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TECHNICAL NOTE

ODONTOLOGY

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Orthopantomographic Evaluation of Canine and First Premolar Using Demirjian's Stages in Central India: New Approach to Forensic Age Estimation

ABSTRACT: Teeth development is widely used for age estimation in forensic science. The aims of this study were as follows: first, to establish Indian data on canine and first premolar development for age estimation and second, to investigate population differences in teeth development. Orthopantomograms of 340 Indian children aged between 5 and 14 years were analyzed. Demirjian's stages were recorded for the developmental evaluation of canine and first premolar and for further descriptive statistical analysis. A two-way ANOVA was performed to test the significance of difference in teeth development by sex and stage. A one-way ANOVA was performed to investigate population differences in teeth development. Results showed statistically significant differences in teeth development by sex and stage. Accordingly, teeth development was earlier in girls. No statistically significant differences were observed in timings of Demirjian's stages among different populations. In conclusion, the findings of this study could be used for age estimation of Indian children.

KEYWORDS: forensic science, forensic odontology, age estimation, dental maturity, Demirjian's stages, canine, first premolar, orthopantomograms

Age estimation plays an important role not only in forensic medicine, but also in clinical dentistry (1) and archeology (1,2). From a forensic perspective, sufficiently precise and reliable determination of age is required. There is an increasing demand by the courts for appropriate estimation of age in living individuals, suspected of being minors in the absence of legal documentation of age in criminal cases, adoptions, asylum-seekers, refugees, and immigrants (3, 4). Various methods have been used to estimate age for medicolegal purposes, but the radiological evaluation of dental age is considered as the most accurate method. The radiological methods used for determination of dental age in children are based on scoring system, among which the Demirjian's method (5) is widely used worldwide (6–15). However, an inherent limitation of the methods based on scoring system is simultaneous evaluation of seven left mandibular teeth (excluding third molar). Therefore, these methods cannot be applied to those children in whom either the teeth are missing or radiographic image is obscure (11,16,17). This difficulty can be solved by calculating the mean age of attainment for each developmental stage of individual teeth. Moreover, a well-chosen tooth provides more accurate age assessments as compared to the use of all developing teeth (18). For that reason, in many studies, emphasis has been placed on the use of individual teeth for age estimation (19–21). Considering the above facts, the aim of this study was to evaluate mandibular permanent canine and first premolar gender specifically for age estimation in forensic applications among Indian children using the Demirjian's criteria. Additionally, we decided to test the possibility of population differences in timings of Demirjian's teeth formation stages by comparing mean age results from this study with the findings noted from reviewed literature.

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Materials and Methods

The material consisted of 340 orthopantomograms of Indian children (175 boys and 165 girls) from central India, aged between 5 and 14 years. The orthopantomograms were taken in the period from March 2008 to May 2009 as a part of routine treatment. Only healthy well-nourished children belonging to middle socioeconomic group with no history of chronic illness were considered. Exclusion criteria were image deformity affecting visualization of mandibular canine and first premolar or gross pathology affecting these teeth. The research protocol was approved by Institutional ethical committee.

The X-ray machine used for the exposure was Planmeca PM 2002 EC Proline Panoramic X-ray Unit (Helsinki, Finland) The radiographic film used was standard Kodak T-Mat G film of size 6″ × 12″ (Carestream Health, Inc., Rochester, NY). To assess the developmental stages of left mandibular permanent canine and first premolar, the classification system proposed by Demirjian et al. (5) was used. This system divides the process of teeth development into eight stages, from A to H. The left mandibular teeth were selected as they are seen more clearly on orthopantomograms and have been widely used to assess the degree of calcification (5,22,23). All assessments were performed in a dark room with a radiographic illuminator to ensure contrast enhancement of teeth images. The chronological age for each subject was calculated by subtracting the date of birth from the date when the radiograph was taken for that particular individual. The chronological age thus obtained was then converted into decimal age.

Descriptive analysis was performed for the evaluated stages of canine and first premolar for both genders. Stage H (mature apex) was excluded from analysis as this would represent the age distribution and not the parameter of growth. To test the statistical significance of difference in mean ages by sex and stage, two-way analysis of variance (ANOVA) was used. In this analysis, interaction between sex and stage was also tested. The statistical significance of population differences in the mean ages of Demirjian's stages from this study and those noted from reviewed literature was tested by one-way ANOVA followed by Bonferroni correction for multiple comparisons. All the statistical analysis was performed using statistical software, STATA, version 10.1, 2008 (StataCorp LP, College Station, TX).

