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The applicability of Demirjian's and Nolla's dental age estimation methods for children in Surabaya, Indonesia*

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Abstract

Accurate age estimation in children is crucial in various justice-related contexts, including adoption, asylum applications, and immigration cases. Additionally, dental age estimation plays a key role in treatment planning within pediatric dentistry and orthodontics. This study aimed to evaluate the applicability of two widely used dental age estimation methods—Demirjian and Nolla—for children aged 6 to 15 years in Surabaya, Indonesia. A total of 200 panoramic radiographs from the Dental Hospital of Universitas Airlangga were analyzed to compare chronological age (CA) and estimated dental age (DA). The results revealed significant differences between CA and DA when using the Demirjian method for males ($p < 0.05$) and the Nolla method for both sexes ($p < 0.05$). However, no statistically significant differences were found for females using the Demirjian method. The Demirjian method demonstrated greater accuracy, with the lowest mean absolute error (MAE) of 0.92 years for males and 0.82 years for females, compared to the Nolla method, which showed an MAE of 1.11 years for males and 0.87 years for females. These findings suggest that the Demirjian method is more reliable, particularly for estimating the dental age of females in the Surabaya population. Moreover, the Demirjian method showed higher accuracy in younger children (ages 6–10 years), whereas the Nolla method performed better in older children (ages 11–15 years).

Keywords: age determination by teeth; forensic dentistry; Indonesians; legal identity; tooth calcification

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Introduction

Dental age estimation holds significant legal and humanitarian importance, particularly for children and adolescents, where chronological documentation may be absent or unreliable. These include cases of illegal immigration, adoption processes, asylum requests involving unaccompanied minors, and other civil issues. Accurate dental age estimation is also essential in pediatric dentistry and orthodontics as a basis for diagnosis and treatment planning (1,2).

Bones and teeth are the primary indicators for age estimation among biological structures (3). Although bone maturity provides valuable insights, its utility is limited to specific age ranges and is often influenced by substantial factors such as dietary habits, socioeconomic status, and genetics (4,5). On the other hand, teeth are less affected by these variables and can be applied for age estimation from early childhood to adulthood due to the predictable nature of tooth development (6). Dental age estimation can be based on various parameters, including stages of tooth development, morphological changes, and biochemical analysis (7,8).

Two of the most widely used methods are the Demirjian (9) and Nolla (10). These rely on the radiographic assessment of tooth development to estimate an individual's age. Although both have shown acceptable performance in various populations, a notable gap remains in their validation and application to Indonesian children. This study aimed to address this gap by assessing the applicability of Demirjian's and Nolla's methods for age estimation in children from Surabaya, Indonesia. This study focuses solely on age estimation in individuals below 18 years, without addressing the legal adult threshold.

Materials and Methods

This study received ethical approval from the Health Research Ethical Clearance Commission of the Dental Hospital, Universitas Airlangga (Approval Number: 23/UN3.9.3/Etik/PT/2023). A total of 200 high-quality digital panoramic radiographs (93 from males and 107 from females) were retrospectively selected from the radiograph archives at the Dental Hospital, Universitas Airlangga, Surabaya. The inclusion criteria were the availability of complete medical records (including the patient's sex, date of birth, and date of radiographic examination) and clear visibility of mandibular teeth from the central incisor to the second molar. Radiographs were excluded if they showed mandibular teeth that had undergone root canal treatment, exhibited pathological conditions, were restored with artificial crowns, or were fitted with orthodontic appliances.

The chronological age (CA) of each subject was calculated by subtracting the date of birth from the date of the radiographic examination. Both CA and the sex of each subject were systematically recorded and tabulated using Microsoft Excel. The estimated dental age (DA) was determined using Demirjian's and Nolla's methods. DA was independently assessed by an observer (AK), who has over seven years of experience in forensic odontology. Each radiograph was assessed in two separate sessions, at least one week apart. The final dental age was calculated as the mean of both observations. Intra-observer reliability was assessed using the Intraclass Correlation Coefficient (ICC) test.

The Demirjian method is based on the calcification stages of permanent teeth. In this method, seven left mandibular teeth (teeth 31 to 37) were assessed, and each tooth was assigned one of eight calcification stages (A–H), with each stage corresponding to a maturity score. The total dental maturity score was calculated by summing the individual scores of all assessed teeth. The total maturity score was then referenced against a graph developed by Demirjian to estimate individual age (9).

