constitution no 36 year 2009, article 118, section 1 regulated about health, states that every effort must be made to identify unidentified corpses [1].

Individual identification can be performed using two identification methods, namely, primary and secondary identification. Primary identification methods include fingerprint, DNA, and dental examination, whereas secondary identification is used to identify the individual through age, race, gender, skin color examination, and other identifications.

In living individuals, age estimation is required for legal certainty, trust right, insurance, marriage, age determination of athletes, possession of identity card, and age determination of legal liability [2,3].
In individuals over 13 years old, age estimation can be performed by various methods such as morphological changes to teeth (Gustafson method) and dental pulp chamber changes (Kvaal and TCI method) [4,5]. Several age estimation methods using the development of the third molar can be classified into three methods [2,6]. The first is the Demirjian method, which is based on the formation of the crown and root of the first incisors into the second molars. Because this method can only be applied in individuals aged 13 years and older, Sisman et al. Liversidge et al. and Ajmal et al. extrapolated and applied the Demirjian method to the third molars by categorizing the developmental stages of third molars, starting from the formation of the crown to the root canal closure [7]. The second method was proposed by Olze et al. and is based on the eruption of the third molar through the alveolar bone [8]. This method observes the position of the third molar through the alveolar bone until complete eruption reaches the occlusal plane. This method is simpler than the third molar crown and root development but is influenced by dental morphology, position, age variation of third molar eruption, and crowding teeth conditions [8]. The third method was proposed by Thevissen et al. and is based on the addition of the root length of the third molars. It measures the root length of the second and third molars using dental radiography [9].

One of the limitations of age estimation methods using third molars as an indicator in individuals aged 13 years and over is the high frequency of variations position, age, eruption, and morphology of these teeth. It is known that growth and tooth development is influenced by nutritional intake and gender. Another consideration that often occurs in the identification process, both in live individuals and corpses, is the high frequency of incomplete third molars on the upper and lower jaws, due to tooth extraction, impaction, or absence of third molar buds (agenesis) [10,11].

Racial and ethnic factors affect the growth and development rate of third molars and their eruption age. Furthermore, some studies using the Demirjian method have shown differences in development time of the third molar in the Negroid, Caucasian, and Mongoloid populations [10,12,13].

2. Methods
This cross-sectional study was a descriptive analysis of the relationship between the calcification stage of the third molars and chronological age using panoramic radiography. Inclusion criteria were Indonesian individuals undergoing panoramic radiography who were between 8 and 25 years old. Good quality panoramic radiography criteria included upper and lower molar teeth balanced in mesiodistal dimensions, clear radiograph images, and visible supporting alveolar bone. The third molars were present in a sample of panoramic radiographs. Records of date of birth, gender, and date the photo was taken were available. The exclusion criteria were panoramic radiograph that could not be assessed because of superimposition of the third molar with other teeth or rotation of the third molar and distorted radiographs.

The total number of samples collected in this study was 407, consisting of 185 males and 222 females from an Indonesian population. Figure 1 shows the composition of the following tribes included in this study.
The Demirjian method used in this study the third molars and categorized the growth of the crown and root of third molar into eight stages of calcification, from A to H (table 1 and Figure 2).

Figure 1. Sample distribution of tribes in Indonesia involved in this study.

| Stage | Description |
|-------|-------------|
| A     | Initial calcification of teeth, fusion has not yet formed. |
| B     | Calcification of occlusal points along with fusion of calcification of other parts. |
| C     | Crown formed halfway. |
| D     | Crown formation is complete up to the cemento–enamel junction. |
| E     | Length of tooth roots is shorter than the crown. |
| F     | Length of tooth roots exceeds the height of the crown. |
| G     | Root formation is complete but apical foramen still open. |
| H     | Apical foramen are closed. |

Table 1. Stages of calcification of third molar based on application of the Demirjian method [13].
3. Results

The distribution pattern of the average age in the Indonesian population was obtained as shown in Table 2.

| M₃ Development Stages | Min. age (y) | Max. age (y) | \( \bar{x} \) | SD |
|-----------------------|--------------|--------------|--------------|----|
| A                     | 9.02         | 11.57        | 9.56         | 2.70 |
| B                     | 9.06         | 11.75        | 10.01        | 1.5 |
| C                     | 10.09        | 12.93        | 11.12        | 1.03 |
| D                     | 10.12        | 16.22        | 12.26        | 1.4 |
| E                     | 11.32        | 18.43        | 14.00        | 0.73 |
| F                     | 14.10        | 20.94        | 16.92        | 0.47 |
| G                     | 15.77        | 23.04        | 19.61        | 0.42 |
| H                     | 20.04        | 25.73        | 23.25        | 0.57 |

M₃, third molar
Table 2 shows the chronological age that was estimated on the basis of the calcification stage of the third molar in the Indonesian population ranging from a minimum of 9.02 years to a maximum of 25.75 years.