Results

The developmental stages of canine and first premolar were analyzed in both sexes. The descriptive measures (age range, mean age, standard deviation, standard error of mean, and 95% confidence interval) for the evaluated Demirjian's stages are shown in Tables 1 and 2. Mean ages for the developmental stages of canine and first premolar were observed to be earlier in girls as compared to boys. The sex difference in early stages representing crown development was small, whereas the sex difference was larger in later stages representing root development. For canine, sex difference in mean ages for stage "D," "E," "F," and "G" was 0.02, 0.71, 1.17 and 1.32 years, respectively. For first premolar, sex difference in mean ages for stage "C," "D," "E," "F," and "G" was 0.07, 0.46, 0.78, 0.56 and 1.1 years respectively. Two-way ANOVA revealed significant differences (p-value < 0.05) in mean ages for the developmental stages of canine (Table 3) and first premolar (Table 4) by sex and stage. In addition, two-way ANOVA revealed significant sex-stage interactions for canine and first premolar. The model for canine explained 90% of total variance (R-squared = 0.90), whereas the model for first premolar explained 91% of total variance (R-squared = 0.91).

The mean age results for the developmental stages of canine and first premolar from this study and those noted from reviewed literature are summarized in Tables 5 and 6 for testing the possibility of population differences in timings of Demirjian's stages. The one-way ANOVA followed by a Bonferroni correction for multiple comparisons revealed no significant differences in timings of Demirjian's teeth formation stages among different populations (Table 7).

Further investigation included determining the accuracy of age estimation based on this study by calculating the differences between the estimated age and actual age (Tables 8 and 9). The results showed that the estimated age was within ±1.0 year of the actual age in 79.88% of boys and 86.8% of girls for canine

TABLE 1—*Descriptive statistics in years for individual stages of mandibular permanent canine.*

Stage	Sex	n	Range	Mean	SD	SEM	95% Confidence Interval Lower	95% Confidence Interval Upper
D	Boys	40	5.01–6.96	5.76	0.45	0.07	5.62	5.91
	Girls	31	5.01–6.18	5.74	0.38	0.06	5.60	5.88
E	Boys	47	6.45–9.41	7.77	0.82	0.12	7.53	8.01
	Girls	29	5.88–8.16	7.06	0.56	0.10	6.85	7.27
F	Boys	41	8.71–12.02	10.05	0.86	0.13	9.78	10.33
	Girls	41	7.64–10.6	8.88	0.72	0.11	8.65	9.11
G	Boys	41	10.71–13.31	12.19	0.78	0.12	11.95	12.44
	Girls	43	9.65–12.54	10.87	0.74	0.11	10.64	11.10

TABLE 2—*Descriptive statistics in years for individual stages of mandibular permanent first premolar.*

Stage	Sex	n	Range	Mean	SD	SEM	95% Confidence Interval Lower	95% Confidence Interval Upper
C	Boys	36	5.01–6.28	5.72	0.42	0.07	5.58	5.87
	Girls	20	5.01–6.18	5.65	0.43	0.09	5.45	5.86
D	Boys	25	5.59–7.38	6.9	0.49	0.09	6.69	7.10
	Girls	26	5.55–7.89	6.44	0.66	0.13	6.17	6.71
E	Boys	37	7.49–11.38	8.77	0.93	0.15	8.46	9.08
	Girls	36	6.8–9.46	7.99	0.74	0.12	7.75	8.25
F	Boys	34	8.71–12.02	10.25	0.82	0.14	9.97	10.54
	Girls	29	8.62–10.62	9.69	0.67	0.12	9.43	9.95
G	Boys	37	10.87–13.31	12.34	0.68	0.11	12.11	12.56
	Girls	39	9.65–12.54	11.24	0.82	0.13	10.97	11.51

TABLE 3—*Two-way ANOVA table for canine.*

Source	Partial Sum of Squares	d.f.	Mean Square	F	$p > F$
Model	1515.61229	7	216.516042	440.18	0.0000
Sex	50.0578913	1	50.0578913	101.77	0.0000
Stage	1448.08432	3	482.694772	981.33	0.0000
Sex*Stage	19.1052716	3	6.36842388	12.95	0.0000
Residual	150.022242	305	0.491876202		
Total	1665.63454	312	5.33857223		

TABLE 4—*Two-way ANOVA table for first premolar.*

Source	Partial Sum of Squares	d.f.	Mean Square	F	$p > F$
Model	1588.1376	9	176.4597	354.24	0.0000
Sex	26.7231	1	26.7231	53.65	0.0000
Stage	1507.7149	4	376.9287	756.67	0.0000
Sex*Stage	8.9779	4	2.2445	4.51	0.0015
Residual	153.9254	309	0.4981		
Total	1742.0630	318	5.4788		

TABLE 5—*Mean ages and SD in years for developmental stages of canine from present study and reviewed literature.*

