The applicability of dental age estimation based on the staging and atlas approaches in Indonesian children and adolescents

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SUMMARY

Accurate age estimation holds paramount importance across various fields, encompassing forensic sciences, civil law, and the medicolegal domain. The applicability of the staging and atlas method for calculating dental age in Indonesian children and adolescents was assessed for this purpose. This study encompassed 104 orthopantomographs from outpatients (54 males and 50 females, aged 5-18 years) at the Airlangga University Dental Hospital in Surabaya, Indonesia. An analysis was conducted to determine the significance of the difference and the correlation between chronological age (CA) and estimated dental age (EDA). The findings unveiled a robust correlation between CA and EDA, with correlation coefficients surpassing 0.9 for both approaches. Although the London Atlas method exhibited a marginally lower Mean Absolute Error (MAE) of 0.81 years in comparison to the Nolla method's MAE of 0.88 years, the difference between the two was deemed insignificant. The outcomes of this study provide valuable insights into the utility of the Nolla and London Atlas methods for estimating dental age among Indonesian youth. However, it is imperative to note that further investigations are warranted to validate these findings and to ascertain the generalizability of these methods across diverse populations.

Key words: Adolescent – Dental age estimation – Forensic dentistry – Human rights – Jurisprudence

INTRODUCTION

The Interpol Disaster Victim Identification (DVI) Guide 2018 recommends three primary methods for identifying humans: deoxyribonucleic acid (DNA), fingerprints, and dental records (INTERPOL, 2018). The field of forensic sciences has seen a significant rise in interest in dental identification due to the valuable information that teeth may offer, including characteristics such as sex, age, and population affinity (Grover

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Submitted: January 25, 2024. **Accepted:** March 1, 2024

https://doi.org/10.52083/UJVG7422

et al., 2012). Accurately determining an individual's age holds great significance across forensic sciences, civil law, and medicolegal domains, encompassing areas such as school enrollment, marriage, employment, and the establishment of criminal responsibility (Sousa et al., 2020; Ishwarkumar et al., 2022). The precise age documentation is vital in addressing legal inquiries and upholding human rights. Additionally, age estimation is crucial in identifying unknown human remains, particularly in scenarios involving crime scenes and mass disasters (Cameriere et al., 2009; Kurniawan et al., 2022; Prakoeswa et al., 2022). Assessing the dental age of a patient is one of the most important aspects of orthodontic diagnosis, especially for planning and initiating fixed appliance orthodontic therapy. Sukhia et al. demonstrated that initiating orthodontic treatment at a later stage in patients with delayed dental maturity resulted in reduced treatment duration and enhanced treatment stability (Sukhia et al., 2012).

The Arbeitsgemeinschaft für Forensische Altersdiagnostik (AGFAD) study group specializing in forensic age diagnostics proposes three examinations for achieving reliable age estimation results: a physical examination, radiographic assessment of the left hand, and dental evaluation (Schmeling et al., 2016; Paz Cortés et al., 2019). Dental age estimation encompasses the assessment of tooth development, histological changes, and biochemical analysis. The development and eruption sequences of permanent teeth are considered highly accurate age indicators in children due to their minimal susceptibility to external influences. Similarly, the progression of the third molar serves as a dependable parameter for estimating the biological age of adolescents (Erbudak et al., 2012; Naik et al., 2017). Regarding dental age estimation, the literature supports the preference for radiographic methods due to their cost-effectiveness, non-invasive nature, ease of use, and applicability to both living and deceased individuals (Sharma and Wadhwan, 2020).

Previous studies indicate that variations in developmental rates within some populations can impact age estimations. It is advisable to consider population-specific criteria for individuals with known population affinity. However, for circumstances when the population affinity is unknown it is preferable to use aging standards derived from a diverse sample (Adams et al., 2019). The precision of an age-estimating method is affected by the possibility of correctly interpreting the teeth's staging and the statistical methodologies used. Therefore, it is essential to consider population-specific standards and the potential impact of different developmental rates on the accuracy of dental age estimation methods (Mohammed et al., 2015)

The present study aims to evaluate the efficacy of dental age estimation methods in Indonesian children and adolescents by assessing the staging and atlas approaches. The results of this research will increase understanding and practical application of dental age estimation techniques in Indonesian youths, thus facilitating forensic identification and supporting law enforcement efforts.

