Adults’ dental age estimation by Cameriere’s method using mandibular canines’ pulp/tooth ratio in Surabaya, Indonesia*

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Adults' dental age estimation by Cameriere's method using mandibular canines' pulp/tooth ratio in Surabaya, Indonesia*

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Abstract

Human dentition is widely used as a growth marker in dentistry, anthropology, archaeology, and forensic sciences, allowing comparison between individuals and populations. Adult dental age estimation is challenging for forensic odontologists because a variety of endogenous and exogenous factors influence dentition as age increases. This study aimed to assess the reliability of the pulp/tooth ratio in estimating the biological age of adults in Surabaya, Indonesia. Periapical radiographs of canines of males and females were involved in this study and the dental age assessment was performed following Cameriere's method using Adobe Photoshop CS6. The statistical analysis of the present study was carried out using SPSS Statistics version 23.0. This study found a significant correlation between the pulp/tooth ratio and biological age. Females showed a higher level of reliability with a smaller MAE (5.34 years) than males (MAE= 7.40 years). Further, the middle adult group (31-50 years old) demonstrated greater reliability, MAE being 3.90 years. This study suggests that the pulp/tooth ratio has a high degree of reliability in estimating individual age and can be applied as a supporting method for age determination in adults in Indonesia. This method performs best for estimating dental age in females between the ages of 31 and 50 years. A future study of dental age estimation using the pulp/tooth ratio is suggested to develop a specific equation for the Indonesian population.

Keywords: age estimation; chronological age; human rights; identification; legal identity

Introduction

The establishment of an individual's identity is an implication of human rights and must be performed through a scientific procedure of forensic identification. According to the Interpol Disaster Victim Identification (DVI) Guide, teeth are categorized as the primary human identifiers as well as DNA and fingerprints (1–3). Forensic odontologists play an essential role in the identification process through the examination of the dentition. Human dentition stores a variety of important information, such as sex, biological age, and DNA profile. Teeth are the hardest tissue of the human body that can withstand extreme conditions like physical, mechanical, and chemical trauma (4–6).

With the global increase in migration movement, mass disasters, criminality, and terrorism, age estimation has become crucial for both deceased and living individuals. In the forensic fields, individual age estimation is discussed in two aspects: chronological age and biological age. The chronological age is also known as the "documented age", whereas the biological age represents the aging of the body (7,8). Dental age estimation is one of the sub-specialist fields of forensic odontology that focuses on developing a reliable, accurate, and appropriate method for determining an individual's age (9–11).

Dental age estimation can be evaluated based on morphological parameters, radiographic examination, and biochemical changes (12). The radiographical method is preferred by forensic odontologists due to its time and cost efficiency, as well as religious and ethical considerations (13,14). Radiographic techniques for estimating dental age have been developed by evaluating tooth development stages, secondary dentin formation, and other post-formation changes (15,16). The tooth development parameter is an accurate and reliable age estimator for children and adolescents. In adults, however, various endogenous and exogenous factors have influenced dentition, making dental age estimation challenging for forensic odontologists (5,17,18). Cameriere et al. (2007) published a study of dental age estimation based on the pulp/tooth ratio of canine teeth. Canines' teeth were chosen for a variety of reasons, including their longevity and ease of analysis due to their

large pulp area. Cameriere's findings suggest that canine teeth are an appropriate morphological parameter for individual age estimation (15,19).

Indonesia is the largest archipelagic country, located in the ring of fire area, which is prone to natural disasters. Therefore, an accurate age estimation method is required to achieve effective individual identification. The purpose of this preliminary study was to assess the reliability and applicability of Cameriere's dental age estimation method for adults in Surabaya, Indonesia.

Methods

Sample collection

This preliminary study was conducted under approval from the Independent Ethics Committee (number 424/HRECC.FODM/IX/2020). The present study included 42 periapical radiographs of mandibular canines from outpatients (21 males and 21 females, 20–50 years old) at the University Dental Hospital, Surabaya. The Belmont Phot-X II 303 dental x-ray, which was set to 60 kV, F.09 speed, and 0.32 second exposure time, was used to take all of the periapical radiographs. The inclusion criteria for the periapical x-ray were as follows: good quality periapical radiographs, available birthdate and radiographic recording date, and not rotated position of the mandibular canine. All the required information, such as chronological age, sex, and date of radiographic examination, was tabulated in Microsoft Excel. To ensure a blinded study, these data were closed during the calculation of the dental age.

