ORIGINAL ARTICLE

Evaluation of Accuracy of Clinical method for Age Estimation in 6–14 Year old Children in Vadodara City: An Institute based Cross-sectional Study

Shah R,[1] Poonacha KS,[2] Dave B,[3] Bargale S,[4] Deshpande A,[5] Kariya P.[6]

1-6. Department of Pediatric and Preventive Dentistry, K. M. Shah Dental College and Hospital, Sumandeep Vidyapeeth, Vadodara.

Abstract:

Age of an individual is important in order to identify a person, living or dead. Unavailability of such important detail mandates estimation of such parameters using different methods. Age estimation using teeth can be highly valuable since teeth are highly durable, resistant to putrefaction, fire, chemicals and shows minimal post mortem destruction. One such age estimation method based on teeth eruption was given by Foti B et al in French Population. However, individual growth factors like genetics, race, ethnicity, tend to exhibit difference in eruption timing and sequence in different population. Hence, the present study aimed to check the accuracy of such models in the Indian subpopulation. And to develop a more accurate and reliable age estimation formula for the children of Vadodara. 80 Children aged 6 – 14 years born in Vadodara were clinically evaluated to check the number of erupted teeth. Foti's clinical method of age estimation based on eruption status of permanent teeth was used to derive the age of each child. A new age estimation formula specific to local population was derived. A comparative evaluation of the Age_New_Formula was done with Foti's equations and chronological age. Statistical analysis revealed higher correlation between chronological age and estimated dental age using Age_New_Formula as compared to original equations given by Foti. Age_New_Formula is based on teeth eruption pattern of the local population. Hence, this equation can be more accurate and reliable for age estimation in 6-12 year of children in Vadodara City.

Keywords: Age estimation; Tooth eruption; Forensic anthropology.

Introduction:

Forensic odontology has grown explicitly worldwide in the past few decades. Human identification is a prime challenge in a lot of criminal cases. Age estimation of the living or dead can be an important determinant in forensic medicine especially in an over populated country like India. Age estimation also has a wide role in situations like child adoption, child marriage, penal code, infanticide, rape, judicial punishment, commercial or sexual exploitation, domestic employment, requests for political asylum, issues of inheritance and pension claims of the elderly etc.[1,2] Unavailability of crucial details like 'Age' mandates estimation of such parameter using various available techniques. Age estimation methods most frequently used in children includes skeletal maturation and number of erupted teeth and its developmental stages. Among the two, age estimation using teeth has demonstrated higher correlation.[3,4] Also, teeth are a valuable tool as they are highly durable, resist to putrefaction, fire, and chemicals and shows minimal post mortem destruction.

The first known attempt to use teeth as an indicator of age originated from England. Edwin Saunders, a dentist, was the first to publish information regarding dental implications in age assessment by presenting a pamphlet entitled “Teeth A Test of Age” to the English parliament in 1837.[5] The time of eruption of primary and permanent teeth are fairly constant in a population, and assessment of age of an individual by the examination of teeth is one of the accepted methods of age determination. There are multiple such methods based on eruption of teeth, which can be used for age identification. Principally, these methods are Radiographic and Clinical methods.[6] However, in areas with unavailability of radiographs, it is important to have accurate Clinical age estimation method. Also, clinical method is quicker, inexpensive and does not require any special equipment.

One such age estimation method was given by Demirjian et al. It seems that both the original and simplified formulas of Demirjian et al.,[6] Demirjian and Goldstein[7] are easy to use and have practical interests. However, this method did not yield reliable results in Asian people[8] and Indians,[9] which was explained by diversity of development stages in children between 5 and 12 years of age.[10] Another such method for estimation of age using clinical as well as radiologic method was given by Foti B et al. in French Population.[11] He proposed mathematical models (equations) for age calculation based on counting erupted teeth. This novel method for age determination in children with calculation models is simple, accurate, and reliable. However, as mentioned above, individual growth factors like genetics, race, ethnicity, geographical location, tend to exhibit difference in eruption timing and sequence in different population groups. The normal tooth eruption patterns that were recorded for a western society cannot be applied to an Indian scenario.[12] Acharya et al. thus derived an Indian specific regression formula using Demirjian's 8-teeth method.[13]

Hence, the present study aimed to check the accuracy of such models in the Indian population. And to develop a more accurate

Corresponding Author
Dr. Ridhika Shah (Post Graduate Student)
Email: riddhikashah13@gmail.com
Mobile No.: +91 9834654508

Article History
DOR : 28.08.2023; DOA : 03.12.2023

and reliable age estimation formula for the children of Vadodara city of central Gujarat.

