

Comparison of Demirjian’s comprehensive chart with the London atlas of tooth development in children and adolescents: a pilot study

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Abstract

Dental age estimation has its application in various subdisciplines of medicine and dentistry. New methods of dental age (DA) estimation are emerging and it is important that we compare different methods to determine which one is more closely related to the chronological age. Demirjian’s method is one of the most widely used techniques and has been tested in various ethnic populations globally. In 2016, another approach to DA estimation is the London atlas of human tooth development and eruption. No study has compared Demirjian’s comprehensive chart and London atlas method in the Indian population. Hence, in the current study, we estimated DA using Demirjian’s comprehensive chart and London atlas method for association with the known chronological age in children and adolescent population. The study also attempted to determine if sexual dimorphism existed in DA estimated by the two methods. Estimation was performed for both methods on 100 orthopantomogram records (50 males and 50 females, aged 6–16 years) of orthodontic patients. The data were compared and analysed using paired *t*-tests. There was an overestimation of DA by Demirjian’s comprehensive chart on an average of +1.3 years in males and +0.5 years in females, whereas using London atlas, it was +1.4 years in males and +0.5 years in females. The mean of underestimation was –0.6 years in males and –0.8 years in females using Demirjian’s comprehensive chart, whereas it was –0.8 years in males and –0.5 years in females. A statistically significant difference ($P < 0.0001$) was found when mean chronological age (11.6 ± 2.6) years of the participants was compared with DA estimated using either Demirjian’s comprehensive chart (12.3 ± 2.8) years or London atlas (11.8 ± 2.9) years. The trends in this pilot study point towards more accuracy of London atlas over Demirjian’s method when done using comprehensive chart for estimating DA. In summary, the results of the current pilot study indicates greater accuracy of London atlas method over Demirjian’s comprehensive chart method for estimating DA in Indian population. This finding should be validated by conducting similar studies using larger sample, on diverse Indian ethnic populations, for applicability in pedodontic, orthodontic, and forensic domains.

Key points

- No study has compared Demirjian’s comprehensive chart and London atlas method in the Indian population.
- The dental age estimated by London method was closer to chronological age as compared to Demirjian’s method in our study sample.
- Significant difference was found in chronological age and estimated age using London atlas method in both males and females.

Keywords: dental age estimation; Demirjian’s method; DAEcc; London atlas; interdisciplinary research; age determination by teeth

Introduction

The age of an individual can be described in different ways such as chronological age (CA), radiographic age, dental age (DA), sexual age, and mental age. Age estimation of living children and adolescents is becoming increasingly important in many civil and criminal matters [1, 2].

Apart from relationship of DA and oral pathology [3], it also plays a vital role in other subdisciplines of dentistry including “Pedodontics and Preventive Dentistry” and “Orthodontics and Dentofacial Orthopaedics” for diagnosis and treatment planning [4]. Therefore, accurate and simplified methods for DA estimation (DAE) are increasingly in demand [5]. Interdisciplinary research in craniofacial region has resulted in the development of many different methods of

DAE in recent past. Multiple methods for DAE have been introduced, which estimate the stages of mineralization of developing teeth [6].

Demirjian’s method was developed in 1973 and was first tested on the French-Canadian population and is one of the most widely used techniques for DAE [7]. This method was jaw-radiograph-based and was classified the mineralization stages of the tooth. Although it has been applied in varied ethnic populations [8–10], the original Demirjian’s DAE method poses disadvantages of being time consuming and includes many tables for its calculations. Hence, a Demirjian’s comprehensive chart for DAE (DAEcc) was developed by Jain et al. [11] in 2016. DAEcc was later tested in the National Capital Region of the Indian population and the study validated

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that no significant difference exists between DA estimated by DAecc and the original Demirjian's DAE method [5]. In addition, DAecc has significant advantages of accuracy in forensic on-field applications, being time- and cost-effective with a reduced paper load, and ease in comprehension. This augments the possibility of interdisciplinary application by forensic and dentistry backgrounds with varying levels of experience.

