A Comparative Evaluation of Three Different Dental Age Estimation Methods in India: A Test of Ethnic Variability

Kirti Chaudhry[1], Manjit Talwar[2], Narasimha RV Vanga[3], Gurvanit K Lehl[4], Ashish Choudhary[5], Arun K Patnana[6]

ABSTRACT

Aim: The present study aimed to evaluate and compare the applicability of Demirjian, Willems, and Haavikko methods of dental age estimation in southeastern (Dravidian ethnicity) and northwestern regions (Aryan ethnicity) of the Indian population.

Materials and methods: The study includes the orthopantomographs (OPGs) of 303 individuals (173 males and 130 females) of age ranging from 5 to 14 years. The participants in the present research were evaluated under two study groups: group I: participants of the southeastern region and group II: participants of the northwestern region. Dental age was calculated using Demirjian, Willems, and Haavikko methods and compared with the chronologic age of each participant. The accuracy of dental age estimation methods was evaluated by mean absolute error. One-way analysis of variance (ANOVA) and Student's *t* tests were used to test the significant difference between the chronologic age and estimated dental ages.

Results: The Demirjian method showed overestimation, while Willems and Haavikko methods showed underestimation for boys and girls in both the ethnic groups of Indian population. The Willems method of dental age estimation showed comparatively more accurate and reliable results in both the ethnic groups of the Indian population.

Conclusion: The dental age estimation by Demirjian, Willems, and Haavikko methods showed no significant variation between the different ethnicities of the Indian population.

Clinical significance: The present research will be helpful in pedodontic, orthodontic, and forensic investigations for accurate and reliable dental age estimation in different parts of Indian population.

Keywords: Demirjian method, Dental age estimation, Forensic odontology, Forensic sciences, Haavikko method, Willems method.

International Journal of Clinical Pediatric Dentistry (2020): 10.5005/jp-journals-10005-1708

INTRODUCTION

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

The Demirjian method showed inaccurate results when applied to population groups other than the French Canadians.[5–8] In the quest of improving the applicability of the Demirjian technique of dental age estimation, Willems modified the Demirjian technique by creating new tables from which tooth developmental stages were directly expressed in years.[9] In the Willems method, the tiresome step of converting maturity score to dental age was omitted to make it simpler, yet retaining the advantages of the Demirjian technique. The dental age estimation by using the maxillary and mandibular teeth were developed by Haavikko.[10] In the Haavikko method, age estimation is based on the determination of 1 of 12 radiographic stages (six relating to the crown formation and six relating to root formation, with stage "O" allocated for the appearance of a crypt of a tooth) of incisor to second molars in the maxilla and mandible.[10]

Although various dental age estimation methods revealed a high degree of accuracy and reliability specific to a population

[1,5,6]Department of Dentistry, All India Institute of Medical Sciences, Jodhpur, Rajasthan, India

[2,4]Department of Dentistry, Government Medical College and Hospital, Chandigarh, Haryana, India

[3]Department of Pedodontics and Preventive Dentistry, GITAM Dental College and Hospital, Visakhapatnam, Andhra Pradesh, India

Corresponding Author: Arun K Patnana, Department of Dentistry, All India Institute of Medical Sciences, Jodhpur, Rajasthan, India, Phone: +91 9966117228, e-mail: arun0550@gmail.com

group, ethnic differences between various population groups are found to affect the accuracy and reliability of different dental age estimation methodologies.[5,9] However, the concept of ethnic variability in dental age estimation methods is still unclear, as the reports of testing ethnic variability in dental age estimation have come with no significant results.[7]

In such a context, India is a unique country with variable ethnicities; there is always a need to evaluate the applicability of different dental age estimation methods in different ethnic groups of the Indian population.[11] Though various studies have been done to estimate the dental age in different parts of India, a similar assessment has been found lacking in evaluating the applicability

of dental age estimation methods in different ethnic groups of India. So, the present study aimed to evaluate and compare the applicability of Demirjian, Willems, and Haavikko methods of dental age estimation in southeastern (Dravidian ethnicity) and northwestern regions (Aryan ethnicity) of the Indian population.

MATERIALS AND METHODS

The present multicentric research was conducted in two different medical colleges and a dental college during the period of December 2016 to December 2017. The study includes the orthopantomographs (OPGs) of 303 individuals (173 males and 130 females) in the age group ranging from 5 years to 14 years. The OPGs and dental records including data of birth of study participants were collected during the period of 2016–2017 from the Department of Dentistry of two different medical colleges and hospitals and Department of Pedodontics and Preventive Dentistry of a dental college. The good-quality OPGs with no history of medical or surgical deformity affecting the left mandibular teeth visualization were included. Individuals with known systemic diseases, consanguineous anomalies, hypodontia of teeth, and premature birth histories were excluded from the present study.