Nolla's dental age estimation method is based on the evaluation of the developmental stages of permanent teeth using a 10-stage system, ranging from Stage 0 (absence of crypt) to Stage 10 (apical end of root completed). The corresponding stage number (0–10) is assigned to each tooth based on its radiographic appearance and summed up. The total score was then compared to the reference table to estimate the individual's age (10).

Descriptive statistics were used to calculate the CA and DA, with results presented as mean values and standard deviations. The difference between CA and DA was also calculated for each method; a positive value indicated an overestimation of age, while a negative value indicated an underestimation. Statistical significance of the differences between CA and DA for each method was analyzed using the Wilcoxon signed-rank test, with a 95% confidence interval. All statistical analyses were conducted using IBM® SPSS® Statistics version 23.0.

Results

This study analyzed 200 panoramic radiographs of individuals aged between 6.01 and 15.60 years. The mean CA of the total sample was 9.71 ± 2.50 years, with males averaging 9.77 ± 2.47 years and females averaging 9.65 ± 2.54 years. The results of the ICC test indicate that the first and second DA assessments had good reliability and consistency, with coefficients of 0.903 for Demirjian and 0.893 for the Nolla method.

Table 1 summarizes the mean age differences for males, females, and the total sample, indicating a general trend of overestimation. An exception was observed in females using the Demirjian method, which showed a slight underestimation of –0.07 years ($p = 0.945$). Overestimation occurred in 56.5% of the total sample using the Demirjian method and 59.0% using the Nolla method. The mean absolute error (MAE) between CA and DA further supported the higher accuracy of the Demirjian method, which had the lowest MAE of 0.87 years, compared to 0.98 years for the Nolla method. The Wilcoxon signed-rank test revealed statistically significant differences between CA and DA across the total sample ($p < 0.05$), except in females assessed with the Demirjian method, where no significant difference was found.

Analysis of differences between CA and DA for each age group is presented in Table 2. Both the Demirjian and Nolla methods exhibited a general trend of overestimation across most age groups. Slight underestimations of ages were noted with the Demirjian method at groups 10, 13, and 15 years and with the Nolla method at groups 12 and 15 years. A significant age difference was observed in the age groups of 6 and 7 years for the Demirjian method and age groups of 8 and 9 years for the Nolla method, $p < 0.05$.

In this study, the accuracy of both methods was assessed based on the MAE values. The Demirjian method demonstrated smaller MAE values in the younger age range (6 to 10 years), suggesting greater applicability for age estimation during early childhood. In contrast, the Nolla method showed lower MAE values in the older age range (11 to 15 years), indicating better accuracy in late childhood (Figure 1).

Table 3 provides an analysis of accuracy rates of age estimation, stratified by age group and categorized into discrepancies of <1 year, 1–1.99 years, and >2 years. The Demirjian method demonstrated the highest overall accuracy, with 68% of estimates falling within <1 year of the CA and the lowest rate of discrepancies >2 years (8%). The highest rates of accurate estimates within <1 year were observed in the 6-year age group for the Demirjian method (92.59%) and the 14-year age group for the Nolla method (84.62%). Conversely, the greatest rates of discrepancies exceeding >2 years occurred in the 12-year age group for the Demirjian method (35.71%) and the 10-year age group for the Nolla method (22.22%).

Discussion

Dental age estimation can be performed using three main approaches: morphological, biochemical, and radiological (11). The morphological approach involves microscopic analysis of extracted teeth. While effective for postmortem cases, these methods are invasive and raise ethical concerns when applied to living individuals (12). Biochemical methods, such as the method by Ritz et al. (1995), use a dentin biopsy to estimate age without tooth extraction, making it more suitable for living individuals. However, this approach requires specialized laboratory resources, limiting its widespread application (13).

Radiological approaches are the most commonly used method in forensic odontology, pediatric dentistry, and orthodontics. The Demirjian, Willems, Nolla, and AlQahtani methods are extensively studied among diverse populations. While each method offers distinct advantages, their accuracy and applicability can vary significantly depending on the studied population, highlighting the importance of choosing an appropriate method tailored to specific demographic and environmental contexts (14,15).