Material and methods:

The present study was an Observational Cross-sectional study. Ethical clearance was obtained from Sumandeep Vidyapeeth Institutional Ethics Committee. 80 healthy children between 6 – 14 years of age residing in Vadodara since past two generations were selected from the Outpatient Department of Pediatric & Preventive Dentistry. Informed consent was obtained from the parents of these children before initiation on the study. The age group of 6-14 year was selected based of timings of permanent teeth eruption. Patients with any medical history, or Congenital anomalies were not included.

Chronological Age: A photo copy of Birth Certificate/ Aadhar Card was obtained from the parent of each study participant. Based on birth date, age of the child was then calculated. For the convenience of statistical analysis, age was converted to a decimal value (e.g. 7 years 6 months and 5 days was rounded of to 7.6 years, No. of days above 15 was rounded off to a higher number e.g. 7 years 6 months and 25 days was rounded of to 7.7 years) In order to avoid observer bias, these values were calculated independently by a person other than the observer.

Age estimation: A meticulous intraoral clinical examination was done by the principal investigator in presence of sufficient natural light, using mouth mirror and dental probe. The tooth numbers of erupted permanent teeth in each quadrant were filled in the proforma sheet. A tooth was considered to have erupted if at least part of the tooth had pierced the gingiva (gingival emergence/ eruption). Foti's Age estimation Models (1,2,3) were used to calculate the age of each child and this data was compared with the chronological age in order to check the accuracy of this method on the study population. The original regression models derived by Foti B. et al are as follows:

- Model no. 1 (FOTI 1): based on all the teeth present in the oral cavity at the time of examination

  ESTIMATED AGE = 13.652 - (0.514 x number. of deciduous. upper incisors) - (0.236 x number of deciduous. upper molars) + (0.314 x number of permanent Upper canines) - (1.748 x number of permanent Upper 1st molars) + (1.012 x number of permanent Upper 2nd molars) + (0.944 x number of upper 3rd molars) + (0.252 x number of lower premolars) + (0.285 x number of permanent Lower 2nd molars) + (1.537 x number of lower 3rd molars)

- Model no. 2 (FOTI 2): regression model based on all teeth present in upper jaw

  ESTIMATED AGE = 13.704 - (0.567 x number of deciduous upper incisors) - (0.367 x number of deciduous upper molars) + (0.530 x number of permanent Upper canines) - (1.449 x number of permanent Upper 1st molars) + (1.359 x number of permanent Upper 2nd molars) + (2.041 x number of erupted 3rd molars)

- Model no. 3 (FOTI 3): regression model based on teeth present in the lower jaw

  ESTIMATED AGE = 9.726 - (0.571 x number of deciduous lower incisors) - (0.378 x number of permanent Lower canines) + (0.579 x number of lower premolars) + (1.056 x number of permanent Lower 2nd molars) + (2.236 x number of lower 3rd molars)

Statistical Analysis: The chronological age of each individual was compared with the estimated values obtained using Foti's Model 1, 2 & 3. Further, the data collected based on eruption timings of local population from the study population was subjected to forward stepwise linear regression in order to derive the variables of higher significance in the study population. The

Table1. Represents the forward stepwise linear regression analysis.

