Predictive accuracy of Demirjian's, Modified Demirjian's and India specific dental age estimation methods in Odisha (Eastern Indian) population

Ipsita Mohanty[1],
Swagatika Panda[1],
Radha Prasanna Dalai[2],
Neeta Mohanty[1]

[1] Department of Oral Pathology and Microbiology, Institute of Dental Sciences, Siksha 'O' Anusandhan University, Odisha, India
[2] Department of Community Dentistry, Institute of Dental Sciences, Siksha 'O' Anusandhan University, Odisha, India

Corresponding author:
swagatikapanda@soa.ac.in

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KEYWORDS

Chronological Age; Orthopantomograph; Demirjian's method; modified Demirjian's method; Acharya's Indian Formula; Age estimation

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ABSTRACT

This study is aimed at finding the predictive accuracy of Demirjian's (D), modified Demirjian's (MD) and India specific age estimation methods (AA) Indian specific age estimation methods in 522 healthy children of Odisha population among 3-18 years. Correlations between chronological age (CA) and derived age (DA) by above mentioned methods were evaluated by Wilcoxon signed rank test and Pearson's correlation analysis. Analysis of mean absolute error concluded that D and MD predicted the CA with fair accuracy, whereas, AA had lower accuracy in Odisha children. Odisha specific polynomial regression formula, derived in this study is showing a strong correlation with CA (r=0.84). Comparison of mean absolute error of D, MD, AA and Odisha specific method indicated a better predictive accuracy of Odisha specific method.

INTRODUCTION

Age is a significant intellectual, religious and social event. Chronological age (CA) of an individual should be derived from date of birth, which is conventionally confirmed by documents of birth registration. Surprisingly, birth registration is not followed stringently in many parts of the world. Globally, largest number of unregistered children belong to South Asia accounting up to 22.5 million which is more than 40% of the whole non-registered births in 2000 (1). Being recognized as an index of health, growth and development age is of great interest to physicians, dentists and anthropologists as well as forensic experts. In the context of uncertain date of birth, biological ages like skeletal age, morphological age, secondary sex character and dental age have been developed as maturity markers to estimate age (2). Tooth development may be a pragmatic measure of maturity and may serve as a maturity marker for any individual. Especially in growing children, dental-age evaluation is accepted as the most precise, dependable, and rapid technique to estimate age (3). There is maximum degree of association of CA with derived age (DA) than any other biological maturity markers as it is believed to be least affected by malnutrition (4).

Among various dental disciplines DA assessment becomes very essential for orthodontists to devise the treatment modalities of several kinds of malocclusion (2) and paedodontists to know stage of dental maturity of a child to identify the systemic disturbances (5). Age estimation is valuable in bio-archaeology and human anthropology too as it gives substantial information

regarding ancestors. In forensic dentistry, quite often there is a need to determine the age for various medico-legal purposes including personal identification (6-8).

Radiographic assessment among several methodologies of dental age is well-known because of the simplicity, non-invasiveness and reproducibility (9). Fundamentally, this technique noted the mineralization phases of teeth recognized in radiographs and coded them to the corresponding values presented in charts suggested by multiple studies in different populations. The objective of several population based studies on dental age assessment methods is attributed to the wide range of morphological variations among modern human populations with regards to chronology of crown and root formations as well as tooth calcifications (10, 11). Acharya (12) evaluated the age in an Indian population using Demirjian's method and derived a formula which suited an Indian population. The present study was an attempt to determine predictive accuracy of Demirjian's, modified Demirjian's and Acharya's DA assessment method in Odisha (Eastern India) children of age group 3-18 years.