This study revealed that the Demirjian method exhibited an MAE of 0.87 years for the overall subjects, with MAEs of 0.92 years for males and 0.82 years for females. A general overestimation of 0.18 years was observed ($p < 0.05$). A meta-analysis conducted by Hostiuc et al. (2021) also indicated that Demirjian's method tends to overestimate real age by approximately six months for both sexes. The Asian study noted an average age difference of 0.36 years for females and 0.46 years for males. The age intervals of 12–14 and 15 exhibit the least age difference. Hostiuc et al. recommend that the methods be employed with considerable caution after the age of 16, due to the potential for significant errors in the results (16).

Table 1. Descriptive statistics and analysis of the difference between the two dental age estimation methods based on sexes and total samples in this study.

Methods	n	Mean ± SD (yr)	Mean Age diff. (yr)	MAE (yr)	Trend	*p*-value
Male						
Chronological age	93	9.77 ± 2.47				
Demirjian		10.23 ± 2.92	0.46	0.92	O	<0.001*
Nolla		10.20 ± 2.71	0.44	1.11	O	0.006*
Female						
Chronological age	107	9.65 ± 2.54				
Demirjian		9.59 ± 2.44	-0.07	0.82	U	0.945
Nolla		9.92 ± 2.63	0.26	0.87	O	0.006*
Total sample						
Chronological age	200	9.71 ± 2.50				
Demirjian		9.89 ± 2.68	0.18	0.87	O	0.009*
Nolla		10.05 ± 2.71	0.34	0.98	O	<0.001*

**Indicate a significant difference; SD= standard deviation; MAE= mean absolute error; O= overestimation; U= underestimation*

Table 2. Analysis of the difference between the CA, Demirjian, and Nolla methods based on age groups.

Age Groups	n	Chronological	Demirjian			Nolla		
		Mean±SD	Mean±SD	Age diff.	Trend	Mean±SD	Age diff.	Trend
6.00-6.99	27	6.52±0.28	6.75±0.63	0.23	O	6.93±1.41	0.41	O
7.00-7.99	33	7.50±0.31	7.77±0.62	0.27	O	7.82±1.07	0.31	O
8.00-8.99	35	8.55±0.26	8.68±0.67	0.13	O	9.03±1.15	0.48	O
9.00-9.99	29	9.47±0.30	9.56±1.04	0.09	O	9.83±0.93	0.36	O
10.00-10.99	18	10.48±0.32	10.44±1.05	-0.03	U	11.11±1.41	0.63	O
11.00-11.99	17	11.49±0.33	11.94±1.92	0.46	O	11.88±1.50	0.40	O
12.00-12.99	14	12.57±0.28	13.51±1.67	0.94	O	12.43±1.40	-0.14	U
13.00-13.99	9	13.38±0.23	13.31±1.61	-0.07	U	14.11±1.27	0.73	O
14.00-14.99	13	14.39±0.29	14.45±1.61	0.06	O	14.46±1.13	0.08	O
15.00-15.99	5	15.39±0.18	13.98±1.65	-1.41	U	14.60±1.14	-0.79	U

Age diff.= age difference; CA= chronological age; SD= standard deviation; O= overestimation; U= underestimation

Table 3. Rates of correct estimation (in %) with the age difference of <1 year, 1–1.99 years, and ≥2 years among Demirjian's and Nolla's dental age estimation methods.

Age Groups	<1 year		1–1.99 years		≥2 years	
	Demirjian	Nolla	Demirjian	Nolla	Demirjian	Nolla
6.00-6.99	92.59%	62.96%	7.41%	22.22%	-	14.81%
7.00-7.99	87.88%	63.64%	12.12%	30.30%	-	6.06%
8.00-8.99	88.57%	45.71%	11.43%	48.57%	-	5.71%
9.00-9.99	55.17%	72.41%	44.83%	24.14%	-	3.45%
10.00-10.99	66.67%	50.00%	27.78%	27.78%	5.56%	22.22%
11.00-11.99	58.82%	41.18%	5.88%	47.06%	35.29%	11.76%
12.00-12.99	35.71%	35.71%	28.57%	57.14%	35.71%	7.14%
13.00-13.99	33.33%	44.44%	55.56%	44.44%	11.11%	11.11%
14.00-14.99	23.08%	84.62%	61.54%	15.38%	15.38%	-
15.00-15.99	40.00%	60.00%	40.00%	20.00%	20.00%	20.00%
Overall	**68.00%**	**57.00%**	**24.00%**	**33.00%**	**8.00%**	**10.00%**