MATERIALS AND METHODS

The current study obtained ethical approval from the Faculty of Dental Medicine Universitas Airlangga (permit number: 479/HRECC.FODM/VII/2021). A cross-sectional retrospective study utilized orthopantomography (OPG) to scrutinize 104 outpatients (54 males and 50 females) aged 5 to 18 years at the Airlangga University Dental Hospital in Surabaya, Indonesia. The inclusion criteria consisted of high-quality digital OPGs together with the presence of patients' age and sex information. The exclusion criteria included radiographs that were insufficient for visualizing tooth development, radiographs taken from patients using orthodontic appliances, and radiographs from patients with systemic diseases.

This study assesses the chronological age (CA) and estimated dental age (EDA) using teeth development indicators. The calculation of CA involved subtracting the patient's birthdate from the date of the OPG examination, resulting in a decimal number. The EDA was assessed using two techniques: the Nolla method, which classifies dental maturation into ten stages per tooth (ranging from stage 0, indicating the absence of calcification, to stage 10, indicating complete closure of the tooth's apex), and the London Atlas of Tooth

Development method, which presents visual depictions of each tooth's development and eruption stage through colored diagrams (Nolla, 1960; AlQahtani et al., 2010) The staging determination and EDA calculation were performed three times, with a two-week interval between each measurement, to confirm the reproducibility of the results.

The statistical analysis of this study utilized IBM® SPSS® Statistics version 23.0 (IBM, Armonk, NY, USA) with a 95% confidence interval. Descriptive statistics were employed to summarize data, including the age difference, mean absolute error (MAE), and discrepancies between sexes and age groups. Overestimation of age was defined as a positive difference between DA and CA, while a negative value denoted underestimation.

The intraclass correlation coefficient (ICC) test was used to assess the reliability of the measurements. The Wilcoxon signed-rank test was utilized to compare the performance of EDA and CA within the different approaches. The differences between DA and CA were calculated and compared based on sex and age group to evaluate the accuracy of dental age estimation. Pearson's correlation test was also conducted to examine the correlation between CA and EDA using the London Atlas and Nolla methods.

RESULTS

This study examined 104 digital OPGs from outpatients at Airlangga University Dental Hospital, comprising 54 males and 50 females. The average chronological age (CA) for the study group was 11.61 ± 3.58 years. Males had an average CA of 11.53 ± 3.53 years, while females had an average CA of 11.70 ± 3.67 years. The reliability of EDA calculation using the London Atlas and Nolla methods was deemed excellent, as evidenced by an ICC value exceeding 0.9.

Table 1 presents a summary of the mean EDA using both the London Atlas and Nolla methods. The overall mean EDA using the London Atlas was 12.09 ± 3.59 years, with males and females showing mean EDA values of 12.09 ± 3.54 years and 12.08 ± 3.67 years, respectively. The disparity between CA and EDA using the London Atlas method varied among groups, with values of 0.48 ± 0.92 years for the entire subjects, 0.56 ± 0.75 years for males, and 0.38 ± 1.08 years for females. In the 14.00–14.99 age group, there was an observed underestimation of -0.31 years. The MAE for the entire study population was 0.81 years, indicating a statistically significant difference between CA and EDA ($p<0.05$). For males, the MAE was 0.76 ($p<0.05$), while for females, it was 0.87 ($p<0.05$). Notably, the London Atlas method exhibited

Table 1. Descriptive analysis of the chronological age (CA) and estimated dental age (EDA) using the London Atlas and Nolla's method.

Subjects	**CA**	**London Atlas**			**Nolla**		
		x̄ + SD	**Age diff.**	**MAE**	**x̄ + SD**	**Age diff.**	**MAE**
All subjects	11.61+3.58	12.09+3.59	+0.48*	0.81	11.75+3.25	+0.14	0.88
Male	11.53+3.53	12.09+3.54	+0.56*	0.76	12.08+3.25*	+0.55	0.96
Female	11.70+3.67	12.08+3.67	+0.38*	0.87	11.39+3.25	-0.31	0.79
Age group							
5.00 - 5.99	5.47 + 0.29	6.50+0.00	+1.03	1.03	6.78+0.38	+1.31	1.31
6.00 - 6.99	6.44 + 0.25	7.13+0.52	+0.68	0.69	7.46+0.78	+1.02	1.07
7.00 - 7.99	7.59 + 0.27	8.14+0.81	+0.55	0.62	8.55+0.75	+0.96	0.99
8.00 - 8.99	8.57 + 0.26	9.06+0.53	+0.48	0.55	8.74+0.70	+0.17	0.58
9.00 - 9.99	9.44 + 0.24	10.06+0.53	+0.61	0.61	9.78+0.60	+0.33	0.54
10.00-10.99	10.49+0.26	10.72+0.97	+0.23	0.60	10.59+0.72	+0.10	0.42
11.00-11.99	11.58+0.26	12.13+1.19	+0.55	1.09	11.33+1.43	-0.24	1.27
12.00-12.99	12.55+0.29	13.50+1.15	+0.95	1.13	13.48+1.83	+0.92	1.38
13.00-13.99	13.47+0.36	14.00+1.31	+0.53	1.17	13.42+1.42	-0.05	0.94
14.00-14.99	14.47+0.39	14.17+1.86	-0.31	1.19	13.56+1.77	-0.92	1.14
15.00-15.99	15.43+0.24	15.50+1.15	+0.07	0.95	14.90+0.66	-0.52	0.61
16.00-16.99	16.43+0.26	16.79+0.83	+0.36	0.65	15.76+1.07	-0.67	0.90
17.00-17.99	17.31+0.19	18.10+0.55	+0.79	0.79	17.40+0.89	+0.09	0.59