In order to obtain the regression analysis or correlation regression between age and development of each third molar, a correlation analysis between each third molar and chronological age was performed (Table 3).

### Table 3. Correlation of each third molar and chronological age.

| Molar | Correlation coefficient | P value | Total subject (n) | Correlation coefficient | P value | Total subject (n) | Correlation coefficient | P value | Total subject (n) |
|-------|-------------------------|---------|------------------|-------------------------|---------|------------------|-------------------------|---------|------------------|
| 18    | 1.000                   | -       | 390              | 0.995                   | <0.001  | 372              | 0.961                   | <0.001  | 377              |
| 28    | 0.964                   | 0.919   | 395              | 0.966                   | 0.20    | 394              | 0.989                   | 0.929   | 384              |
| 38    | 0.961                   | 0.929   | 384              | 0.989                   | 0.935   | 384              | -                       | -       | 389              |
| 48    | 0.964                   | <0.001  | 384              | 0.935                   | <0.001  | 384              | -                       | <0.001  | 389              |

Statistical analysis using Pearson correlation test (parametric test) showed a correlation between the variables of 18, 28, 38, and 48 third molars, and age was very strong ($p < 0.05$) with a correlation coefficient $>0.75$. It showed that 18, 28, 38, and 48 third molars were each potentially strong enough to be variables in chronological age estimation.

Among 18, 28, 38, and 48 third molars, the correlation was very strong, which indicated an autocorrelation between each tooth. Thus, these four third molars could not be used together to estimate chronological age. Furthermore, 18, 28, 38, and 48 third molars could not be used together in a model if they were all considered as variables. In order to include all of them in the same model, these four variables were required to be made as variables, using the summation and mean models. Thus, there were two alternative groups of equation models, that is, the summation equation model and the mean equation model.

#### 3.1. Regression equation of the third molar
The strength of the linear regression between two variables could be rated by the regression coefficient ($r$), whereas the calculation of formula deviation could be rated by the size of standard error (SE).

#### 3.2. The regression of one third molar and age
The correlation between each third molar and age is shown in Table 4.
Table 4. Linear regression between one third molar and age in the Indonesian population.

| Formula | N  | Regression equation | SE  | r   | r²  |
|---------|----|---------------------|-----|-----|-----|
| R₁₈     | 395| A = 2.375 (18) + 3.238 | 0.310| 0.919| 0.844|
| R₂₈     | 394| A = 2.376 (28) + 3.215 | 0.306| 0.920| 0.847|
| R₃₈     | 384| A = 2.278 (38) + 3.947 | 0.279| 0.929| 0.863|
| R₄₈     | 389| A = 2.288 (48) + 3.777 | 0.266| 0.935| 0.873|

A, age; 18, scoring application of Demirjian method 18; 28, scoring application of Demirjian method 28; 38, scoring application of Demirjian method of 38; 48, scoring application of Demirjian method 48.

In Table 4, the correlation coefficient (r) among each third molar and age was >0.75, indicating a very strong association.

3.3. The regression of summation of third molar and age

Regression of summation of third molar and age could be described by the regression equation model, that is, the summation of two, three, and four third molars.

3.4. The regression of summation of two third molars and age

From four third molars, six kinds of regression between age and the summation of two third molars could be used, as shown in Table 5.

Table 5. Linear regression between the summation of two third molars and age in the Indonesian population.

| Formula | N  | Regression equation | SE  | r   | r²  |
|---------|----|---------------------|-----|-----|-----|
| R₁₈,₂₈  | 390| A = 1.193 (18 + 28) + 3.146 | 0.309| 0.921| 0.847|
| R₁₈,₃₈  | 372| A = 1.192 (18 + 38) + 3.239 | 0.289| 0.933| 0.870|
| R₁₈,₄₈  | 377| A = 1.189 (18 + 48) + 3.203 | 0.279| 0.935| 0.875|
| R₂₈,₃₈  | 373| A = 1.196 (28 + 38) + 3.198 | 0.287| 0.934| 0.872|
| R₂₈,₄₈  | 377| A = 1.189 (28 + 48) + 3.214 | 0.279| 0.935| 0.875|
| R₃₈,₄₈  | 377| A = 1.150 (38 + 48) + 3.750 | 0.270| 0.935| 0.875|

Table 5 shows that the six regressions had correlation coefficients (r) >0.75, indicating that the correlation between chronological age and the summation of two third molars was very strong.