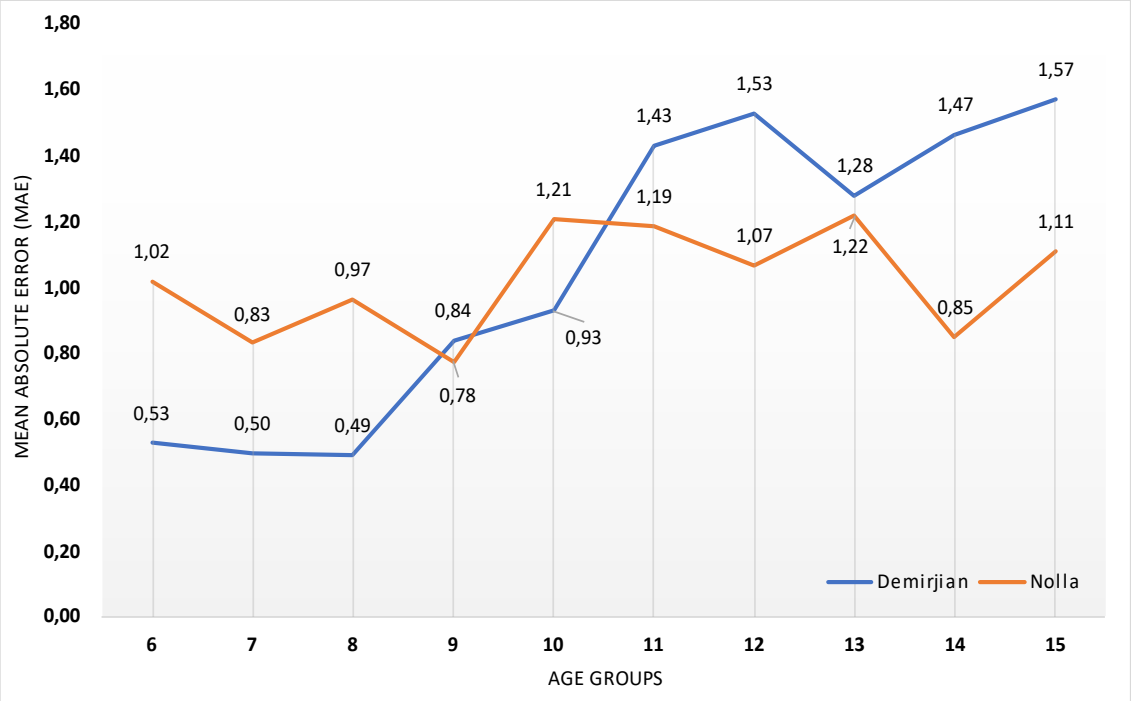

Figure 1. Mean absolute error (MAE) between the chronological age (CA) and estimated dental age (DA) using the Demirjian and Nolla methods.

A meta-analysis by Yan et al. (2013), which examined 26 studies of the Demirjian method in children aged 3.5 to 16.9 years, identified a consistent pattern of overestimations. In addition, the results indicated that Demirjian's method is better suited for Asians than for Caucasians (17). The two meta-analyses of Demirjian's method emphasized that discrepancies between the

study population and the population for which the method is intended may substantially impair its accuracy (16,17).

The Nolla method exhibits varying levels of accuracy across different populations. Although it is traditionally associated with a tendency to underestimate dental age, this study identified a general trend of overestimation. Comparable results have been observed in Malaysian, Northern Chinese, and Indian children (18–20). In contrast, studies involving Bangladeshi, British Caucasian, and Turkish children have consistently demonstrated underestimation when employing the Nolla method (21,22). Paz Cortez et al. (2019) conducted a study on Spanish children, revealing that the Nolla method generally underestimated age and demonstrated greater accuracy for males compared to females (23). The overestimation noted in this study corresponds with findings from populations categorized as Mongoloid, including Indonesians, Malaysians, and Northern Chinese, indicating that common genetic and environmental factors may influence dental development (20,24).

Al-Juhani et al. (2024) evaluated the accuracy comparison of the Nolla and Demirjian methods in a meta-analysis of 25 studies. The study indicated that the Demirjian method overestimated CA in males by an average of 0.5 years, while the Nolla method underestimated age by 0.25 years. In females, the Demirjian method overestimated CA by an average of 0.54 years, and the Nolla method underestimated it by 0.25 years. A notable mean difference of 0.7 years was observed between the two methods. Most of the included studies reported that the Demirjian method overestimated the CA, whereas the Nolla method tended to underestimate it (25).