AlQahtani et al. [12, 13] in 2010 in London introduced an innovative and simple approach to DAE, known as the London atlas of human tooth development and eruption (LAHTDE). LAHTDE utilized schematic sequential reference diagrams of the entire dentition, to derive age between 28 weeks of intrauterine and 23 years. Advantages of LAHTDE method include ease of recording, accuracy, less time consuming and greater applicability in the absence of contralateral teeth in the left or right side of the mandible [14]. LAHTDE has been tested on various populations, including Turkish [15], Thai [16], Saudi [6], Iranian [17], Portuguese [18], and Indian [19], for age estimation. LAHTDE, when applied to the Portuguese population, showed a significant difference between male and female estimations [18].

Keeping in view the global acceptance or testing of DAE, the LAHTDE is yet to be analysed in various ethnic populations from the American or Asian origin, which includes the Indian subcontinent. Hence, comparative studies between Demirjian's method and LAHTDE method are the need of the hour, in order to find the applicability and accuracy of these methods in respective populations.

Therefore, the current study was planned to compare DAE using both DAecc and LAHTDE methods for association with the known chronologic age in children and adolescent population. An attempt to determine if sexual dimorphism existed in DAE using DAecc and LAHTDE methods was also made.

The null hypothesis for this study was that there is no difference in CA of Indian children and adolescents when measured with either DAecc or LAHTDE.

Materials and methods

The current retrospective, cross-sectional pilot study was conducted after obtaining institutional ethical approval of Faculty of Dentistry, Jamia Millia Islamia (FILE NO EC/NEW/INST/2020/574). The sample studied consisted of 100 digital orthopantomograms (OPGs) from children (age: 6–16 years), with equal division of OPGs (50 males, 50 females). OPGs of the participants were obtained from the patient's records of the Department of Orthodontics at a dental college in New Delhi with permission to be used in this study.

None of the OPGs were taken for the purpose of the current study. The inclusion and exclusion criteria are as follows:

Inclusion criteria:

- Good-quality OPGs with correct exposure, optimum contrast, acceptable density, and precise anatomical depiction.
- Patients of Indian nationality.
- Presence of all permanent teeth, excluding the third molars.
- OPGs of the participants whose CA is known.

Exclusion criteria:

- Poor-quality OPGs that exhibited less contrast and/or overlap areas, tooth size discrepancy, and artefacts.

- OPGs from subjects outside of India.
- Patients with any pathologic or systemic or developmental problems of jaw or teeth.
- Subjects with the extraction of teeth or previous orthodontic treatment.

All acquired OPGs were from year 2018 to 2022. We randomly selected OPGs until the desired sample size of 100 (50 males and 50 females) was achieved after the application of inclusion and exclusion criteria. Further measurements of DAecc and LAHTDE were performed in the following steps:

1. Before the initiation of the study, one of the authors (AC) was trained by DAecc experts on a set of OPGs to assure the correct execution of DAE measurements.
2. The CA of each participant was calculated by subtracting the date of the OPG taken from the date of birth registered in the departmental records. Number coding was done for all participants, and all details except gender was hidden from AC.
3. Demirjian's DA was calculated for each included OPG using DAecc method [11].
4. For DAE by LAHTDE, OPGs were assessed directly by comparing with specific figures of the developmental and eruptional stages of teeth and by using the DA calculator feature of software available on the website: www.atlas.dentistry.qmul.ac.uk.

Statistical analysis

All the calculated values were entered in a Microsoft Excel sheet and transferred to SPSS software (version 21.0; Armonk, NY, USA) for statistical analysis. Estimated DA was subtracted from the CA to check for underestimation or overestimation. Here, a positive value indicated underestimation and a negative one indicated overestimation of age. The normality of data was checked by plotting Q–Q plots and normal curve on a histogram. In addition, skewness and kurtosis values were also calculated. As data were following normal distribution, the mean and standard deviation were used to describe the age assessed by both the DAecc chart and LAHTDE. The mean difference in DA between the two methods was evaluated and compared using an independent sample *t*-test. Correlation between CA and estimated age using the two methods was shown using the Karl Pearson coefficient of correlation. *P* value is considered significant at less than 0.05.