3.5. The regression of summation of three third molars and age

From four third molars, four kinds of regression could be made between age and summation of three third molars, as shown in Table 6.
Table 6. Linear regression between the summation of three third molars and age in the Indonesian population.

| Formula     | N   | Regression equation                                  | SE   | r   | $r^2$ |
|-------------|-----|-----------------------------------------------------|------|-----|-------|
| $R_{18,28,38}$ | 369 | $A = 0.804 (18 + 28 + 38) + 3.040$                  | 0.298| 0.931| 0.867 |
| $R_{18,28,48}$ | 373 | $A = 0.798 (18 + 28 + 48) + 3.086$                  | 0.290| 0.932| 0.869 |
| $R_{18,38,48}$ | 365 | $A = 0.791 (18 + 38 + 48) + 3.271$                  | 0.280| 0.937| 0.878 |
| $R_{28,38,48}$ | 366 | $A = 0.792 (28 + 38 + 48) + 3.264$                  | 0.279| 0.937| 0.878 |

Table 6 shows that the four regressions had correlation coefficients ($r$) >0.75, indicating that the correlation between chronological age and the summation of three third molars was very strong.

3.6. The regression of summation of four third molars and age

From four third molars, one regression could be made between age and summation of four third molars, as shown in Table 7.

Table 7. Linear regression between summation of four third molars and age in the Indonesian population.

| Formula     | N   | Regression equation                                  | SE   | r   | $r^2$ |
|-------------|-----|-----------------------------------------------------|------|-----|-------|
| $R_{18,28,38,48}$ | 362 | $A = 0.600 (18 + 28 + 38 + 48) + 3.088$              | 0.287| 0.936| 0.876 |

Table 7 shows a correlation coefficient ($r$) >0.75, indicating that the correlation between chronological age and summation of four third molars was very strong.

3.7. The regression of the mean of third molars and age

The regression between third molars and age was depicted as a regression between age and mean of third molars.

3.8. The regression between two third molars and age

From four third molars, six kinds of regression could be made between age and mean of two third molars, as shown in Table 8.

Table 8. Linear regression between mean of two third molars and age in the Indonesian population.

| Formula     | N   | Regression equation                                  | SE   | r   | $r^2$ |
|-------------|-----|-----------------------------------------------------|------|-----|-------|
| $R_{r18,28}$ | 390 | $A = 2.386 (18 + 28)/2 + 3.146$                     | 0.309| 0.921| 0.847 |
| $R_{r18,38}$ | 372 | $A = 2.385 (18 + 38)/2 + 3.239$                     | 0.289| 0.933| 0.870 |
| $R_{r18,48}$ | 377 | $A = 2.379 (18 + 48)/2 + 3.203$                     | 0.279| 0.935| 0.875 |
| $R_{r28,38}$ | 373 | $A = 2.392 (28 +38)/2 + 3.198$                     | 0.287| 0.934| 0.872 |
| $R_{r28,48}$ | 377 | $A = 2.378 (28 +48)/2 + 3.214$                     | 0.279| 0.935| 0.875 |
| $R_{r38,48}$ | 377 | $A = 2.299 (38 +48)/2 + 3.750$                     | 0.270| 0.935| 0.875 |
Table 8 shows that the six regressions had correlation coefficients \( r > 0.75 \), indicating that the correlation between chronological age and two third molars was strong.

3.9. The regression of mean of three third molars and age

From four third molars, regressions between age and mean of three third molars were created, as shown in Table 9.

| Formula | N | Regression equation | SE  | R   | \( r^2 \) |
|---------|---|---------------------|-----|-----|--------|
| \( R_{R18,28,38} \) | 369 | \( A = 2.412 (18 + 28 + 38)/3 + 3.040 \) | 0.298 | 0.931 | 0.867 |
| \( R_{R18,28,48} \) | 373 | \( A = 2.395 (18 + 28 + 48)/3 + 3.086 \) | 0.290 | 0.932 | 0.869 |
| \( R_{R18,38,48} \) | 365 | \( A = 2.373 (18 + 38 + 48)/3 + 3.271 \) | 0.280 | 0.937 | 0.878 |
| \( R_{R28,38,48} \) | 366 | \( A = 2.376 (28 + 38 + 48)/3 + 3.264 \) | 0.279 | 0.937 | 0.878 |

Table 9 shows that four regressions had correlation coefficients \( r > 0.75 \), indicating that the correlation between chronological age and mean of three third molars was very strong.

