DOI: 10.7860/JCDR/2018/35978.11461

Original Article

Dentistry Section

Dental Age Estimation Using Percentile Curves and Regression Analysis Methods - A Test of Accuracy and Reliability

ARUN KUMAR PATNANA[1], NARASIMHA RAO V VANGA[2], SRINIVAS KUMAR CHANDRABHATLA[3], RAJASEKHAR VABBALAREDDY[4]

ABSTRACT

Introduction: Age estimation using the developmental stages of tooth is considered the most reliable method for forensic investigations and for planning the age dependent treatment modalities in clinical applications.

Aim: To evaluate the accuracy and reliability of percentile curves and regression analysis methods in dental age estimation of Indian population.

Materials and Methods: The study includes orthopantomographs (OPGs) of 224 individuals (107 males and 117 females) belonging to the age group of 8-24 years. The study participants were divided into two groups as Group I (8 to 14 years) and Group II (15 to 24 years). The study groups were evaluated under two percentile curve methods (Demirjian's seven teeth method and Demirjian's eight teeth method) and two regression analysis methods (Indian specific models and South France models). The accuracy of each method was evaluated using Mean Errors (ME), Mean Absolute Errors (MAE) and Root Mean Square Error (RMSE), the reliability of each method was tested using the percentage of misclassifies (%M) under 99% of confidence intervals.

Results: In Group I, for males South France regression models showed accurate (MAE=1.05) and reliable results (%M=0.15), for females Indian models showed accurate results (MAE=1.25) and South France models showed reliable results (%M=0.11). In Group II, for males (MAE=2.16; %M=0.67) and females (MAE=1.71; %M=0.58), Indian models showed accurate and reliable results.

Conclusion: The regression analysis methods showed accurate and reliable results than the percentile curve methods in both the age groups.

Keywords: Developmental stages, Forensic odontology, Forensic sciences

INTRODUCTION

The dental age estimation has a significant role in the forensic investigations and in clinical applications to determine the degree of maturation in individuals [1]. The most commonly used methods for age estimation are based on the radiographic analysis of tooth calcification stages [2,3]. The ease of use and non invasive advantages made the radiographic methods more appropriate for dental age estimation [4]. Demirjian's method using the calcification stages of mandibular left seven teeth is the most widely used dental age estimation method [5]. The representation of the each developmental stage with illustrations and line diagrams made the Demirjian's method widely accepted [1,6].

The researchers around the globe evaluated the applicability of Demirjian's method and found inaccurate results of age estimation when applied on population groups other than French Canadians [5-8]. Hence, in the quest of improving the applicability, the original Demirjian's method was modified in several ways, such as exclusion of the maturity score in dental age calculation, inclusion of third molars for age estimation, modifications in the scoring criteria of the calcification stages of tooth [1,6,9,10].

Demirjian A and Goldstein H, excluded the third molars in dental age estimation because of its variations in the eruption patterns and tooth development [1]. However, there is no other biological indicator except third molars available for dental age estimation in late adolescents [1,9]. Thus, Chaillet N et al., have included the third molar to widen the dental age estimation methodologies in higher age groups up to 18 years [9,10]. The 8 stage scoring scale (A to H scale) suggested by Demirjian A and Goldstein H was modified by Chaillet N et al., to ten stage scoring scale (0 to 9 scale), where two additional stages of Stage '0' (No initiation of dental calcification) and Stage '1' (Crypt stage with no tooth germ) were added to improve the accuracy of the dental age estimation methodologies [1,9]. Chaillet N et al., have also developed gender specific weighted scores using percentile curves for accurate dental age estimation using seven teeth and eight teeth to improve the accuracy of dental age estimation [9]. Along with the addition of third molars, modifications in the tooth scoring system, and new gender specific percentile curves, researchers also suggested the development of population specific regression models for reliable dental age estimation around the globe [9-13].

Irrespective of various modifications and adaptations in the dental age estimation methodologies, variations of dental maturity in different ages and populations limits the applicability of any specific method to all the age groups and all population groups [10-14]. Hence, the aim of the present research was to compare the accuracy and reliability of percentile curves and regression analysis methods in dental age estimation of Indian population. The null hypothesis states that there would be no difference in the percentile curve methods and regression analysis methods for dental age estimation in Indian population.

MATERIALS AND METHODS

The present cross sectional study was conducted in GITAM Dental College and Hospital, Visakhapatnam, Andhra Pradesh, India during the time period of March 2014 to March 2015. The study included the OPGs of 224 individuals (107 males and 117 females) in the age ranging from 8 to 24 years. The OPGs and dental records including data of birth of study participants were collected during the time period of 2012 to 2014 from Department of Pedodontics and Department of Orthodontics. The good quality OPGs with no evidence of medical or surgical deformity affecting the left mandibular teeth were included.