	Sex	Developmental Stages: Stage D	Stage E	Stage F	Stage G
Present study	Male	5.76 ± 0.45	7.77 ± 0.82	10.05 ± 0.86	12.19 ± 0.78
	Female	5.74 ± 0.38	7.06 ± 0.56	8.88 ± 0.72	10.87 ± 0.74
Nystrom et al. (17)	Male	5.88 ± 0.93	7.58 ± 1.14	9.97 ± 1.21	12.05 ± 1.48
	Female	5.14 ± 0.72	6.86 ± 0.93	8.62 ± 1.11	10.52 ± 1.28
Liversidge et al. (27)	Male	5.82 ± 1.14	7.74 ± 1.07	9.78 ± 1.22	12.02 ± 1.33
	Female	5.35 ± 1.03	7.08 ± 0.97	8.81 ± 1.08	10.85 ± 1.28
Lee et al. (41)	Male	4.8 ± 1.0	7 ± 1.0	10.3 ± 1.3	12.5 ± 1.3
	Female	4.7 ± 0.7	6.5 ± 0.9	9.3 ± 1.2	11.5 ± 1.0

TABLE 6—*Mean ages and SD in years for developmental stages of first premolar from present study and reviewed literature.*

		Developmental Stages				
	Sex	Stage C	Stage D	Stage E	Stage F	Stage G
Present study	Male	5.72 ± 0.42	6.9 ± 0.49	8.77 ± 0.93	10.25 ± 0.82	12.34 ± 0.68
	Female	5.65 ± 0.43	6.44 ± 0.66	7.99 ± 0.74	9.69 ± 0.67	11.24 ± 0.82
Nystrom et al. (17)	Male	4.88 ± 0.84	6.56 ± 0.87	8.10 ± 1.01	10.2 ± 1.17	11.91 ± 1.39
	Female	4.60 ± 0.71	6.19 ± 0.89	7.74 ± 0.90	9.59 ± 1.12	11.20 ± 1.29
Liversidge et al. (27)	Male	4.99 ± 1.10	6.64 ± 1.04	8.35 ± 1.05	10.29 ± 1.24	12.14 ± 1.23
	Female	4.73 ± 0.78	6.26 ± 0.96	7.92 ± 0.93	9.77 ± 1.14	11.46 ± 1.18
Lee et al. (41)	Male	4.6 ± 0.6	6.3 ± 0.8	7.9 ± 1.0	10.5 ± 1.2	12.4 ± 1.1
	Female	4.5 ± 0.6	6.0 ± 0.7	7.6 ± 0.9	10.1 ± 1.1	11.8 ± 0.9

TABLE 7—*Bonferroni correction following one-way ANOVA.*

	Canine Boys		Canine Girls		1st Premolar Boys		1st Premolar Girls	
Bonferroni's Multiple Comparison Test	Mean Difference	*p*-Value	Mean Difference	*p*-Value	Mean Difference	*p*-Value	Mean Difference	*p*-Value
Present study vs. Nystrom et al. (17)	0.0725	0.9719	0.3300	0.8514	0.4660	0.7971	0.3380	0.8408
Present study vs. Liversidge et al. (27)	0.1025	0.9603	0.0925	0.9581	0.3140	0.8623	0.1740	0.9176
Present study vs. Lee et al. (41)	0.2925	0.8873	0.1150	0.9480	0.4560	0.8014	0.2020	0.9045
Liversidge et al. (27) vs. Nystrom et al. (17)	−0.0300	0.9884	0.2375	0.8954	0.1520	0.9331	0.1640	0.9222
Nystrom et al. (17) vs. Lee et al. (41)	0.2200	0.9150	−0.2150	0.9028	−0.0100	0.9956	−0.1360	0.9355
Liversidge et al. (27) vs. Lee et al. (41)	0.1900	0.9265	0.0225	0.9898	0.1420	0.9375	0.0280	0.9867

TABLE 8—*Accuracy of age estimation using canine.*

	Range of Error (years)				
Gender	Within ± 0.2	Within ± 0.3	Within ± 0.5	Within ± 1.0	Within ± 2.5
Male (%)	18.34	26.63	49.70	79.88	100
Female (%)	21.53	35.42	60.42	86.80	100

TABLE 9—*Accuracy of age estimation using first premolar.*

	Range of Error (years)				
Gender	Within ± 0.2	Within ± 0.3	Within ± 0.5	Within ± 1.0	Within ± 2.5
Male (%)	20.71	30.77	56.21	86.39	100
Female (%)	15.33	24	48	84.67	100

(Table 8). For first premolar (Table 9), the accuracy was within ±1.0 year of actual age in 86.39% of boys and 84.67% of girls.