The individuals in the present study were evaluated under two study groups: group I—participants of the southeastern region (75 males and 75 females) and group II—participants of the northwestern region (98 males and 55 females). The OPGs included in the present research were coded by a noninvestigator to avoid bias while scoring the radiographs. The OPGs were scored by two investigators who were not aware of the chronologic age of the participants. Radiographs were evaluated under the OPG viewer in a dark room and were scored according to the Demirjian and Haavikko staging of tooth development separately.

The interobserver variability was evaluated on the first 50 OPGs and intraobserver variability was assessed in 50 randomly selected OPGs that were reexamined by the same observer 2 months after the first examination. The dental age of each participant was calculated by using Demirjian, Willems, and Haavikko methods of dental age estimation.

In the Demirjian method, mandibular left teeth excluding the third molars were assessed for calcification stages of teeth. Each tooth with a specific developing stage was converted into a score using the standard tables given by Demirjian et al., for boys or girls separately. The maturity score of the particular individual was calculated by summing up all the scores of individual teeth. Dental age is assigned based on the maturity score using reference tables given by Demirjian.[3]

The Willems method of dental age estimation is much similar to the Demirjian method. The calcification stages of the tooth development were scored according to Demirjian scoring criteria and the scores of each calcification stage were directly expressed in years for each of the seven left mandibular teeth separately for boys and girls. The scores of all the seven teeth were summed up to give dental age in years directly using the reference tables given by Willems.[9]

In the Haavikko method, both maxillary and mandibular teeth were scored using the 12-stage scoring criteria of tooth development. All the scores of 14 teeth (seven maxillary and seven mandibular) were summed up; dental age was given by dividing the summed up scores by the number of teeth examined.[10] The chronologic age of each participant was determined by subtracting the date of birth from the date of OPG taken.

Statistical Analysis

The intraobserver and interobserver variability was evaluated by Kappa statistics. The descriptive statistics were done separately for boys and girls to evaluate the mean, standard deviation, confidence interval of the chronologic age, and estimated dental ages. The mean absolute error (MAE) and mean error (ME) were calculated for estimated dental ages to evaluate the accuracy of each dental age estimation method.

One-way ANOVA test was applied to test the significant difference between the chronologic age and estimated dental ages for boys and girls separately in both the population groups. The two-tailed t test was applied to evaluate the significance between the chronologic age and estimated dental age by Demirjian, Willems, and Haavikko methods. The p value of less than 0.05 was considered as statistically significant. The statistical analysis was performed using the SPSS software (16.0 version).

RESULTS

The inter- and intraobserver analysis of dental developmental scoring showed weighed kappa statistical scores of 0.83 and 0.86, respectively. Descriptive statistics for southeastern and northwestern population groups of chronologic age and estimated dental ages using Demirjian, Willems, and Haavikko methods are presented in Table 1.

The one-way ANOVA test for intergroup variance values of chronologic age and estimated dental ages by Demirjian, Willems, and Haavikko methods for the southeastern population group are presented in Table 2. The statistical tests showed a significant difference between the chronologic and three dental age estimation methods in the southeastern population group for both males (p value $= 9.24 \times 10^{-17}$) and females (p value $= 2.24 \times 10^{-18}$).

The paired t tests to analyse the significant difference between the two groups showed a significant difference between all the groups except between chronologic age and dental age estimation by the Willems method in both males (p value $= 0.24$) and females (p value $= 0.08$). The results infer that there was no significant difference between the chronologic age and the estimated dental age for both males and females by the Willems method with a mean difference of 0.04 years for males and 0.14 years for females (Table 3).

The one-way ANOVA test for intergroup variance values of chronologic age and estimated dental ages by Demirjian, Willems, and Haavikko methods for northwestern population group are presented in Table 4. The statistical tests showed a significant difference between the chronologic and three dental age estimation methods in the southeastern population group for both males (p value $= 0.00069$) and females (p value $= 4.33 \times 10^{-5}$).

The paired t tests to analyse the significant difference between the two groups showed a significant difference between all the groups except between chronologic age and dental age estimation by the Willems method in both males (p value $= 0.38$) and females (p value $= 0.27$). The results infer that there was no significant difference between the chronologic age and estimated dental age for both males and females by the Willems method with a mean difference of 0.04 years for males and 0.11 years for females (Table 5).