Excluded Variables[a]						
Model		Beta In	t	P value	Partial Correlation	Collinearity Statistics
						Tolerance
1	DUI	-.118[b]	-1.299	.198	-.146	.792
	DUM	-.392[b]	-3.365	.001	-.358	.432
	PUC	-.143	1.413	.162	.159	.639
	PU1M	-.011[bb]	-.137	.891	-.016	.957
	OY/2N	-.369[b]	4.485	<0.001	.455	.787
	LPM	-.228[b]	1.664	.100	.186	.346
	PL2M	-.378[b]	4.276	<0.001	.438	.693
	DLI	-.098[b]	-1.176	.243	-.133	.942
2	DUI	-.126[c]	-1.550	.125	-.175	.791
	DUM	-.217[c]	-1.789	.078	-.201	.352
	PUC	-.012[c]	.120	.905	.014	.572
	PU1M	-.025[c]	-.329	.743	-.038	.955
	LPM	-.065[c]	.494	.623	.057	.314
	PL2M	-.183[c]	1.304	.196	.148	.269
	DLI	-.079[c]	-1.050	.297	-.120	.939

a. Dependent variable: Chro. Age
b. Predictors in the Model: (Constant), PLC
c. Predictors in the Model: (Constant), PLC, PU2M

Table 2. Represents the R value and standard error of estimate.

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
2	.768[b]	.590	.580	1.1932791

b. Predictors: (Constant), PLC, PU2M.

Table 3. Represents the Comparison of the chronological age in terms of {Mean (SD)} with the age calculated using FOTI's age estimation formula model 1, 2 & 3 and Age_New_Formula using paired t test. (p < 0.05 - Significant*, p < 0.001 - Highly significant).**

		N	Mean±SD	Mean Difference ± SD	t	P Value
Pair 1	Chro. Age	80	10.38±1.84	-1.32.03	-5.74	<0.001
	FotiM1	80	11.68±2.53			
Pair 2	Chro. Age	80	10.38±1.84	-0.52±1.47	-3.16	0.0002
	FotiM2	80	10.9±2.17			
Pair 3	Chro. Age	80	10.38±1.84	-0.02±1.86	-0.10	0.923
	FotiM3	80	10.4±2.12			
Pair 4	Chro. Age	80	10.38±1.84	0±1.18	0.00	0.997
	Age_New_Formula	80	10.38±1.41			

 DOI : 10.48165/jiafm.2024.46.2(Suppl).14

Regression Analysis suggests that Permanent Lower Canine (PLC) and Permanent Upper 2nd Molar (PU2M) are the most relevant constant variable in the study population. Thus, these two variables were included in the new formula for age prediction. The newly derived formula is titled Age New Formula.

Age = 8.832 + 1.015 (PLC) +0.840 (PU2M);

R value of 0.768 and SEE of 1.1932 years

The Statistical software IBM SPSS statistics 20.0 (IBM Corporation, Armonk, NY, USA) was used for the analyses of the data and Microsoft word and Excel were used to generate graphs, tables etc.

Results:

Forward Stepwise Linear Regression analysis was used to procure the most significant 'variables' necessary for deriving a new formula. Table 1. represents the constant variable derived for the new formula. Here, permanent lower canine (PLC) and Permanent Upper Second Molars (PU2M) are the constant predictors. This suggests that these two teeth are the most relevant constant variables with minimum variation in eruption timing for the study population. A part of regression analysis was used to derive the coefficients in the formula. Here 8.832 is the constant. The unstandardized coefficient for PLC is 1.015 and for PU2M is 0.840.

Table 2. represents the R value and Standard Error of Estimate. An R value of 0.768 represents a good co-relation between chronological age and the newly derived formula. SSE value represents the Standard Error of estimate in age. Thus, an error of 1 year and 1 month can occur in the Estimated Age using the new formula.

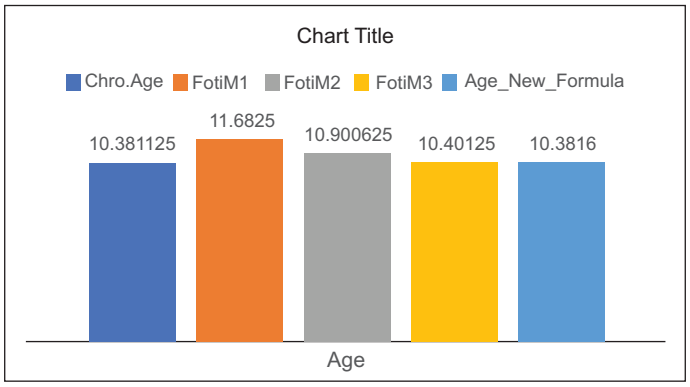

Figure 1. Represents the bar graph of the mean values of chronological age & age calculated using foti's models and age_new_formula.