Results

A total of 100 (50 males and 50 females) OPGs in the age range of 6–16 years were analysed by both the DAecc chart and LAHTDE. Overall, DAecc chart observation (70/100) showed more overestimation compared to LAHTDE (52/100). DAecc chart observations (16/100) showed less underestimation as compared to LAHTDE (45/50). Overall number of perfect scores was more using the DAecc chart (14/100) when compared with LAHTDE (3/100) (Table 1).

Our results showed that the average overestimation of DA by DAecc was +1.3 years in males and +0.5 years in females, whereas in LAHTDE it was +1.4 years in males and +0.5 years in females. Underestimation mean was –0.6 years

Table 1. Tabulation of overestimated, underestimated, and perfect observations ($N = 100$).

	Number of DAEcc observations	Mean	Number of LAHTDE observations	Mean
Overestimated data	70		52	
Male	31	1.3	33	1.4
Female	39	0.5	19	0.5
Underestimated data	16		45	
Male	9	0.6	17	0.8
Female	7	0.8	28	0.5
Perfect data	14		3	
Male	10	–	0	–
Female	4	–	3	–

DAEcc: comprehensive chart for dental age estimation; LAHTDE: London atlas of human tooth development and eruption.

in males and -0.8 years in females using DAEcc, whereas it was -0.8 years in males and -0.5 years in females using LAHTDE. A statistically significant difference ($P < 0.0001$) was found when the mean CA (11.6 ± 2.6) of the participants was compared with either DA estimated using the DAEcc chart (12.3 ± 2.8) or the LAHTDE method (11.8 ± 2.9). The difference between the mean age was more for DAEcc chart method as compared to the LAHTDE method. The mean absolute error for DAEcc was (0.76 ± 2.80) years and (0.29 ± 2.90) years for LAHTDE method (Table 2).

The mean CA of males (11.7 ± 1.8) and females (11.5 ± 3.3) was calculated separately. When CA of males and females was compared with the DA estimated using DAEcc and LAHTDE methods, a statistically significant difference was found in both methods ($P < 0.0001$). Most of the time, the two formulae had overestimated the age over CA except in the case of comparison of the CA of females and the LAHTDE (Table 3). A significant correlation was observed between the CA and DA estimated using the two methods of the study participants ($P < 0.01$, Table 4).

Discussion

The null hypothesis is rejected as significant difference was found in CA and DA when estimated using DAEcc and LAHTDE on a sample of Indian population. Various methods for DAE exist [15], and these include Moorrees et al. [20], Kvaal et al. [21], Haavikko [22], Demirjian et al. [7], Willems et al. (modified Demirjian's) [23], and LAHTDE [12, 13] methods. Cummaudo et al. [24] in a scoping review have done mapping of present population data status and have found 439 papers on DAE. Since growth and development can vary based on different populations, there is always a need and search for more accurate DAE methods. Therefore, our study tested two newer and innovative methods for DAE, i.e. Demirjian's (by DAEcc) and LAHTDE.

Research prospects (checking feasibility and applicability)

The literature provides evidence from few studies conducted across the globe that have compared LAHTDE and

Table 2. Comparison between CA and DA by DAEcc chart and LAHTDE ($N = 100$).

DAE method	Age (mean \pm SD)	Absolute mean error (mean \pm SD)	95% CI
CA vs DA by DAEcc chart*	11.6 \pm 2.6	0.76 \pm 2.80	11.1, 12.1
	12.3 \pm 2.8		11.7, 12.9
CA vs DA by LAHTDE*	11.6 \pm 2.6	0.29 \pm 2.90	11.1, 12.1
	11.8 \pm 2.9		11.3, 12.4

* $P < 0.0001$, highly significant difference. CA: chronological age; DA: dental age; DAEcc: comprehensive chart for dental age estimation; LAHTDE: London atlas of human tooth development and eruption.

Table 3. Gender-wise comparison between CA and DA by DAEcc chart and LAHTDE ($N = 100$).