The individuals in the present study were evaluated under two study groups {Group I-Participants of 8 to 14 years age (n=86) and Group

II-Participants of 15 to 24 years age (n=138)}. The dental age was estimated for every participant included in both the groups using two percentile curve methods (Demirjian's seven teeth and Demirjian's eight teeth method) [9] and two regression analysis methods (Indian population specific regression models and South France population regression models) [9,15] [Table/Fig-1]. The OPGs included in the study were evaluated initially by a single trained observer for recording the demographic and dental findings. The OPGs were further allocated to the other trained observer who is completely unaware of the demographic details and actual age of the included participant.

The dental age estimation using Demirjian's seven teeth percentile method include the calculation of maturity scores using the gender specific ten stage scoring scale for each tooth in the mandibular left permanent teeth excluding the third molars [9]. The calculated maturity scores were converted to estimated dental age using the percentile tables (50^{th} percentiles) given by Chaillet N et al., separately for boys and girls in South France [9]. The dental age estimation for Demirjian's eight teeth percentile method is similar to the seven teeth method, where the left mandibular third molar was also used for maturity score calculation and converting it to the estimated dental age [9].

The dental age estimation using the regression models, include the calculation of maturity scores using the Demirjian's eight teeth method as explained above and then substitution of those maturity scores in the regression formulas for Indian specific population and South France population [9,15]. Chronologic age of each individual was calculated by subtracting the date of birth from the date of OPG taken. The first fifty OPGs were allocated to two trained observers for evaluating the interobserver variability. If no difference was evident between the two observers, further scoring of the OPGs were done only by a single chief observer. In order to evaluate the intra observer variability, 50 randomly selected OPGs were allocated to the chief observer again, three months after the initial examination of OPGs.

STATISTICAL ANALYSIS

The inter and intra observer variability was evaluated by Kappa statistics. The two tailed t-test was applied to evaluate the statistical significance in the chronologic age and maturity scores in Group I and Group II. The p-value of less than 0.05 was considered as statistically significant. The applicability of dental age estimation methods in various clinical and forensic investigations were determined by the accuracy and reliability of the particular method [9]. The accuracy is determined by the mean of absolute mean differences between the estimated dental age to the actual real age of the each individual (MAE) [15] whereas the reliability of the age estimation methodology was determined by the percentage of individuals whose actual real age is not within the 99% confidence interval (% of misclassifies) [10]. Hence, in the present study, four different age estimation methods were evaluated for accuracy and reliability using ME, MAE, RMSE and percentage of misclassifies (%M) using 99% confidence interval. The statistical analysis was performed using the SPSS software version 16.0.

RESULTS

The inter and intra observer analysis for scoring the developmental stages of mandibular left permanent teeth were 0.90 and 0.89 respectively. The descriptive statistics for chronologic age and maturity score in the present study are shown in [Table/Fig-2]. The mean chronologic age in both the groups were observed to be relatively lower for females than males. The two tailed t-test showed no statistical significant difference in Group I (p=0.12) and in Group II (p=0.82) for chronologic age between males and females. The mean maturity scores were observed to be relatively lower for females than males in both the age groups analysed (Group I and II). The two tailed t-test showed no statistical significance (p=0.36) of maturity scores between males and females in Group I, where as the two tailed t-test showed statistical significance (p=0.008) of maturity scores between males and females in Group II.

In males of Group I, Indian specific regression model method showed the lowest mean difference (0.06 years), however, the South France regression model method showed the lowest MAE (1.05). The Demirjian's seven teeth percentile method shows maximum RMSE of 1.90 when compared to other methods. The South France regression model method showed the least number of misclassifies percentage (0.15) when compared to all other methods in the present study. In females of Group I, Indian specific regression model method showed the lowest mean difference (0.26 years), lowest MAE (1.25). The Demirjian's seven teeth percentile method shows maximum RMSE of 2.13 when compared to other methods. Similar to the males, the South France regression model method showed the least number of misclassifies percentage (0.11) when compared to all other methods in the present study [Table/Fig-3].

In males of Group II, Indian specific regression model method showed the lowest mean difference (1.62 years), and lowest MAE (2.16). The South France regression model method shows maximum RMSE of 5.36 when compared to other methods. The Indian specific regression model method showed the least number of misclassifies percentage (0.67) when compared to all other methods in the present study. In females of Group II, Indian specific regression model method showed the lowest mean difference (1.34 years), and lowest MAE (1.71). The South France regression model method shows maximum RMSE of 5.14 when compared to other methods. However, the Demirjian's eight teeth percentile method, Indian specific regression model method and South France regression model method shows equal and lowest misclassifies percentage of 0.58 in the present study [Table/Fig-4].