Several studies found that the Nolla method had greater accuracy than Demirjian's. For instance, Nur et al. (2012) analyzed 673 panoramic radiographs of northeastern Turkish children aged 5–15.9 years and reported a mean error of −0.54 years for the Nolla method and 0.86 years for the Demirjian method (26). Similar results were discovered by Melo and Ata-Ali (2017) in a study of 2,641 Spanish children aged 7–21 years (27). A study by Han et al. (2020) found that the Demirjian method had the highest MAE compared to the Willems and Nolla methods in a Northern Chinese population. In contrast, the Nolla method showed the lowest MAE and mean error, indicating greater reliability for this population (20).

In contrast to previous research, this study found that the Demirjian method exhibited lower MAE values than Nolla's across males, females, and the total subjects in the Surabaya population. These results highlight the importance of validating age estimation methods before applying them to certain populations since factors like genetics, environment, and nutritional factors can greatly affect dental development (20).

An analysis of MAE by age group revealed that the Demirjian method yielded smaller MAE values in the younger age group (6 to 10 years), whereas the Nolla method demonstrated lower MAE values in the older age group (11 to 15 years). These results were supported by the findings of Pliska et al. (2024), who reported that the Demirjian method had a greater accuracy for younger ages, while the Nolla method tends to align more closely with CA in older ages (28). Lopes et al. (2018) found that the Nolla method was particularly effective for age estimation around the onset of the growth spurt at 11 to 12 years in Brazilian children (29).

Currently, there is no universally accepted method for accurate dental age estimation, as each technique presents specific strengths and limitations. The Nolla method categorizes dental development into ten stages, effectively capturing the continuous maturation of permanent teeth. However, the subjectivity of observation can make the Nolla method challenging to apply consistently (30). In addition, it has been suggested that the increased number of stages in the Nolla method could moderately decrease the precision of the method while also complicating the assessment (21). Conversely, the Demirjian method focuses on eight tooth developmental stages. This technique offers a structured and less subjective approach. However, the method's reliance on double numerical conversion for age estimation may limit its practicality in clinical applications (31).

The limitations of this study must be acknowledged. First, the sample size, while acceptable for preliminary validation, is relatively small and may not capture the full range of variability in the Indonesian children's population. Second, we did not compute prediction intervals for individual age estimations, which would be valuable in forensic practice where uncertainty need to be quantified.

Based on the findings of this study, it is recommended that the accuracy of the Nolla, Demirjian, and other dental age estimation methods be rigorously validated for specific populations since regional differences in genetic,

environmental, and nutritional factors can influence dental development. Forensic odontologists can determine the best approach by considering population-specific accuracy, age group, sex, and the context of the case. The combined use of both methods offers cross-verification, comprehensive assessment, bias mitigation, and enhanced reliability (25).

Conclusion

The present study evaluated the applicability of the Demirjian and Nolla dental age estimation methods in Indonesian children. The results of this study suggested that Demirjian's method had better applicability for females. In addition, the Demirjian method showed higher accuracy in younger children, whereas the Nolla method performed better in older children. While each method has its unique advantages, using both methods in tandem can provide a more robust and reliable age estimation in forensic practice. Future studies with larger samples should focus on developing calibrated models tailored to the demographic and environmental contexts of specific populations for effective application in forensic and legal settings.

Declarations of interest

None

Author Contributions

AK: conceptualization, formal analysis, methodology, writing original draft, review & editing, supervision; AA: writing original draft, methodology, supervision; MIM: writing original draft, review & editing; BNR: writing original draft, review & editing; BFWRP: writing original draft, review & editing; PSJ: conceptualization, methodology, data curation, formal analysis; JMEL: investigation, data curation; RD: investigation, data curation; AM: methodology, writing original draft, review & editing; AA: conceptualization, writing original draft, review & editing; RAAR: formal analysis, writing original draft, review & editing.

Statement on the use of artificial intelligence in manuscript preparation

The authors acknowledge the use of artificial intelligence (AI) tools in the preparation of this manuscript to assist in language editing, grammar correction, and refining sentence structure to improve clarity and readability. The intellectual content, study design, data interpretation, and conclusions presented in this manuscript are solely the work of the authors. All critical thinking, scientific analysis, and decision-making were performed by the authors, and no generative AI was used for data generation, analysis, or drawing scientific conclusions.

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