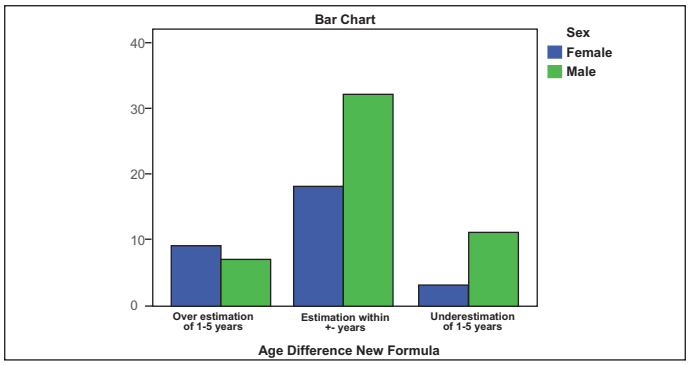

Figure 2. Shows the comparison of estimated values using age_new_ formula among males and females using chi square test.

Chronological age was then compared with Foti et. al's Models and Age_New_Formula using paired t test (Table 3). On comparison of the mean values of chronological age with Foti's Models the mean values of FotiM1 and FotiM2 was higher and statistically significant with a p value of <0.05. The Mean value of FotiM3 represents least Mean difference of 0.02±1.86 when compared with chronological age suggestive of accuracy of FotiM3 as compared to model 1 and 2. Further, when the Age_New_Formula was compared with the Chronological age the difference between the Mean (SD) was 0.0015 indicating a very high correlation between these two formulae.

Further, Chi square test was used to check the distribution of over-estimated and under estimated values in males and females for Foti's Models and Age_New_Formula. Overall Foti's Model 1, 2 have shown overall higher levels of over estimation and under estimation of age in males as compared to females. Foti Model 3 showed over-estimation almost similar in both the genders. However, underestimation was more in males as compared to females. Figure 2 shows the comparison of estimated values using Age_New_Formula among males and females. The Age_New_Formula has shown least values in terms of over-estimation and under estimation. An over estimation of 1-5 years was seen in 9 females and 7 males. Whereas, underestimation of 1-5 years was seen in only 3 females and 11 males. A total of 50 Individuals among which 18 are female and 32 are Male falls in the category of estimation within +/- 1 year indicating that the Age_New_Formula is the most accurate equation to be used for age estimation.

Discussion:

Age determination is an important part of Forensics. The age of cadavers is determined for a variety of reasons, including criminal cases and the severely dismembered victims of mass tragedies like fires, accidents, collisions, killings, feticides, and infanticides. Age estimation is done for people to determine whether the child has reached the age of a person's criminal liability in situations like rape, kidnapping, employment, marriage, orthodontics, premature births, adoption, unlawful immigration and pediatric endocrinopathy malocclusion, especially where records are questionable and the birth certificate is unavailable.[18-21] Kumar et al in a resent study in the year 2023 suggested, the most common and reliable techniques used for fast and secure identification are dental data, fingerprints and DNA comparisons.[22] Age estimation using dental remnants plays a crucial role in the identification of living and dead subjects as dental hard tissues are the least salvageable tissues in the body. Various physical, chemical, and histological methods have evolved over the years to estimate age using the teeth.[23] However, the majority of them result in the loss of physical evidence. Thus, Estimation of age by assessing the sequence of eruption has often been the preferred method as it closely coincides with the chronological age.