Gender	DAE method	Items	Number	Age (mean \pm SD)	MAE (SD)	95% CI
Male	DAEcc chart	CA	50	11.7 \pm 1.8	0.88 (2.1)	11.2, 12.2
		DA*	50	12.4 \pm 2.1		11.8, 13.1
	LAHTDE	CA	50	11.7 \pm 1.8	0.77 (2.4)	11.2, 12.2
		DA*	50	12.3 \pm 2.4		11.5, 13.0
Female	DAEcc chart	CA	50	11.5 \pm 3.3	0.65 (3.4)	10.6, 12.5
		DA*	50	12.2 \pm 3.4		11.2, 13.2
	LAHTDE	CA	50	11.5 \pm 3.3	-0.12 (3.2)	10.6, 12.5
		DA*	50	11.4 \pm 3.2		10.5, 12.4

* $P < 0.0001$, highly significant difference. CA: chronological age; DA: dental age; DAEcc: comprehensive chart for dental age estimation; LAHTDE: London atlas of human tooth development and eruption; MAE: absolute mean error.

Table 4. Correlation between CA and as calculated by DAEcc chart and LAHTDE.

DAE method	Correlation coefficient (<i>r</i>) ^a	Significance
DAEcc chart	0.94	<i>P</i> < 0.01
LAHTDE	0.91	<i>P</i> < 0.01

^aPearson's correlation. CA: chronological age; DAEcc: comprehensive chart for dental age estimation; LAHTDE: London atlas of human tooth development and eruption.

Demirjian's DAE methods, as being used in our study [14, 25, 26]. Although one study has evaluated and compared the accuracy of LAHTDE and Cameriere's method in Indian children [19], no study has compared LAHTDE and Demirjian's DAE methods in the Indian population.

Two separate comparative DAE studies (LAHTDE *vs* Demirjian's) on Saudi Arabian population have found Demirjian's DAE method to be more accurate [25, 26], whereas one of the studies conducted on Würzburg (Germany) population found LAHTDE to be more accurate [14] (Table 5). Our results are in sync with the latter study as we found that the difference between the mean age was greater for DAEcc method as compared to the LAHTDE method.

We tested the feasibility of conducting DAE using DAEcc and LAHTDE, and our results can form the basis for planning future larger sample-sized studies. We also suggest that comparisons be made at different operator levels for assessment of DA by DAEcc as well as LAHTDE from undergraduates to trained professionals adept at reading OPGs. These experiments can test the ease of comprehension, accuracy, and time taken for both DAE methods.

In current pandemic times, such retrospective studies involving no patient contact are preferable. Such planned studies can have a scientific impact yet be safe for both observer and the patient.

Applicability of DAE methods in civil and criminal context

Concerns regarding age estimation in children have been highlighted by the United Nations Convention on the Rights of the Child [27]. Our study has included children between 6 and 16 years of age as a study sample, which is an important range of age, especially in an Indian context, since there is a rapid rise in criminal cases involving juveniles, high prevalence of child labour, non-registration of births, age forgery in sports, child pornography, and other forms of civil and criminal matters involving minors [5, 19, 28].

Combining various DAE methods involving different anatomic landmarks has been recommended to be tested on

various populations globally [26]. Studies like ours, which test newer, innovative, and applicable methods, can form the basis for further research in the arena of age estimation or forensic age estimation purposes in respective populations.

Application of LAHTDE and eruption and DAEcc for DAE in sexual dimorphism context

It has been reported that there was no significant difference in the accuracy of age estimation between males and females when LAHTDE was tested on Indian children [19], whereas a study on Saudi Arabian children found significant difference between both sexes [25]. Our results also show a significant difference in CA and estimated age using LAHTDE in both males and females. Although a statistically significant difference was found when the mean of CA was compared with DAE calculated using both methods, future studies with larger sample are required to prove this observation.

Few studies on various populations using Demirjian method for DAE have reported that dental maturation was more advanced in the studied females than in the examined males [29, 30]. Similarly, our study found DAEcc's frequency of overestimation of age to be more in females than males, highlighting the need of developing gender-specific charts. These findings also signify that hormonal variations in growing or puberty periods affect the tooth formative stages [31].