MATERIALS AND METHODS:

A total of 522 (boys=251, girls=271) orthopantomographs along with birth certificates were collected from a cohort of children and adolescents of age group 3-18 years requiring orthopantomograph for treatment planning. Children with developmental anomalies, malnutrition and endocrine disorders, prematurely born children and children with birth defects were excluded from the study group. This cross-sectional study was approved by ethical Committee (Ref No/DMR/IMS-SH/SOA/16026), of Institute of Medical Sciences (IMS) and Sum Hospital, Siksha 'O' Anusandhan Deemed to be University Bhubaneswar (Odisha state, India). Date of birth deducted from date of orthopantomogram yielded CA of the child after which it was converted to the decimal age. For example, patients with ages ranging from 3.00 to 3.99were denoted as the 3-year old group.

While the age group of 7-16 has been selected in modified Demirjian's method, Demirjian had chosen 3-18 years in his study. Therefore the age group in this study has been confined to 3-18 years to obtain a fair comparison. A larger sample size was chosen to minimize the sampling error (Standard error = 4.5). The acceptable margin of error usually falls between 4% to 8% at 95% confidence interval.

Development stages of seven left mandibular permanent teeth were focused in Demirjian's method of age estimation. All teeth were rated on a scale 'A to H' comparing the tooth with Demirjian's calcification chart. The sum of the stages was converted into a maturity score using the tables and graphs provided in the original paper (2) which then was transformed into a DA.

In modified Demirjian's method, the third molar was taken into consideration. The radiograph was compared to tooth development chart and each tooth was assigned any one of the developmental stages from 0 to 9. Corresponding to the selected developmental stage, each tooth was given a numerical score as provided in the original paper. Eight numerical scores were obtained, which were added to attain a total maturity score (S) which was then substituted in Demirjian's formula to derive the DA.

In addition India-specific formula developed by Acharya was also tested on the Odisha sample. The procedure mentioned above for modified Demirjian's method was followed to calculate the total maturity score (S) value and DA was estimated using India-specific formula (12).

The data collected by each method were remodeled to a SPSS Version 21 statistical program to execute the statistical analysis. To observe the normality of distribution of data Kolmogorov-Smirnov test was applied which produced a significant result ($p < 0.05$). Therefore a non-parametric test, Wilcoxon signed rank test was employed. The significance of the difference between CA and DA was evaluated. A P-value of < 0.05 was accepted as statistically significant.

Taking total maturity score obtained by adding individual scores corresponding to developmental stages of tooth in x-axis and CA in y-axis a polynomial regression equation was derived. This formula was again applied in the given sample (n=522) to find out the accuracy of predicting age. Mean absolute error of estimating age by Demirjian's, modified Demirjian's, Acharya's method and the equation derived in this study were found out to compare the predictive accuracy.

Fifty radiographs were again scored according to all three methods by the same observer and another observer. The intra-class correlation coefficient analysis for intra-observer and inter-observer reliability expressed as r value presented in Table 1. This process has minimized non-sampling error.

Table I. Intra-observer and inter-observer correlation coefficient for reliability

Reliability	Methods		
	D	MD	AA
Intra (r value)	0.910-0.924 *	0.920-0.951 *	0.923-0.945 *
Inter (r value)	0.977-0.998 *	0.879-0.885*	0.913-0.959*

*- p<0.05

RESULTS

Reliability of the data was established upon the r-value nearing to one in both inter- and intra-class correlation coefficient analysis as presented in table number 1. Comparisons between the mean ages derived by the three studied methods and the mean CA showed that there was an overestimation by Demirjian's and Acharya's formula while the modified Demirjian's method underestimated all values (Table 2).