Dental age calculation

The periapical x-ray was digitized and saved in JPEG format using a digital scanner HP Deskjet 2135 at 1200 dpi resolution. Adobe® Photoshop® CS6 was used to process the digital periapical images. The magnetic lasso tool in Adobe® Photoshop® CS6 is used to determine and record the measurement of the pulp chamber and canine teeth area (Figure 1). A minimum of 20 and 10 points was required to contour the entire canine and pulp area, respectively (Figure 2). The pulp and tooth area measurement was recorded using the "record measurement" tool in the Adobe® Photoshop® CS6 (Figure 3). The measurement of the pulp and tooth area was reexamined three times by the same observer with a one-week interval to test interobserver reproducibility. The estimated dental age was calculated by taking the average of the three measurements.

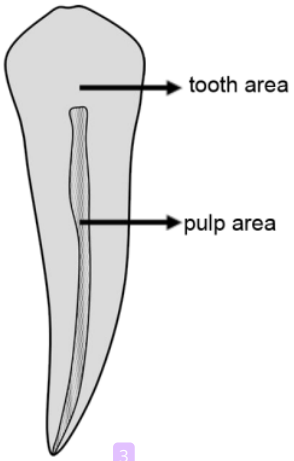


Figure 1 An illustration of the tooth and pulp area for measurement of the pulp/tooth ratio.

The pulp/tooth ratio of the lower canine is defined as x1 variable as follows (15):

x1 = (pulp area) / (tooth area)

x1 = the pulp/tooth ratio of the lower canine (in pixels)

The estimated ages were calculated and tabulated in Microsoft Excel using the equations by Cameriere et al. (15):

Estimated Age = 89.456 – 461.873x1

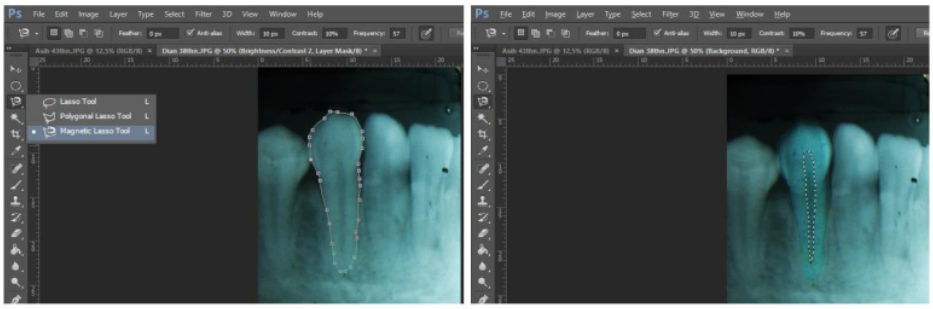
Statistical analysis

The subjects of this study were divided into two groups based on sex and a certain age range. The statistical analysis was carried out using IBM® SPSS® Statistics version 23.0 (IBM, Armonk, NY, USA). The mean absolute error (MAE) value was calculated for each group and used to assess the accuracy of Cameriere's dental age estimation method. Simultaneously, the Spearman correlation test was performed to determine the reliability level of the pulp/tooth ratio and biological age. The paired sample t-test was also performed to investigate the difference between chronological and biological ages.

Results

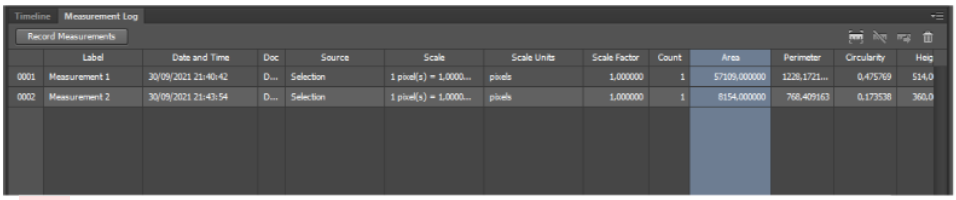
Overall Reliability Levels

The average chronological age of the total subjects is 30.24+7.33 years, while the average



a b

Figure 2 Magnetic lasso tool in Adobe Photoshop and selection of the tooth area. A minimum of 20 points was required to contour the entire tooth area; (b) The pulp area of canine teeth. A minimum of 10 points was required to contour the pulp area.



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0002	Measurement 2	30/09/2021 21:43:54	D...	Selection	1 pixel(s) = 1,0000...	pixels	1,000000	1	8154,000000	768,409163	0,173538	360,0

Figure 3 Record measurement tool and the measurement log in Adobe Photoshop CS6.

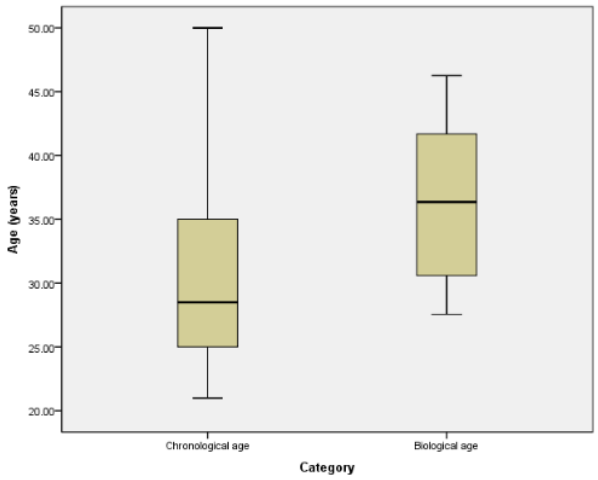

Figure 4 Distribution of the chronological and biological age of all subjects.