Indication for the more accurate DAE method in growing children and adolescents

Some studies have tested the accuracy of LAHTDE with Cameriere's open apex method on the Indian population [19]. Since Demirjian's method is still the most widely use method for DAE [32], establishing the accuracy of Demirjian's method compared to LAHTDE using a larger sample and observers will make it possible to make an informed decision about the most applicable method in growing children for forensic age estimation.

Applicability of DAE methods in wider ethnic populations

Human population worldwide exhibits heterogeneous patterns of growth and development. Environmental influences and social variations, which are subtle yet confounding, cause changes in the rate of development and CA of various ethnic groups. To address this, scientists globally correct and modify existing methods of DAE [26]. Trend of our results shows that DAE by LAHTDE method has derived CA closer than DAEcc chart on North-Indian population; hence, both these methods can be conveniently tested in diverse ethnic populations of the Indian subcontinent.

Table 5. Performance of Demirjian's vs LAHTDE in comparative studies.

Reference	Year	Sample size	Other method	Country/population	More accurate (Demirjian's/LAHTDE)
Alshihri [24]	2016	Demirjian: 198 OPGs; LAHTDE: 241 OPGs	Mincer's	Saudi Arabia (Western)	Demirjian's
Gelbrich [14]	2020	500 OPGs	Willems	Würzburg (Germany)	LAHTDE
Ashraf et al. [25]	2020	350 OPGs	Willems	Saudi Arabia	Demirjian's
Chowdhry et al. ^a (present study)	2022	100 OPGs	–	North India	LAHTDE ^a

^aPilot study (larger sample required to validate). LAHTDE: London atlas of human tooth development and eruption.

Limitation of the study

Few authors have highlighted the impediment of using LAHTDE, particularly, that this method estimates age between 0.5 years. This has implications while assessing age, as the investigator may be constrained to enter an age range with an underestimation or overestimation mean of 11 months. In addition, the LAHTDE occasionally produces multiple age estimates, as the assessed teeth may correspond to diverse ages [33]. Sample size of our pilot study was small, and the data collected were not categorized age-wise. The data were a bias one with maximum sample entries from 11-year ($n=30$) age group, consisting of overestimation and underestimation each ($n=15$). Further larger sample size, population-based studies can be planned, to apply overestimation and underestimation conclusions to various age groups.

Although a statistically significant difference ($P < 0.0001$) was found when the mean of CA was compared with DAE calculated using the DAEcc chart or the LAHTDE method, future studies can have more than one observer and larger sample for better reliability and less bias.

Conclusion

This pilot study successfully checked the feasibility of the testing DAEcc chart and LAHTDE on the New Delhi (North-Indian) population. Although appropriate power and sample size was not calculated in our pilot study, the trends of our results point towards more accuracy of LAHTDE than DAEcc chart (Demirjian's method). Diversion of recourses to conduct larger sample size studies using these two methods helps to confirm their applicability on various Indian populations.

Once the applicability and accuracy of both methods are established, it can be proposed to be included in the dental undergraduate and postgraduate curriculum. This will enable students to perform age estimation by these innovative and simple methods. Furthermore, our results can also prove to be very useful in providing recommendations for the application of these two methods in clinical dentistry and forensic sciences in an Indian context.

Authors' contributions

Aman Chowdhry designed the study, performed literature research, and wrote and reviewed the manuscript. Priyanka Kapoor performed literature research, and wrote and reviewed the manuscript. Deepak Bhargava, Dinesh Kumar Bagga and Abhishek Mehta coordinated the study, and wrote and reviewed the manuscript. All authors contributed to the final text and approved it.

Compliance with ethical standards

The study was conducted after obtaining Institutional Ethical approval from Faculty of Dentistry, Jamia Millia Islamia (FILE NO EC/NEW/INST/2020/574). The sample studied consisted of 100 digital orthopantomograms (OPGs) of the study participants obtained from the patients' records of Department of Orthodontics at a dental college in New Delhi with permission.

Disclosure statement

None declared.

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