Pearson's correlation analysis (Table 3) showed a moderately strong correlation between CA and DA by Demirjian's (boys - r value = 0.854, p=0.000; girls - r value = 0.779, p=0.000) and modified Demirjian's methods (boys - r value = 0.860, p=0.000; girls - r value = 0.859, p=0.000). However age derived by Acharya's formula showed a lower correlation (r value = 0.385, p=0.000) with CA in boys and moderately strong correlation in females (r value = 0.718, p=0.000). Line diagram comparing mean differences of CA and DA by three methods in boys (Figure 1) and girls (Figure 2) indicated that in Demirjian's method the difference was very big in age group of 3, 4, 11 and 16-18 years whereas the difference is limited to 1-1.5 years in other age groups. The difference between CA and DA in modified Demirjian's method indicated that the difference of maximum 1.5 years till age group of 15 years after which the difference increases. Age derived by this method closely resembling the CA except in age group 16-18 years. The difference between CA and DA by Acharya's method showed that there was a big difference in the younger age group whereas this difference decreases as age advances. Because none of the three methods could accurately predict dental age in Odisha children of age group 3-18 years, there was a need to derive a polynomial regression equation that suits this population. Taking total maturity score obtained by adding individual scores corresponding to developmental stages of tooth in x-axis and CA in y-axis a polynomial regression equation was derived as follows.

For girls Age = $0.0026\ S^2 - 0.1876\ S + 9.9751$ (S-total maturity score) (correlation coefficient = 0.87, 95% confidence interval)

For boys Age = $0.001\ S^2 + 0.0349\ S + 2.952$ (S-total maturity score) (correlation coefficient = 0.84, 95% confidence interval).

Error of less than one year is regarded as good whereas an error rate of more than 2 years is regarded as inaccurate (12). The results (Table 4) indicated that Demirjian's and modified Demirjian's method having MAE > 1 could predict the DA with fair accuracy in Odisha children of 3-18 age group whereas Acharya's formula having MAE > 2 could predict dental age with lower accuracy in Odisha children of age group 3-18. Odisha specific method could predict age with better accuracy when compared to Demirjian's, modified Demirjian's and Acharya's method. The accuracy of prediction by Odisha specific method is in fact better in girls compared to boys.

Table 2. The mean age of boys (n = 251) and girls (271) calculated by different methods

	Boys (n = 251)			Girls (n=271)		
	Mean (±Std. Deviation)	Minimum	Maximum	Mean (±Std. Deviation)	Minimum	Maximum
CA	12.05 ±4.08	3.00	18.00	13.43 ± 3.48	5.00	18.00
DA-MD	11.50 ±3.67	2.00	16.00	12.32 ±2.96	3.00	16.00
DA-AA	14.73 ±3.12	10.00	19.00	15.22 ±3.41	9.00	20.00
DA-D	12.42 ±3.63	5.00	16.00	13.88 ±2.82	6.00	16.00

Table 3. Pearson correlation coefficient analysis: Correlation of CA age and dental age

		MD	AA	D
Male CA	Pearson correlation N	0.860 (0.000) 251	0.385 (0.000) 251	0.854 (0.000) 251
Female CA	Pearson correlation N	0.859 (0.000) 271	0.718 (0.000) 271	0.789 (0.000) 271

derived by all three methods for boys and girls in the age group 3-18 years
Correlation is significant at the 0.01 level (2-tailed).

Figure 1 – Line diagram showing comparison between mean differences of CA age and age derived by three methods in boys

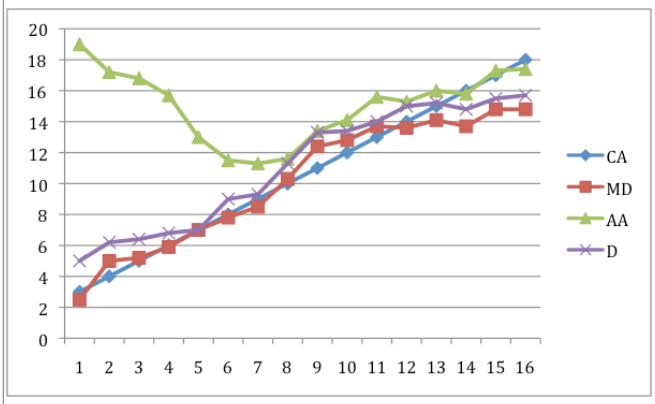

Figure 2 - Line diagram showing comparison between mean differences of CA age and age derived by three methods in girls.