Table 1. The descriptive statistics of the chronological and biological age of the total subjects (in years).

Sex	N	Chronological age		Biological age		Age Difference		
		Mean	SD	Mean	SD	MAE	Sig.	Remarks
Male	21	31.29	7.21	37.96	5.45	7.40	0.003	Overestimate*
Female	21	29.19	7.48	34.17	5.58	5.34	0.001	Overestimate*
Total	42	30.24	7.33	36.07	5.78	6.37	0.001	Overestimate*

MAE = mean absolute error/ absolute mean of the difference between the chronological age and biological age
**= significant difference*

Table 2. The correlation test and the reliability levels of the pulp/tooth ratio & the biological age of the total subjects.

Sex	N	MAE (years)	Spearman Correlation Test		
			Sig.	Correlation Coefficient	Reliability Levels
Male	21	7.40	0.004	-0.615	High correlation
Female	21	5.34	0.001	-0.797	Very high correlation*
Total	42	6.37	0.001	-0.721	High correlation

MAE = mean absolute error/ absolute mean of the difference between the chronological age and biological age
**= very high correlation*
The Spearman correlation coefficient value close to -1.0 or +1.0 represent stronger correlation than value closer to zero

Table 3. The correlation test and the reliability levels of the pulp/tooth ratio & the biological age in the specific age range.

Age range	N	MAE (years)	Spearman Correlation Test		
			Sig.	Correlation Coefficient	Reliability Levels
21 – 30	25	8.04	0.023	-0.454	Moderate correlation
31 – 50	17	3.90	0.000	-0.782	Very high correlation*

MAE = mean absolute error/ absolute mean of the difference between the chronological age and biological age
The Spearman correlation coefficient value close to -1.0 or +1.0 represent stronger correlation than value closer to zero
**= very high correlation*

biological age is 36.07+5.78 years (Figure 4). Out of 42 subjects studied, an overestimation of the estimated dental age was observed in male (6.68+5.79 years) and female (4.98+4.03 years) subjects. The result of the independent sample t-test revealed a significant estimated age difference between males and females, $p<0.05$. This finding implies that, in general, an overestimation of age should be noticed in the calculation of male and female biological ages, $p<0.05$ (Table 1).

In the current study, the overall MAE value for all subjects was 6.37 years. The Spearman correlation test shows that the correlation coefficient of this study was -0.721, with $p<0.05$. It indicates a high correlation between the pulp/tooth ratio of the lower canine and biological age.

Accuracy and Reliability Levels based on Sex

According to this study, the MAE value of the estimated age in male subjects was 7.40 years, while it was 5.34 years in females. Table 2 shows the results of the Spearman correlation test and the pulp/tooth ratio reliability levels. A negative correlation coefficient indicates that there is a high correlation between the pulp/tooth ratio of the lower canine and biological age. Female subjects had a higher in correlation (-0.797, $p<0.05$) than male (-0.615, $p<0.05$).

Accuracy and Reliability Levels of Certain Age Range

The subjects of this study were divided into two groups based on their age range. The young adult group (21-30 years) consists of 25 subjects and the middle adult group (31-50 years) consists of 17 subjects. The MAE value of the young adult group was 8.04 years, while the middle adult group was 3.90 years. A moderate correlation between the pulp/tooth ratio and the biological age was found in the young adult with a correlation coefficient of -0.454, $p=0.023$. The correlation coefficient in the middle adult group was -0.782, $p<0.05$. This value indicates a higher reliability level of the pulp/tooth ratio and the biological age than the young adult group (Table 3).

Discussion

Age estimation forms an important aspect in establishing an individual identity. Although several parameters of the human body can be used for age estimation, teeth provide good and accurate age indicators (20). Teeth are frequently used to estimate age because they can be observed clinically and radiographically with minimal radiation exposure (21). Mandibular canines were used in this study for several reasons: single-rooted with a large pulp chamber, less worn over time, and most individuals retain their canines until old age.

This study was conducted in Surabaya, Indonesia, which is classified as Austronesian. Many ethnic groups in Indonesia are classified as Austronesian based on ancestry, including Dayak, Aceh, Batak, Sundanese, Balinese, and Javanese (the largest ethnic group in Indonesia). Therefore, the subjects of this study were enrolled from the Javanese population in Surabaya, Indonesia (22,23). Cameriere et al. (2007) developed the original dental age estimation method in Caucasian population countries (15).