CA chronological age, *SD* standard deviation, *MAE* mean absolute error
+ indicates overestimation, – indicates underestimation, * indicates a significant difference between CA and EDA

the lowest MAE in the 8.00-8.99 age group (0.55 years) and the highest MAE in the 14.00-14.99 age group (1.19 years).

On the other hand, employing Nolla method yielded a mean EDA of 11.75 ± 3.25 years for the entire study population. The overall age difference between EDA and CA using Nolla method was 0.14 ± 1.18 years, a non-significant finding (p>0.05). In terms of sexes, males demonstrated an overestimation of EDA (0.55 ± 1.08 years), while females exhibited an underestimation (-0.31 ± 1.14 years). Specific age groups, namely 11.00–11.99 and 13.00–16.99, displayed underestimation ranging from -0.05 to 0.92 years. The MAE values for Nolla method in the entire study population, males and females, were 0.88, 0.96, and 0.79, respectively (refer to Table 1). The age group with the smallest MAE using Nolla method was 10.00-10.99 (0.42 years), while the highest MAE was observed in the 12.00-12.99 age group (1.38 years). Notably, the mean age difference using Nolla method was not statistically significant for females (p>0.05), whereas for males, there was a statistically significant difference between the mean CA and EDA (p<0.05).

While evaluating the entire subject population, the London Atlas method exhibited a lower MAE compared to the Nolla method. However, the Mann-Whitney U test did not reveal a statistically significant difference in MAE between the London Atlas and Nolla methods (p>0.05). Pearson's correlation test results showed a noteworthy correlation between CA and EDA in both the London Atlas and Nolla methods, with correlation coefficients of 0.967 and 0.945, respectively (see Table 2).

Table 2. Correlation of the chronological age (CA) with estimated dental age (EDA) in total subjects, males and females.

Group	Methods	Correlation with CA	
		***r*-value**	***p*-value**
Total	London Atlas	0.967	<0.05*
	Nolla	0.945	<0.05*
Male	London Atlas	0.978	<0.05*
	Nolla	0.953	<0.05*
Female	London Atlas	0.957	<0.05*
	Nolla	0.953	<0.05*

* Indicates a significant correlation between CA and EDA

DISCUSSION

Accurate dental age estimation holds significant importance in forensic sciences, particularly when determining the chronological age of individuals without proper legal records. The discourse on dental age estimation in children and adolescents encompasses several vital considerations. This discussion is centered on identifying the most precise and reliable methods for assessing dental age, taking into account factors such as tooth development, eruption patterns, and root formation (Kurniawan et al., 2020; Schmeling, 2023). The progression of permanent tooth development typically follows a sequential timeline, with first molars emerging around ages 6 to 7, incisors between 6 and 9, canines around 9 to 12, and concluding with the eruption of the third molars at approximately age 21 (Singh and Juneja, 2007).

The assessment of dental age in children through the analysis of tooth morphology using dental radiography is widely recognized as a highly dependable technique for age estimation, applicable to both deceased and living individuals. OPG is preferred for age estimation in children and adolescents among various imaging techniques due to challenges in obtaining distortion-free intraoral radiographs (Grover et al., 2012). The accuracy of dental age estimation holds immense significance in forensic sciences, ensuring that the estimated age closely corresponds to the actual chronological age. Over time, advancements in dental age estimation methods have introduced various approaches, including the atlas and staging methods explicitly tailored for age estimation in children and adolescents (Lewis and Senn, 2015).