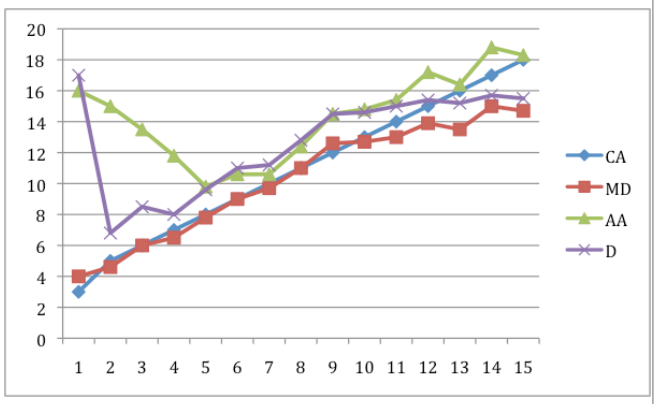

Table 4. Mean absolute error (MAE) of Demirjian's, modified Demirjian's, Acharya's India specific regression formula and Odisha specific age estimation methods.

	Boys (mean±std deviation)	Girls (mean±std deviation)
MD	1.64±1.4	1.7±1.5
AA	3.5±3.5	2.5±2.2
D	1.6±1.4	1.8±1.6
ODISHA	1.2±1.1	0.8±0.9

Correlation is significant at the 0.01 level (2-tailed)

DISCUSSION

Methodologies for estimating an individual's growth and development are of great importance in fields like forensic odontology and anthropology. In spite of the controversial influence of systemic factors such as hormonal and nutritional status upon tooth development it is believed that this harmonizes well with the CA (6). Therefore, knowledge regarding the stages of tooth development has long been used for estimation of age. From the pre-natal era of tooth development till adulthood, between the ages of 2.5 to 18 years radiological method may be implemented for age estimation (13-15).

Conventionally, Demirjian popularized an age estimation method among individuals of all age groups (2) based on stages of development of all seven teeth in the left side mandible. Although this technique encouraged understanding the divergence of the dental maturity for an individual, it was not found to be accurate in every population (16). The modification of Demirjian's technique incorporated the third molar for applicability among a wider age-group and derived regression formulae for assessing age in French children. This method too in populations apart from the French demonstrated patterns of comparatively delayed or advanced

dental development (7, 10, 17, 18). This motivated several authors to check the applicability of Demirjian's method and to advocate population specific standards. Meantime polynomial functions were introduced in forensic science by Chaillet and Demirjian in 2004 (16) which were found to be highly reliable. In fact application of standards formulated for European population in Indian population may lead to misrepresentations of the result. Therefore, with an objective of suitability of above two methods in Indian population Acharya (12) studied radiographs of predominantly south-western Indian population and derived an Indian regression formula. This Indian specific regression formula has been found to estimate the age variably in few parts of India (19, 20). A thorough literature analysis along with the result of this study indicates that the there is a need for population specific formulae to predict DA because of the considerable variation between and within populations (21). A thorough literature analysis demonstrated discrepancies in dental development within and among populations (22, 23).With the objective of checking suitability of above mentioned three DA estimation methods in Odisha (Eastern India) population we have conducted this study and found out that none of the three methods of age estimation can be applied suitably to Odisha population between age group of 3-18 years.

An overestimation of CA by 1.16 years and 1.37 years in boys and girls respectively by Demirjian's method as found in this study is in accordance with most of the studies conducted on various populations like Chinese (17), Iranian (24, 25), Turkish (22), Malayan (6, 26) and Tunisian (27). Even in India, study among various states has produced similar results (28-31). Overestimation of age ranged from 0.14 years (29) to 3.04 years (28) in boys and 0.04 years (29) to 2.82 years (28) in girls among Indians. Contrary to this study Demirjian's method underestimated CA in Kuwaiti (32), Turkish (33), North Chinese (34) and appeared to be accurate in Norwegian children (35). This method was also found to be accurate in school going children of few states of India (37-39). Modified Demirjian's method was found to underestimate the CA by 0.55 (±2.09) years and 1.08(±1.82) years for boys and girls respectively. With a handful of studies applying this method overestimation of CA was observed in population of Sydney (36), Hungary (41) and Tibet (37) whereas underestimation of CA by modified Demirjian's method was the conclusion in a few Indian populations (38-40).