DISCUSSION

The variability of maturation standards in different ethnic groups suggests the need for ethnic-specific dental age estimation methodologies around the world. The Indian population consists

Table 1: Descriptive statistics for chronologic age and estimated dental ages by Demirjian, Willems, and Haavikko methods for southeastern and northwestern population groups

Group	Method	Sex	Range	Mean ± SD	95% CI	MAE
Southeastern population	Chronologic age	Males (n = 75)	6.25–14.99	12.27 ± 1.60	0.36	–
		Females (n = 75)	8.08–14.66	11.94 ± 1.62	0.37	–
	Demirjian method	Males (n = 75)	7.08–15.91	12.81 ± 1.80	0.42	0.95
		Females (n = 75)	7.75–15.75	12.47 ± 1.83	0.42	0.88
	Willems method	Males (n = 75)	6.41–14.66	12.23 ± 1.51	0.37	0.70
		Females (n = 75)	7.41–15	11.80 ± 1.64	0.37	0.73
	Haavikko method	Males (n = 75)	6.57–12.58	10.20 ± 1.38	0.24	2.08
		Females (n = 75)	6.83–14	10.01 ± 1.30	0.30	2.17
Northwestern population	Chronologic age	Males (n = 98)	4.72–13.9	10.20 ± 2.43	0.55	–
		Females (n = 55)	5.28–14.04	10.27 ± 2.49	0.67	–
	Demirjian method	Males (n = 98)	4.5–16	10.68 ± 2.73	0.57	1.35
		Females (n = 55)	6.1–16.21	10.95 ± 2.73	0.73	1.30
	Willems method	Males (n = 98)	4.09–16.03	10.24 ± 2.59	0.54	1.17
		Females (n = 55)	4.86–15.79	10.15 ± 2.65	0.71	1.06
	Haavikko method	Males (n = 98)	4.86–16.4	9.40 ± 2.57	0.56	1.63
		Females (n = 55)	5.28–14.39	8.68 ± 2.26	0.61	1.92

Table 2: One-way ANOVA variance between the chronologic age and estimated dental ages by Demirjian, Haavikko, and Willems methods in Southeastern population

Sex	Age	Average	Variance	F value	p value
Males	CA	12.27	2.56	29.59	9.24×10^{-17}*
	EA-DM	12.76	3.44		
	EA-WM	12.18	2.66		
	EA-HM	10.51	1.09		
Females	CA	11.94	2.63	32.89	2.24×10^{-18}*
	EA-DM	12.47	3.38		
	EA-WM	11.80	2.69		
	EA-HM	10.01	1.70		

CA, chronologic age; EA, estimated dental age; DM, Demirjian method; WM, Willems method; HM, Haavikko method
*p value < 0.05 is considered statistically significant

Table 3: The mean changes between chronologic age and estimated dental age by Demirjian, Willems, and Haavikko methods of dental age estimation in southeastern population group

Sex	Age estimation method	ME in years	p values determined using paired t test
Males	CA	–	0.004*, 0.24[†], 2.06×10^{-26}[‡]
	EA-DM	0.53	7.1×10^{-10}[§], 4.07×10^{-24}[∥]
	EA-WM	−0.04	4.6×10^{-20}**
	EA-HM	−2.07	
Females	CA	–	2.34×10^{-5}*, 0.08[†], 5.73×10^{-20}[‡]
	EA-DM	0.52	8.32×10^{-14}[§], 8.37×10^{-24}[∥]
	EA-WM	−0.14	2.1×10^{-19}**
	EA-HM	−1.93	

ME, mean error (difference of estimated dental age and chronologic age); CA, chronologic age; EA, estimated dental age; DM, Demirjian method; WM, Willems method; HM, Haavikko method
p value < 0.05 is considered statistically significant (*CA vs EA-DM; [†]CA vs EA-WM; [‡]CA vs EA-HM; [§]EA-DM vs EA-WM; [∥]EA-DM vs EA-HM; **EA-WM vs EA-HM)

of multiple ethnic, linguistic variable population groups, that further warrant the evaluation of different dental age estimation methodologies around different regions of the Indian subcontinent. Thus, the present research was undertaken to evaluate the reliability of three different dental age estimation methodologies in southeastern and northwestern population groups of India.

The Demirjian method in the present study showed a significant overestimation of dental age for males and females in both the population groups. The results of overestimating the dental age by the Demirjian method are in accordance with the earlier reports on applicability of the Demirjian method in the Indian population.[5,12–15] The overestimation of dental age by the Demirjian method in the Indian population could be because of different population groups studies in the present research (Indian population) and the original research (French Canadian population).[9,12] However, the Demirjian method shows overestimation of dental age in both the population groups, which infer that the dental age estimation by the Demirjian method does not vary with different ethnicities in the Indian population.