According to Cameriere's study, the overall MAE value is 4.38 years. However, the present study shows the overall MAE value is 6.37 years. This finding indicates slightly higher accuracy than the previous study by Jeevan et al., 2011, in the Indian population (MAE value = 6.39 years) and a study in the Brazilian population by Azevedo et al., 2015, (MAE value = 6.54 years) (24,25). In the second study by Cameriere et al., 2009, in Portugal and Italy populations with mandibular canines showed a higher accuracy level of 4.33 years. Although this study found significant differences between chronological and estimated ages, a deviation of fewer than ten years is acceptable to support individual identification (15,24,26–28).

A previous study by Cameriere et al. explained that sex had no significant influence on age estimation (15). However, the present study found a significant difference in MAE between males and females. According to Singh et al. (2014), tooth attrition was thought to be a significant factor in males' overestimation of biological age (29). Males had higher attrition scores than females because they have a stronger masseter function, greater muscle fiber mass, and stronger ligaments, resulting in a greater biting force (30,31). Severe canine tooth attrition in males may affect the calculation of the pulp/tooth ratio and result in a significant overestimation of the estimated age.

Based on a specific age range, the middle adult group showed a higher accuracy level (MAE = 3.90 years) compared with the young adult group. This finding was consistent with the findings of Kvall et al. (1995) and Hidayat et al. (2018). Secondary dentine deposition is highly correlated with increasing age (32,33). The pulp cavity

gradually becomes narrower due to secondary dentine deposition (24). Hidayat et al. (2018) explained that secondary dentin deposition is slower in people aged 35–40 years old. In addition, tooth wear was considered as a factor that could influence the calculation of the dental age in adults (33). Thippanna et al. (2017) discovered that younger age groups had the lowest attrition scores involving only enamel, whereas older age groups had attrition involving both enamel and dentine (31).

Secondary dentine deposition is a physiological process that occurs after root formation is complete. Burke and Sammarawickrama (1995) discovered that pulp and dentin respond to a variety of physiological and pathological conditions. The pulp-dentinal complex's response leads to the reduction of pulp chamber size. As a result, secondary dentine deposition is an important parameter for estimating adult dental age (34). Solheim (1992) found a strong correlation between increasing age and secondary dentine thickness. The total pulp area decreased significantly with advanced age due to secondary dentine formation (35,36).

Different studies may yield varying levels of accuracy and reliability due to a variety of factors that may influence the research, such as individual tooth size variation, secondary dentin apposition patterns, tooth wear, differences in radiographic image magnification, and human resource errors during the radiographic recording process (37). Periodontitis, tooth morphology, gene expression in odontoblasts, hormonal homeostasis, and occlusal pressure are all factors that can influence pulp size (38). The findings of several studies revealed low levels of reliability; therefore, it is suggested that the focus of the dental age estimation study should be on the accuracy and reliability of the method to be applied to a different population (28,39).

The quality of the radiograph images is an important factor that may have an impact on the results of the dental age estimation study. Clear periapical radiographs will yield an accurate pulp/tooth ratio calculation and vice versa. Furthermore, image distortion during periapical radiograph digitization may occur, causing the pulp/tooth ratio to be miscalculated and lowering the accuracy of dental age estimation (40,41).

Conclusions

The findings of this study suggest that the pulp/tooth ratio has a high degree of reliability in estimating individual age. Furthermore, Cameriere's dental age estimation method can be applied as a supporting method for individual identification in adults in Indonesia. This method performs best for estimating dental age in females between the age of 31 and 50. However, a thorough investigation is required when applying this method to male subjects in Surabaya, as a significant difference between chronological age and biological age was discovered. The limitation of the present study includes a limited number of samples due to the COVID-19 pandemic situation. A larger sample size study in Indonesia is recommended to obtain a better result with lower error rates. It is suggested that a future study of dental age estimation using the pulp/tooth ratio be conducted to develop a specific equation for the Indonesian population.

Abbreviations

CBCT = Cone-beam computed tomography
MAE = Mean Absolute Errors

Conflict of interest

The authors have no conflict of interest to declare.

Ethical approval

The ethical clearance of this study was obtained from the Ethics Committee of the Faculty of Dental Medicine, Universitas Airlangga, Indonesia, number: 424/HRECC.FODM/IX/2020.

Authors' contributions

The authors contributed to this work, as follows: AK, AC, MIM, BNR, and BFWP contributed to the conception, design of the study, and acquisition of data. AK, MRRW, and AA contributed to the statistical analysis. AK, AA, AC, MIM, MS, and BNR contributed to drafting and revising the article. AK is the supervisor of the present study. All authors have read and approved the final manuscript.

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