In the present study, Acharya's India-specific regression formula over estimated dental age by 2.73 (+4.08) years in boys and 1.85(+2.62) years in girls. Overestimation of age by AA method was also found in studies conducted in Chennai (20) south Indian, (38, 39, 41) and Haryana, north India (19) population. Overestimation ranged from 0.21 years (39)to 1.72 years (38) in boys and 0.47 years (41) to 1.91 years (38) in girls. However AA method was found to underestimate the age in Gujarati population though the lower value of mean absolute error allowed its applicability (42). Of importance is the finding that as age increases the accuracy of prediction by Acharya's method increases. This finding was in concordance with that of Khorate et al (40) who conducted a study in Goan population and reported that for age group from 10.01 to 19 years the mean absolute error was less than 1.5 year. For individuals under seven years Acharya's age estimation methods over estimated with mean absolute errors panning from 10.9 to 17.62. Acharya in his study (12) in a south-western Indian population has applied the India specific regression formula to the wider age group of 7-25 years whereas Acharya's method has been applied to an age group of 3-18 years in this study. Therefore this Odisha specific regression formula may be considered as a modification of Acharya's formula for the age group 3-18 years of Indian population. However this can only be confirmed with further application of this formula in other Indian populations aged 3-18 years.

Efficacy of age prediction is represented by the mean absolute error (MAE) (43, 44) which is calculated by subtracting the CA from the derived dental age. An error of less than one year is accepted as good whereas an error of more than two years is regarded as inaccurate (12). Because Demirjian's and modified Demirjian's methods resulted in mean absolute error <2 years, it may be concluded that these two methods may predict the dental age with fair accuracy While Acharya's method having an error rate of >2 may not predict the age accurately the formula derived in this study with MAE 1.2 in boys and 0.8 in girls may predict age more accurately especially in children younger than seven years. A close comparison between the age derived by modified Demirjian and this study in both genders may indicate a close comparison of maturity standard of French and Odisha children with slight advanced dental development in

Odisha children. Most of the researchers have in fact supported the delayed growth in French children when compared to other populations (45-47).

The possible reasons which can explain this variability in predicting dental age could be attributed to variations in ethnicity, dietary habits, environmental factors, socio-economic status, that differ in various population groups and most importantly reasonable time difference between studies on the development of tooth among these children. Consequence of malnutrition on tooth development remains controversial with inconsistent conclusions suggesting a significant impact (48, 49) as well as no impact (4, 50). Supporting the earlier studies (51,52), the present study is demonstrating that girls are ahead of boys in tooth development in Demirjian's and Modified Demirjian's method but not in Acharya's study owing to sexual dimorphism during mineralization of teeth. Sexual dimorphism is defined as the differences among both genders in regards to biology. In humans, the sexual dimorphism is minimally appreciable before the onset of puberty. At puberty because of surge of hormones modifications occur in the skeletal system and beginning of secondary sexual characteristics, such as the widening of the pelvis in females. However our study has shown early development of tooth in girls compared to boys for the 3-18 years age group.

CONCLUSION

Digital orthopantomographs offer the advantage of accurate estimation of developmental stages of teeth precision accuracy of which are dependent upon very few variables like age distribution, sample size and statistical approach. To conclude, for the dental age estimation, stage of calcification may be a better indicator and population specific polynomial regression formulae should be derived through population specific standards of tooth development. There may be incorporation of all population specific standards in a common database which may be used for determining DA in forensic as well as anthropological requirements. Having a statistically significant correlation with chronologic age Odisha specific DA estimation formula derived in this study may appropriately be used to estimate DA in Odisha population aged 3-18 years. This study also offers new avenue for further research with an objective to test this method in other Indian populations aged 3-18 years.

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