Regression model	Males	Females
Indian population specific regression model	$EA=27.4351-(0.0097\times S^2)+(0.000089\times S^3)$	$EA=23.7288-(0.0088\times S^2)+(0.000085\times S^3)$
South France population specific regression model	$EA=(0.000055\times S^3)-(0.0095\times S^2)+(0.6479\times S)-8.4583$	$EA=(0.0000615xS^3)-(0.0106\times S^2)+(0.6997\times S)-9.3178$

[Table/Fig-1]: Regression formulas used in the present study [9,15].
EA: Estimated dental age; S: Maturity score

Groups	Sex	Chronologic age			Maturity score		
		Range	(Mean±SD)	p-value	Range	Mean±SD	p-value
Group I	Males (n=41)	9.75-14	12.17±1.24	0.12	78.42-96.69	90.18±5.43	0.36
	Females (n=45)	8-14.08	11.69±1.55		68.75-97.81	91.39±6.76	
Group II	Males (n=66)	15-24.41	19.82±2.43	0.82	90.87-100	98±2.53	0.008*
	Females (n=72)	16-24.83	19.72±2.28		89.56-100	96.79±2.77	

[Table/Fig-2]: Descriptive statistics for chronologic age and maturity score in the present study.
*Statistically significant difference (p=<0.05)
Two tailed t-test was used for statistical analysis

Age estimation methods	Males					Females				
	EA (M±SD)	ME (years)	MAE (years)	RMSE (years)	Misclassifies %	EA (M±SD)	ME (years)	MAE (years)	RMSE (years)	Misclassifies %
Demirjian's seven teeth percentile method	11.12±1.80	- 1.04	1.41	1.90	0.67	10.41±1.74	-1.28	1.73	2.13	0.69
Demirjian's eight teeth percentile method	11.23±1.83	- 0.94	1.44	1.89	0.70	10.31±1.47	-1.38	1.60	1.93	0.55
Indian specific regression model method	12.10±1.60	- 0.06	1.21	1.53	0.65	11.42±1.58	-0.26	1.25	1.57	0.63
South France regression model method	13.19±1.40	1.02	1.05	1.08	0.15	13.28±1.70	1.59	1.59	1.62	0.11

[Table/Fig-3]: Mean error, Mean absolute error, Root mean square error and percentage of misclassifies observed using the percentile and regression analysis methods in Group I.
EA: Estimated age; ME: Mean error; MAE: Mean absolute error; RMSE: Root mean square error

Age estimation methods	Males					Females				
	EA (M±SD)	ME (Years)	MAE (years)	RMSE (years)	Misclassifies %	EA (M±SD)	ME (years)	MAE (years)	RMSE (years)	Misclassifies %
Demirjian's seven teeth percentile method	15.99±0.95	- 3.82	3.90	4.52	0.79	16.18±1.67	-3.54	3.57	4.17	0.69
Demirjian's eight teeth percentile method	17±1.54	-2.8	2.97	3.50	0.68	15.87±1.78	-3.85	3.85	4.28	0.58
Indian specific regression model method	18.19±1.50	-1.62	2.16	2.61	0.67	18.38±1.74	-1.34	1.71	2.29	0.58
South France regression model method	15.33±2.44	-4.48	4.48	5.36	0.97	14.92±0.98	-4.80	4.80	5.14	0.58

[Table/Fig-4]: Mean error, Mean absolute error, Root mean square error and percentage of misclassifies observed using the percentile and regression analysis methods in Group II.
EA: Estimated age; ME: Mean error; MAE: Mean absolute error; RMSE: Root mean square error

DISCUSSION

The Demirjian's dental age estimation method using developmental stages of mandibular left seven teeth is widely used in forensic and clinical investigations [1]. The present research was undertaken to evaluate the efficiency of percentile curve methods to the regression analysis methods in Indian population. In the present research, participants were divided into two study groups (8 to 14 years and 15 to 24 years) as the dental maturation varies in different age groups [9,14]. The division of participants based on age was in accordance with Acharya AB [15], and Thevissen PW et al., [16], who observed that, in late adolescence (after 14 years) third molars are the only tooth which undergoes development to aid in the dental age estimation.