Discussion

Age estimation in subadults for medico-legal purposes is an important issue, and several methods have been established for this in forensic medicine. The most commonly used maturity indicators for age estimation in subadults include dental age (teeth development and eruption), skeletal age, morphological features, and sexual development (19,24). Among these, age estimation by radiological evaluation of teeth development has been considered as more accurate as compared to other maturity indicators (10). This is because teeth development is known to be controlled by genes (25) and seems to be independent of factors such as malnutrition (26,27) and endocrine status (28) as compared to other maturity indicators (27,29). Furthermore, teeth development is associated with less variability in relation to chronological age as compared to other maturity indicators (19,29–31). Last, teeth development is considered superior to teeth emergence, as emergence is a short period determined by the time of appearance of the teeth in mouth (10). This may be altered by local factors such as lack of space in the dental arch, extraction of deciduous predecessors, impacted teeth (5,15,19) and infection (32). Additionally, factors such as nutritional status (1,33) and socioeconomic environment (34) also influence the eruption of teeth. Poster et al. (33) in their study concluded that malnutrition is significantly associated with delay in exfoliation of primary dentition and in the eruption of permanent dentition. Regarding the impact of socioeconomic background on teeth eruption, Clements et al. (34) found that children from higher socioeconomic group show earlier teeth eruption than children from lower socio economic group.

Among the methods for the determination of age based on teeth development, Demirjian's method was preferred over the other methods such as Moorrees et al. (19), Nolla (23), Liliequist and Lundberg (35), Nielsen and Ravn (36), Nicodemo et al. (cited in Matuda et al. [37]), and Hotz et al. (cited in Koupis et al. [38]). Advantage of Demirjian's method is that it is a staging system with only eight stages of teeth development and is easy to understand because of its clear descriptive criteria's line diagrams and radiographic illustrations for each stage of teeth development. Moreover, Demirjian's stages require only relative measurements. For these reasons, it is used widely by clinicians and forensic practitioners, especially forensic odontologists all over the world for age determination in children (6–15).

In the present study, permanent mandibular canine and first premolar were selected over other teeth for age estimation. In small children particularly in incisor area, the tomographic layer is seldom ideal and developing teeth may not conform well to the plane of the tomographic unit. Shadow of cervical spine also interferes with staging of incisors and image of lateral incisor is often distorted, which affects the assessment of stages (17). Second premolar and lateral incisor are the most frequently congenitally missing teeth excluding third molar (39). Mandibular first molar is by far the most frequently extracted teeth because of disease like dental caries (40). In case of two-rooted mandibular second molar, the fusion of roots may occur giving the appearance of a single root, which creates difficulty while interpreting age from developmental stage of second molar. The third molar germs were excluded from our study, as most of them could not be observed in our study group. Therefore, in the present study canine and first premolar were selected for the determination of age in children.

The most important finding from the present study was the lack of significant population difference in the timings of Demirjian's teeth formation stages, as revealed by the one-way ANOVA followed by Bonferroni correction. The populations studied were the Indian population from present study and populations from reviewed literature such as Finnish population from Nystrom et al. (17), Korean population from Lee et al. (41), and combined data of eight countries provided by Liversidge et al. (27). This observation regarding lack of population differences in timings of Demirjian's stages is consistent with the study performed by Liversidge et al. (27). Liversidge et al. (27) in their study investigated the possibility of population differences in timings of Demirjian's stages in children from eight countries namely Australia, Belgium, Canada, England, Finland, France, South Korea, and Sweden. The results of their study suggested no major differences in the timings of Demirjian's stages between these children from eight countries.

In the present study, it was observed that the girls were ahead of the boys in all stages of evaluation for the canine and first premolar. This finding is consistent with the studies performed by Nystrom et al. (17), Liversidge et al. (27), Demirjian and Levesque (32), Lee et al. (41), Garn et al. (42), and Liversidge and Speechly (43). In addition, it was observed that the earlier development in girls was before the tenth year of life. This suggests that the sex difference in teeth development cannot be attributed primarily to difference in the timing of sex hormone secretion. This finding is in accordance with the study of Garn et al. (42).

In conclusion, the timings of Demirjian's stages for canine and first premolar from the present study can be used for the estimation of age in Indian children, especially in cases where any teeth are missing or radiographic image is obscure. Moreover, the accuracy required in age determination for forensic purposes is provided by the results of the present study. In addition, this research has revealed significant sex difference in the timings of teeth formation stages, and thus sex-specific norms should be used while estimating age from teeth development in children. Finally, the present study has showed that there is lack of any significant population difference in timings of Demirjian's teeth formation stages.

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