Primarily, radiographic & clinical methods are used for this purpose. However, absence of radiographic facility in parts of

Rural India demands accurate clinical methods independent of radiographs. As stated by Dsouza et al.[14] among the clinical methods, methods based on tooth eruption have been established as the most accurate. However, Towlson and Peck questions the reliability of tooth eruption as age indicator.[24] It is generally accepted that no single method can provide an accurate measure of an individual, be it adult or child. It is said that various methods of age estimation should be used in unison to achieve accurate levels of accuracy.[25]

Foti et al. conducted a study in the year 2003 in French children aged 6 to 20 years and proposed 4 regression models based on number of permanent teeth erupted in oral cavity and tooth germs. The 1st model proposed by Foti et al required presence of Orthopantomogram facility whereas the next three models were purely based on clinical evidence of tooth eruption. Since, genetic makeup of Indian population is much more diverse, it was necessary to check the accuracy to these models in Indian population.

When Foti el al's. models were assessed for their accuracy in the study population, Model 1 and 2 showed high level of inaccuracy to that of the chronological age. Model 3 showed highest level of accuracy among the 3 models. These results are in accordance with a study conducted by Dsouza et al.[14] in coastal children of India where they have also found that Model 3 has highest level of accuracy and least error among Foti's 3 Models.

Age_New_Formula shows a mean difference of 0.0015 when compared with chronological age using paired t test. This suggests that Age_New_Formula is more accurate for the study population. Similar results were found in the study by Dsouza et al.[14] wherein the population specific formula's showed better accuracy than Foti et al's models.

Dinkar et al.[26] in the year 2014 also studied the accuracy of Foti's models in Goan Population and concluded that Regression models based of local population showed high levels of accuracy. This difference could be attributed to ethnic and social diversity in a vast country like India. As stated by Khan AS (2020)[12] 'The growth and development patterns cannot be universally applied to the various ethnic variations.' They have also concluded that eruption time of different teeth was either directly or indirectly related to the BMI. Thus, diverse nutritional and lifestyle habits in India can also add into these factors. Gender wise comparison of Age_New_Formula using Chi square test showed no statistically significant difference between the Males and Females.

Sharma et al.[27] in 2015 conducted a study to assess the corelation between Skeletal age and Dental age in living Children and concluded that combination of these two methods should be used for more accurate estimation of age in living individuals.

This study proposed a simple and accurate age estimation equation for the population of Vadodara city. However, one must be judicious while extrapolating the observations made from the current study to the entire Gujarati population as there exists an enormous amount of genetic admixture and cultural diversities which necessitates population and subpopulation specific studies. Overall, smaller sample size mandates validation of the Age_New_Formula in larger population size.

Conclusion:

India is a country with vast genetic & cultural diversity. Studies have shown that people from different ethnic and racial groups not only show different variations in growth and development but also show difference in eruption pattern and timing of individual teeth.[12] Foti et al's Models were based on tooth eruption patterns in French population. These models have shown high level of inaccuracy in the study population. Age_New_Formula is based on teeth eruption sequence of the local population. Hence, this formula is more accurate equation for age estimation in 6-14 year of children in Vadodara city.

This study opens an expected door for a large sample size to be tested in various local populations with different ethnicity and race. Population specific studies on sequence of age eruption can help in better understanding of such parameters in future. Assessment of accuracy of Age_New_Formula in different regions of India is essential. Such studies can provide us formulae accurate to individual population and such research can revolutionise the future of Age estimation in Forensic odontology.

References:

1. Paul G Stimson. Textbook of Forensic Dentistry. 1997 by CRC Press LLC.
2. Maia MCG, Martins MG, Germano FA et al. Demirjian's system for estimating the dental age of north eastern Brazilian children. J Forensic Sci Int. 2010; 200: 177.e1-177.e4
3. Makkad RS, Balani A, Chaturvedi SS et al. Reliability of panoramic radiography in chronological age estimation. J Forensic Dent Sci. 2013;5(2):129-133.
4. Singh S, Venkatatapathy R, Balamurali PD et al. Digital approach for mea suring dentin translucency in forensic age estimation. J Forensic Dent Sci. 2013;5(1):47-51.
5. Stavrianos C, Mastagas D, Stavrianou I, Karaiskou O. Dental age estimation of adults: A review of methods and principles. Res J Med Sci. 2008; 2:258-68.
6. Demirjian A, Goldstein H, Tanner JM. A new system of dental age assessment. Hum Biol. 1973;45(2):211-27.
7. Demirjian A, Goldstein H. New systems for dental maturity based on seven and four teeth, Ann. Hum. Biol. 3 (5) (1976) 411–421.
8. Davis PJ, Hagg U. The accuracy and precision of the "Demirjian system" when used for age determination in Chinese children, Swed. Dent. J. 18 (3) (1994) 113–116.
9. Koshy S, Tandon S. Dental age assessment: the applicability of Demirjian's method in south Indian children, Forensic Sci. Int. 94 (1–2) (1998) 73–85.
10. Reventlid H, Mornstad A. Teivens, Intra- and interexaminer variations in four dental methods for age estimation of children, Swed. Dent. J. 20 (4) (1996) 133–139.
11. Foti B, Lalys L, Adalian P, Giustiniani J, Maczel M, Signoli M et al. New forensic approach to age determination in children based on tooth eruption. Forensic Sci Int.