The original Demirjian's method was modified by Chaillet et al., by modifying the tooth development staging (0-9 scale) and including third molars for age estimation to improve the reliability in dental age estimation methodologies [9,10]. Though modified Demirjian's method was evaluated for its accuracy in Indian population by Kumar VJ et al., no study have yet compared the efficiency of Demirjian's seven teeth and Demirjian's eight teeth method using modified scoring criteria (0-9 scale) in Indian population [17]. Thus, both the Demirjian's seven teeth and eight teeth percentile curve methods were tested for accuracy and reliability in the present study.

Along with the earlier modifications, Challait N et al., have advocated the use of polynomial regression models for reliable dental age estimation [9]. Though, the use of polynomial equations showed reliable dental age estimation specific to a particular population group [12,13], the applicability of those regression models in other population groups need to be considered depending upon the ethnic variability in different populations around the globe. In such a context, Indian population specific regression models were also developed [15], which showed accurate and reliable results, when compared to the South France population regression models [9] applied in the Indian population. However, considering the fact of diverse regional and ethnic variations in India [14], Indian population specific regression models [15] need to be evaluated for their applicability in different regions of India. In fact, Thevissen PW et al., and Liversidge HM et al., found no variability when single regression model was applied in different ethnic groups, contradicting the concept of developing population specific regression models [16,18]. Hence, the present research also aims at evaluating the necessity of population specific regression models by evaluating both South France regression models [9] and Indian population regression models [15].

The males in the age group of 8 to 14 years, showed accurate and reliable results with the use of regression models developed for South France population rather than regression models developed for Indian population. The results are according to Thevissen PW et al., and Liversidge HM et al., who contradicted the need of population specific regression models for age estimation [16,18]. The present study results are also according to Tandon A et al., where they observed that the Indian population specific models are not applicable in the population of Bahadurgarh, Haryana, India [19]. However, the present study results are contradictory to the results of earlier reports [15,20] who suggested the use of Indian population specific regression models for age estimation in Indian children [15]. The unreliable results with the Indian specific models might be because of variations in the age groups analysed in the present study to the original study (8-14 years) from which Indian specific regression models were developed (7-25 years) [15].

In females of 8 to 14 year age group, Indian population specific regression models gave accurate results and South France regression models gave reliable results in the present study. The accurate results with the Indian specific formulas suggest the use of population specific regression models for accurate results [9,12,13]. In both males and females of 8-14 year age group, reliable results of South France regression models in the Indian population shows the robustness of cubic regression models developed by Chaillet N et al., [9].

The use of ten stage scoring criteria, couldn't improve the accuracy levels of Demirjian's seven teeth percentile curve methods, which shows the least accurate results for both males and females of 8 to 14 year age group in the present study. However, inclusion of third molars in the Demirjian's method improves the accuracy when compared to the Demirjian's seven teeth method for both males and females. Thus, the authors suggest the inclusion of third molars for age estimation, if third molar is evident in the radiographs.

The males and females in the 15 to 24 year age group showed accurate and reliable results with Indian specific regression models, when compared to the South France population regression models. The present study results are in accordance with Acharya AB [15], Mohammed RB et al., [21], where they observed the accuracy and reliability of Indian population specific regression models in South Indian population. The improved accurate and reliable results of Indian population specific regression models over South France regression models can be explained by the construction of population specific regression models with the only developing third molar after 14 years of age. The results of the present study recommend the need of population specific regression models for accurate and reliable age estimation in older age groups (>14 years). However, the results are contradictory to Tandon A et al., where they found an unreliable result with Indian population specific regression models in Northern Indian population [19]. Similar to the Group I, percentile curve methods showed unreliable results in the 15 to 25 year age group, which make the percentile curve methods unreliable and inaccurate when compared to the regression analysis methods in dental age estimation methodologies. .

LIMITATION

The limitations of the present study include the number of participants, where larger participant groups are required in evaluating of age estimation methodologies. The individual year wise analysis of the study participants might further increase the validity of the results in the present study. The authors recommend further studies to evaluate the percentile curves and regression methods in children of smaller age groups (<8 years).

CONCLUSION

The present study recommends the use of regression analysis methods over percentile curve methods for accurate and reliable results in males and females of 8 to 24 years age group. The present study specifically, recommend the use of ethnic independent South France regression models for younger age group (8 to 14 years) and ethnic dependent Indian specific regression models for age estimation in older age groups (15 to 24 years) for accurate and reliable results of age estimation.