3.10. The regression of mean of four third molars and age

From four third molars, one regression between age and mean of four third molars were created, as shown in Table 10.

| Formula | N | Regression equation | SE  | \( r \) | \( r^2 \) |
|---------|---|---------------------|-----|-----|--------|
| \( R_{R18,28,38,48} \) | 362 | \( A = 2.400 (18 + 28 + 38 + 48)/4 + 3.088 \) | 0.287 | 0.936 | 0.876 |

Table 10 shows a correlation coefficient \( r > 0.75 \), indicating that the correlation between chronological age and the mean of four third molars was very strong.

4. Discussion

4.1. Analysis of age average of third molar development in Indonesia compared with other countries

In the present study, the average age of third molar development in an Indonesian population was determined as follows: stage A, 9.56 years; stage B, 10.01 years; stage C, 11.12 years; stage D, 12.26 years, stage E, 14 years; stage F, 16.92 years; stage G, 19.61 years; and stage H, 23.25 years.

This study compared differences in third molar development age in Indonesia with that of other countries (Figure 3).
Figure 3. Comparison of average age of third molar development in Indonesia and other countries.

Figure 3 shows that the average age of third molar development in Indonesia, Turkey, Saudi Arabia, and Japan was different. Indonesia had the earliest average age of third molar development, at 9.56 years. Thus, third molar development could be used as age estimation on individuals above 9 years old in Indonesia. Among Indonesia, Turkey, Saudi Arabia, and Japan, third molar development was complete by age 22–23 years. Therefore, age estimation using third molar development could not be used for individuals aged >23 years in these populations.

The differences in third molar development of individuals from Indonesia compared with those from Turkey and Saudi Arabia was thought to be due to differences in race; Mongoloids were dominant in Indonesia, whereas Caucasians were dominant in Saudi Arabia.

Differences in Indonesians and Japanese could be because Indonesia has a wider ethnic variation, although Mongoloids are dominant in both countries.

4.2. Comparison of age distribution of third molar development at stage D in Indonesia and other countries

According to the stage of third molar development based on the Demirjian method, the first four stages (A–D) include crown formation and the next four stages (E–H) include root formation, until the closure of root canal is complete [13].

A comparison of age distribution of third molar development at stage D (crown formation until formation of the cemento–enamel junction) in Indonesia and other countries is shown in Figure 4.
Figure 4. Age distribution (%) of third molar development at stage D in Indonesia and other countries.

Figure 4 shows the difference of the third molar development at stage D. In Indonesia, crown formation of the third molar was complete at around 10 to 14 years old, with the highest frequency at 11 and 12 years old. In Turkey, crown formation of the third molar was complete at 10 to 15 years old, with the highest frequency at 12 and 13 years old. And in Japan, crown formation of the third molar was complete at 14 to 20 years old, with the highest frequency at 14 to 15 years old.

The difference in third molar development in the Indonesian and Turkish populations was thought to be due to racial differences. The Indonesian population was predominantly Mongoloid, whereas the Turkish population was predominantly Caucasian. Differences in development stage between the Indonesian and Japanese populations were thought to be due to a greater variation in tribes in the Indonesian population; however, the dominant race was Mongoloid in both.

4.3. *Comparison of age distribution of third molar development at stage G in Indonesia and other countries*

According to the third molar development stage using the Demirjian method, stage G was defined as the point at which root formation was complete but the apical foramen was still open. A comparison of age distribution of third molar development at stage G in Indonesia and other countries is shown in Figure 5.
Figure 5. The age distribution (%) of third molar development at stage G in Indonesia and other countries.

Figure 5 shows the difference in third molar development at stage G among Indonesian, Turkish, and Japanese populations. Third molar development was faster in Indonesian than Turkish and Japanese populations.

In Indonesia, stage G occurred at a wider age range, at 15 to 22 years old, with the maximum frequency at 19 to 20 years old. In Turkey, stage G occurred at 16 to 21 years old, with the maximum frequency at 19 to 20 years old. In Japan, stage G occurred at 17 to 21 years old, with the highest frequency at 18 years old.

The differences in stage G in Indonesia and Turkey were thought to be as result of racial differences. Indonesia is predominantly Mongoloid, whereas Turkey is predominantly Caucasian.