This study evaluated the effectiveness of two distinct methods for estimating dental age in children and adolescents. The staging approach was assessed using the Nolla method, while the atlas approach was evaluated based on the London Atlas of Tooth Developments. A total of 104 OPGs were meticulously selected, ensuring ethnic homogeneity among subjects to account for potential variations in tooth development across different populations. The analysis of both methods revealed a general tendency to overestimate EDA compared to CA, with the Nolla method showing a more negligible age difference that was not statistically significant. Moreover, when assessing age differences based on sexes, the Nolla method indicated underestimation in female subjects, while the London Atlas demonstrated overestimation in both males and females.

The Nolla method utilizes a scale from 1 to 10 to intricately categorize tooth development stages, aiming for greater precision in dental age estimation. This approach evaluates the calcification stages of seven permanent tooth buds, encompassing the central incisor to the second molar, in both the upper and lower jaws (Kırzıoğlu and Ceyhan, 2012). Nevertheless, an ongoing debate surrounds the potential influence of expanding the number of developmental stages on observer errors and the overall accuracy of the outcomes (Hegde et al., 2017).

The present study's findings indicate that the Nolla method demonstrates a heightened level of reliability, as evidenced by the absence of a statistical difference between EDA and CA ($p>0.05$). The MAE associated with the Nolla method in this investigation falls within an acceptable range (MAE=0.88). These results align with previous studies conducted by Nur et al. and Maber et al. on the Turkish, Bangladeshi, and British Caucasian populations. Regarding sex-based EDA using the Nolla method, this study's outcomes are in line with the findings by Koc et al. (2021) of overestimation in males and underestimation in females (Maber et al., 2006; Nur et al., 2012; Koç et al., 2021). Similar trends were also reported by Duruk et al. (2022) and Miloglu et al. (2011), suggesting higher accuracy of the Nolla method in males than females. In our study, a significant age difference was observed in male subjects. Furthermore, within the specific age range of 9 to 11 years, the Nolla method demonstrated increased accuracy for both sexes, with an MAE ranging from 0.42 to 0.54 years. This result coincides with the findings by Duruk et al. (2022) on the Eastern Turkish population. In contrast, a study on a Brazilian population revealed underestimation in both males and females (Kurita et al., 2007; Miloglu et al., 2011; Duruk et al., 2022).

The application of the London Atlas approach in this study resulted in a notable overestimation in both male and female subjects, with an MAE of 0.76 years and 0.87 years, respectively. These findings corroborate the results of previous studies undertaken by Koc et al. (2021) and McCloe et al. (2018), which similarly identified age overestimation through the utilization of the London Atlas approach. In a study conducted by Pavlović et al. (2017) on the Portuguese population, a notable distinction between CA and EDA was found in males, while no statistically significant difference was detected in females. The present study revealed a tendency to underestimate ages between 14 and 14.99 in certain age groups. In addition, Ismail et al. (2018) studied Malay children and discovered that the London Atlas underestimated the ages of ten-year-old and 15-year-olds. In contrast, overestimation was reported in the five-year-old group. Ghafari et al. (2018) reported a decrease in the accuracy of the London Atlas method for individuals older than 12 years. However, the MAE increased from 11 years old in our study. In contrast to our findings, Alsudairi and AlQahtani (2019) found consistent underestimation among Saudi Arabian children aged 6-15, with no statistically significant difference between sexes.

The specific reasons for the observed differences among diverse populations remain unclear. Previous studies have proposed that factors like sample size, distribution, scoring criteria, and statistical analyses may play a role in these variations (Liversidge, 2010). However, recent findings suggest that disparities in dental maturity persist across various populations. Chaillet et al. (2005) conducted a comparative study on dental maturity in eight countries, revealing inter-ethnic differences categorized into three major groups. Additionally, Demirjian et al. (1973) suggested that population-specific standards could enhance the accuracy of converting maturity scores into dental ages, highlighting the impact of population differences on precision. The accuracy of a specific age estimation method may vary across different populations, with one method displaying higher accuracy in one study and the opposite pattern in another study involving a distinct population (McCloe et al. 2018).

In summary, the estimated dental age of the London Atlas and Nolla methods significantly correlates with the chronological age of the Indonesian population. The Nolla method exhibited a smaller age difference, while the London Atlas displayed a diminished MAE. However, a population-specific dental age estimation method is suggested to be developed to achieve more accurate results.

CONCLUSIONS

The careful selection of reliable and culturally appropriate methods for dental age estimation holds significant importance, especially when dealing with diverse populations such as Indonesian children and adolescents. A thorough examination of the effectiveness of the Nolla method and London Atlas was performed in this study, uncovering limitations in their accuracy for predicting chronological age within this specific demographic.

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