REFERENCES

[1] Demirjian A, Goldstein H. A new system of dental age assessment. Hum Biol. 1973;45:211-27.
[2] Maber M, Liversidge HM, Hector MP. Accuracy of age estimation of radiographic methods using developing teeth. Forensic Sci Int. 2006;159:68-73.
[3] Moorrees CF, Fanning EA, Hunt EE. Age variation of formation stages for ten permanent teeth. Journal of Dent Res. 1963;42:1490-502.
[4] Panchbhai AS. Review dental radiographic indicators, a key to age estimation. Dentomaxillofac Radiol. 2011;40:199-212.
[5] Koshy S, Tandon S. Dental age assessment: the applicability of Demirjian's method in South Indian children. Forensic Sci Int. 1998;94:73-85.
[6] Willems G. A review of the most commonly used dental age estimation techniques. J Forensic Odontostomatol. 2001;19:09-17.
[7] Liversidge HM, Speechly T, Hector MP. Dental maturation in British children: are Demirjian's standards applicable? Int J Paediatr Dent. 1999;9:263-69.
[8] Frucht S, Schnegelsberg C, Monting SJ, Rose E, Jonas I. Dental age in southwest Germany: a radiographic study. J Orofac Orthop. 2000;61:318-29.
[9] Chaillet N, Demirjian A. Dental maturity in South France: A comparison between Demirjian's method and polynomial functions. J Forensic Sci. 2004;49:1059-66.
[10] Chaillet N, Nystrom M, Kataja M, Demirjian A. Dental maturity curves in Finnish children: Demirjian's method revisited and polynomial functions for age estimation. J Forensic Sci. 2004;49:1324-31.
[11] Mincer HH, Harris EF, Berryman HE. The A.B.F.O. study of third molar development and its use as an estimator of chronological age. J Forensic Sci. 1993;38:379-90.
[12] Mesotten K, Gunst K, Carbonez A, Willems G. Dental age estimation and third molars: a preliminary study. Forensic Sci Int. 2002;129:110–15.
[13] Uzamis M, Kansu O, Taner TU, Alpar R. Radiographic evaluation of third-molar development in a group of Turkish children. J Dent Child. 2006;67:136–41.
[14] Manjunatha BS, Soni NK. Estimation of age from development and eruption of teeth. J Forensic Dent Sci. 2014;6:73-76.
[15] Acharya AB. Age estimation in Indians using Demirjian's 8-teeth method. J Forensic Sci. 2011;56:124-27.
[16] Thevissen PW, Alqerban A, Asaumi J, Kahveci F, Kaur J, Kim YK, et al. Human dental age estimation using third molar developmental stages: accuracy of age predictions not using country specific information. Forensic Sci Int. 2010;201:106–11.
[17] Kumar VJ, Gopal KS. Reliability of age estimation using Demirjian's 8 teeth method and India specific formula. J Forensic Dent Sci. 2011;3:19-22.
[18] Liversidge HM, Lyons F, Hector MP. The accuracy of three methods of age estimation using radiographic measurements of developing teeth. Forensic Sci Int. 2003;131:22-29.
[19] Tandon A, Agarwal V, Arora V. Reliability of India-specific regression formula for age estimation of population in and around Bahadurgarh, Haryana (India). J Oral Biol Craniofac Res. 2015;5(3):193-97.
[20] Rath H, Rath R, Mahapatra S, Debta T. Assessment of Demirjian's 8-teeth technique of age estimation and Indian-specific formulas in an East Indian population: A cross-sectional study. J Forensic Dent Sci. 2017;9(1):45.
[21] Mohammed RB, Srinivas B, Sanghvi P, Satyanarayana G, Gopalakrishnan M, Pavani BV. Accuracy of Demirjian's 8 teeth method for age prediction in South Indian children: A comparative study. Contemp Clin Dent. 2015;6:05-11.

PARTICULARS OF CONTRIBUTORS:
1. Postgraduate Student, Department of Pedodontics and Preventive Dentistry, GITAM Dental College and Hospital, Visakhapatnam, Andhra Pradesh, India.
2. Professor, Department of Pedodontics and Preventive Dentistry, GITAM Dental College and Hospital, Visakhapatnam, Andhra Pradesh, India.
3. Professor, Department of Pedodontics and Preventive Dentistry, GITAM Dental College and Hospital, Visakhapatnam, Andhra Pradesh, India.
4. Professor, Department of Pedodontics and Preventive Dentistry, GITAM Dental College and Hospital, Visakhapatnam, Andhra Pradesh, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Arun Kumar Patnana,
Postgraduate Student, Department of Pedodontics and Preventive Dentistry, GITAM Dental College and Hospital,
Visakhapatnam-530045, Andhra Pradesh, India.
E-mail: arun0550@gmail.com

FINANCIAL OR OTHER COMPETING INTERESTS: None.

Date of Submission: **Feb 10, 2018**
Date of Peer Review: **Mar 05, 2018**
Date of Acceptance: **Mar 29, 2018**
Date of Publishing: **May 01, 2018**