The differences between Indonesian and Japanese populations in third molar development at stage G were thought to be due to more variation in tribes in Indonesia, although both of them were predominantly Mongoloid.

4.4. Comparison of age distribution of third molar development at stage H in Indonesia and other countries

Using the Demirjian method, stage H of third molar development was defined by the completed closure of the apical foramen. A comparison of age distribution of third molar development at this stage in Indonesian and other populations is shown in Figure 6.
Figure 6. Age distribution (%) of third molar development at stage H in Indonesia and other countries.

Fig. 6 shows that the third molar development at stage H in the Indonesian population was different to that of Turkish and Japanese populations; however, stage H occurred during the same age range.

In Indonesia, stage H occurred from 20 to 25 years old. Fig. 6 shows that in the Indonesian population, stage H of third molar development was complete by >23 years old. In the Turkish population, stage H was complete by 20 to 25 years old, with the highest frequency at 25 years old. And in the Japanese population, stage H was complete by 20 to 24 years old, with the highest frequency at 23 years old.

4.5. Comparison of age estimation deviation of four third molars in Indonesians using the Demirjian method and summation model of four third molars

In cases with four third molars, we used the formula published by Sisman et al. In this model, the summation model of four third molars were used for age estimation in an Indonesian population. In Indonesians, either formula could be used; however, we first reviewed which formula was better to estimate age estimation precisely and close to chronological age.

Analysis was conducted using 30 Indonesian samples. The age estimation calculation using two formulas among 30 samples obtained a deviation of 14.36% and −1.38% using the Sisman et al. formula and the summation model of four third molars, respectively. Comparison analysis on age estimation deviation showed a significant difference ($p < 0.05$).

Our results showed that the summation of four third molars model was more precise than the Sisman et al. formula in our Indonesian samples.

5. Conclusion

This study showed that third molar development analysis using the Demirjian method in Indonesians occurred between 9 and 25 years old. In cases with four third molars, the deviation of summation model (deviation −1.38%) was more precise than the formula published by Sisman et al. (deviation 14.36%).

6. References

[1] Henky S O 2012 Identitas korban bencana massal: praktek DVI antara teori dan kenyataan J. Indonesian Leg. Forensic Sci. 2 7–5

[2] Ajmal M, Mody B and Kumar G 2001 Age estimation using three established methods: A study on Indian population Forensic Sci. Int. 122 150–4

[3] Diana K 2011 Perbedaan Batasan Usia Cakap Hukum dalam Peraturan Perundang-undangan
[4] Drusini A 2008 The Coronal Pulp Cavity Index: A forensic tool for age determination in human adults Cuad Med. Forense 14 235–49
[5] Gustafson G and Malmo O 1950 Age determination on teeth J. Am. Dent. Assoc. 45 54–45
[6] Luthfi M, Suhartono W, Puspita A D and Auerkari E I 2016 Third molar development age range on indonesian population from various ethnics based on radiograph findings: A preliminary study J Int Dent Med Res 10 (2) 299-302.
[7] Demirjian A, Goldstein H and Tanner J 1973 A new system of dental age assessment. Hum. Biol. 45 211–27
[8] Olze A, Pynn B, Kraul V, Schulz R, Heinecke A, Pfeiffer H and Schmeling A 2010 Dental age estimation based on third molar eruption in first nations people of Canada J. Forensic Odontostomatol. 28 32–8
[9] Thevissen P W, Pittayapat P, Fieuws S and Willems G 2009 Estimating age of majority on third molars developmental stages in young adults from Thailand using a modified scoring technique J. Forensic Sci. 54 428–32
[10] Falkner F and Tanner J 1978 Human Growth (New York: Plenum Press)
[11] Manuela A and Olivia P 2008 The Third Molar A Dentistry Topic Requiring An Interdisciplinary Approach In Proc. Rom. Acad. 3 175–8
[12] Olze A, Schmeling A, Taniguchi M, Maeda H, Niekro PV, Werneck KD, Gesericke G 2004 Forensic age estimation in living subjects: the ethnic factor in wisdom teeth mineralization Int. J. Leg. Med. 118 170–3
[13] Sisman Y, Uysal T, Yagmur F and Ramoglu S 2007 Third molar development in relation to chronologic age in Turkish children and young adults Angle Orthod. 77 1045–0
[14] McGettigan A, Timmins K, Herbison P, Liversigde H and Kieser J 2011 Wisdom tooth formation as a method of estimating age in a New Zealand population Dent. Anthropol. Assoc. 24 33–41