The Willems method shows no significant difference between the chronologic age and estimated dental ages for males and

females in different population groups of India in the present study. The dental age estimation by the Willems method showed the decreased MEs and MAEs for both and females in both the population groups in India. The original Demirjian method was modified by Willems et al., where the maturity score calculation was omitted and the tooth calcification stages were directly expressed in years using the standard tables for males and females separately.[9] The adapted method was validated and resulted in more accurate dental age estimations in the Belgian population. The applicability of the Willems method of dental age estimation in the present research was in accordance with different research papers on applicability of the Willems method in the Indian population.[12,14,16]

The estimated dental age by Willems showed the underestimation of dental age in both the population groups

Table 4: One-way ANOVA variance between the chronologic age and estimated dental ages by Demirjian, Haavikko, and Willems methods in northwestern population

Sex	Age	Average	Variance	F value	p value
Males	CA	10.09	5.81	5.83	0.00069*
	EA-DM	10.52	6.19		
	EA-WM	10.11	5.66		
	EA-HM	8.94	6.02		
Females	CA	10.45	6.20	8.01	4.33×10^{-5}*
	EA-DM	11.15	7.46		
	EA-WM	10.34	7.05		
	EA-HM	8.84	5.14		

CA, chronologic age; EA, estimated dental age; DM, Demirjian method; WM, Willems method; HM, Haavikko method
*p value < 0.05 is considered statistically significant

Table 5: The mean changes between chronologic age and estimated dental age by Demirjian, Willems, and Haavikko methods of dental age estimation in the northwestern population group

Sex	Age estimation method	ME in years	p values determined using paired t test
Males	CA		0.003*, 0.38[†], 2.46×10^{-6}[‡]
	EA-DM	0.48	7.27×10^{-13}[§], 5.7×10^{-8}[‖]
	EA-WM	0.04	7.83×10^{-5}**
	EA-HM	−0.79	
Females	CA		0.0006*, 0.27[†], 2.79×10^{-10}[‡]
	EA-DM	0.68	9.07×10^{-10}[§], 1.03×10^{-17}[‖]
	EA-WM	−0.11	2.13×10^{-12}**
	EA-HM	−1.58	

ME, mean error (difference of estimated dental age and chronologic age); CA, chronologic age; EA, estimated dental age; DM, Demirjian method; WM, Willems method; HM, Haavikko method
p value < 0.05 is considered statistically significant (*CA vs EA-DM; [†]CA vs EA-WM; [‡]CA vs EA-HM; [§]EA-DM vs EA-WM; [‖]EA-DM vs EA-HM; **EA-WM vs EA-HM)

except for males in the northwestern population group. However, the results of Gupta et al. are contradictory to the results of the present study, where they reported that the Demirjian method of dental age estimation method is more reliable than the Willems method in females of North Indian population.[17] The differences in the applicability of the Willems method in the north Indian population could be attributed to the sample size variations and the difference in the age groups included in the present research (5–14 years).

The dental age estimation by the Haavikko method showed an underestimation of dental age for both males and females in southeastern and northwestern population groups in the present study. The results of the underestimation of dental age estimation by the Haavikko method are in accordance with earlier reports in the Indian population.[12,14] Butti et al. have tested the adopted Haavikko method on 500 Italian children and found that dental age was underestimated for both girls and boys significantly.[10]

This is in agreement with the present study, where the significant underestimation of dental age was observed for both males and females in both southeastern and northwestern populations of India.

Though earlier reports have compared different dental age estimation methodologies in South Indian and North Indian populations separately, no studies have compared different dental age estimation methodologies in South Indian and North Indian populations to evaluate the ethnic variability of different dental age estimation methodologies.[12,14–16] The dental age estimation methodologies warrant the population-specific models according to the ethnic variations for accurate dental age estimation.[5,9,18] Interestingly, in the present study, Demirjian, Willems, and Haavikko methods of dental age estimation showed similar results for both southeastern and northwestern population groups of India.