2003;132(1):49-56.

12. Khan AS, Nagar P, Singh P, Bharti M. Changes in the Sequence of Eruption of Permanent Teeth; Correlation between Chronological and Dental Age and Effects of Body Mass Index of 5-15-year-old Schoolchildren. Int J Clin Pediatr Dent. 2020;13(4):368-380.
13. Acharya AB. Age Estimation in Indians Using Demirjian's 8-teeth Method. J Forensic Sci. January 2011;56(1):124-127.
14. De Souza N, Manju R, Hegde AM. Accuracy of clinical methods of age estimation based on permanent teeth present as erupted: A study on the coastal population of India. Forensic science international. 2018 Aug 1; 289:448-e1.
15. Periyakaruppan S, Meundi MA, David CM. Accuracy of age estimation in 6-21 year old South Indian population – A comparative analysis of clinical and radiographic methods. J Forensic Odontostomatol. 2018. Dec;(36): 2-10:19.
16. Martrille L, Papadodima S, Venegoni C, Molinari N, Gibelli D, Baccino E et al. Age Estimation in 0–8-Year-Old Children in France: Comparison of One Skeletal and Five Dental Methods. Diagnostics. 2023 Mar 9;13(6):1042.
17. Maber M, Liversidge HM, Hector MP. Accuracy of age estimation of radiographic methods using developing teeth. Forensic science international. 2006 May 15;159:S68-73.
18. Ciapparelli L. The chronology of dental development and age assessment. In: Clark DH, editor. Practical Forensic Odontology. Oxford: Wright Butterworth-Heinemann Ltd.; 1992. p. 22-42.
19. Masthan KM. Age and sex. Textbook of Forensic Odontology. New Delhi: Jaypee Brothers Medical Publishers (P) Ltd.; 2009. p. 59-65. 13.
20. Griner PF, Mayewski RJ, Mushlin AI, Greenland P. Selection and interpretation of diagnostic tests and procedures. Principles and applications. Ann Intern Med. 1981;94:557-92.14.
21. Panchbhai AS. Dental radiographic indicators, a key to age estimation. Dentomaxillofac Radiol. 2011;40:199-212.
22. Kumar DR, Jatti VB, Patil A. Determination of Gender by Palatal Rugae Print. Journal of Indian Academy of Forensic Medicine. 2023 May 12;45(1):4-6.
23. Shafer's Textbook of oral pathology. 5th ed. New Delhi; Saunders; 1993.
24. Acharya, Ashith B. "Age Estimation in Indians Using Demirjian's 8 teeth Method." Journal of forensic sciences. 56.1 (2011): 124-127.
25. Warhekar, Ashish M, Wanjari PV, Phulambrikar T. "Correlation of radiographic and chronological age in human by using Demirjian's method: A radiographic study." Journal of Indian Academy of Oral Medicine and Radiology. 23.1 (2011): 1-4.
26. Khorate MM, Dinkar AD, Ahmed J. Accuracy of age estimation methods from orthopantomograph in forensic odontology: a comparative study. Forensic science international. 2014 Jan 1; 234:184-e1.
27. Sharma GA, Jain A, Yadav A, Kabi D, Kumar A. Correlation between Skeletal Age and Dental Age in Living Individuals. Journal of Indian Academy of Forensic Medicine. 2015;37(3):283-5.