The results of the present results convey that the different dental age estimation methodologies do not vary with population groups in India. The results of nonsignificant ethnic variability were observed by Liversidge et al., where they have evaluated the ethnic variability in dental age estimation between British and Bangladeshi children and found that dental age estimation does not differ with the ethnic group variations.[7] However, contrary to the present study results, recent dental age estimation methodologies recommend the use of population-specific dental age estimation methodologies for accurate and reliable results.[18,19]

The sample size considerations have a significant role in evaluating the reliability of different dental age estimation methodologies. The authors recommend further studies with larger sample sizes to correlate the present study results in different ethnic groups of the Indian population. The present study evaluated only the overestimation or underestimation of different dental age estimation methodologies in different ethnic groups of the Indian population. The authors further recommend the studies that evaluate the maturity standards of one ethnic group over the other ethnic groups by using population-specific regression models in India.

Conclusion

The evaluation of Demirjian, Willems, and Haavikko methods showed no significant variation between the different ethnicities of the Indian population. The present research also concludes that the Willems method of dental age estimation is reliable for both males and females in southeastern and northwestern population groups of India.

References

1. Demirjian A, Goldstein H. A new system of dental age assessment. Hum Biol 1973;45(2):211–227.
2. Maber M, Liversidge HM, Hector MP. Accuracy of age estimation of radiographic methods using developing teeth. Forensic Sci Int 2006;159(1):68–73. DOI: 10.1016/j.forsciint.2006.02.019.
3. Moorrees CF, Fanning EA, Hunt EE. Age variation of formation stages for ten permanent teeth. J Dent Res 1963;42:1490–1502. DOI: 10.1177/00220345630420062701.
4. Panchbhai AS. Review dental radiographic indicators, a key to age estimation. Dentomaxillofac Radiol 2011;40(4):199–212. DOI: 10.1259/dmfr/19478385.
5. Koshy S, Tandon S. Dental age assessment: the applicability of Demirjian's method in South Indian children. Forensic Sci Int 1998;94(1–2):73–85. DOI: 10.1016/S0379-0738(98)00034-6.

6. Willems G. A review of the most commonly used dental age estimation techniques. J Forensic Odontostomatol 2001;19(1):9–17.

7. Liversidge HM, Speechly T, Hector MP. Dental maturation in British children: are Demirjian's standards applicable? Int J Paediatr Dent 1999;9(4):263–269. DOI: 10.1111/j.1365-263X.1999.00144.x.

8. Frucht S, Schnegelsberg C, Monting SJ, et al. Dental age in southwest Germany: a radiographic study. J Orofac Orthop 2000;61(5):318–329. DOI: 10.1007/PL00001902.

9. Willems G, Olmen AV, Spiessens B, et al. Dental age estimation in Belgian children: Demirjian's technique revisited. J Forensic Sci 2001;46(4):893–895. DOI: 10.1520/JFS15064J.

10. Butti AC. Haavikko's method to assess dental age in Italian children. Eur J Orthod 2009;31(2):150–155. DOI: 10.1093/ejo/cjn081.

11. Papiha SS. Genetic variations in India. Hum Biol 1996;68(5):607–628.

12. Patnana AK, Vabbalareddy RS, Vanga NRV. Evaluating the reliability of three different dental age estimation methods in Visakhapatnam children. Int J Clin Pediatr Dent 2014;7(3):186–191. DOI: 10.5005/jp-journals-10005-1262.

13. Prabhakar AR, Panda AK, Raju OS. Applicability of Demirjian's method of age assessment in children of Davangere. J Indian Soc Pedod Prev Dent 2002;20(2):54–62.

14. Mohammed RB, Sanghvi P, Perumalla KK, et al. Accuracy of four dental age estimation methods in southern Indian children. J Clin Diagn Res 2015;9((1):1–8. DOI: 10.7860/JCDR/2015/10141.5495.

15. Malik P, Saha R, Agarwal A. Applicability of Demirjian's method of age assessment in a North Indian female population. Eur J Paediatr Dent 2012;13(2):133–135.

16. Mohammed RB, Krishnamraju PV, Prasanth PS, et al. Dental age estimation using Willems method: a digital orthopantomographic study. Contemp Clin Dent 2014;5(3):371–376. DOI: 10.4103/0976-237X.137954.

17. Gupta S, Mehendiratta M, Rehani S, et al. Age estimation in Indian children and adolescents in the NCR region of Haryana: a comparative study. J Forensic Dent Sci 2015;7(3):253–258. DOI: 10.4103/0975-1475.172453.

18. Acharya AB. Age estimation in Indians using Demirjian's 8-teeth method. J Forensic Sci 2011;56(1):124–127. DOI: 10.1111/j.1556-4029.2010.01566.x.

19. Olze A, Schmeling A, Taniguchi M, et al. Forensic age estimation in living subjects: the ethnic factor in wisdom tooth mineralization. Int J Legal Med 2004;118(3):170–173. DOI: 10.1007/s00414-004-0434-7.