



Estimation of Chronological Age in Pune Population using the London Atlas Software App 2nd Edition, 2021

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ABSTRACT

The aim of this study was to evaluate the accuracy of London Atlas method in determining chronological age in Pune's local population. Three hundred thirty five orthopantomograms were obtained of healthy individuals in ages between 14 yrs till 23.99 years. Uniformity in age and sex were maintained (168 female and 167 male). Ages were estimated and results were evaluated using Stata 15 software. Highest standard deviation were founding age groups 20-20.99 yrs [SD +/- 0.383], 21-21.99 yrs [SD +/- 0.360] and 22-22.99 yrs [SD +/- 0.365]. There's slight overestimation from 14 yrs of age till 21 years of age while underestimation in 21 yrs till 23.99 years. There was statistically significant difference for male participants [P=0.008] while no statistically significant difference was observed with female participants [P=0.170]. London atlas method is not reliable and accurate for estimation of age in Pune population for age group between 14 to 23.99 years of age [P < 0.05]. There is overall overestimation of age using this method.

Keywords: Indian population, London atlas, forensic anthropology, age estimation, forensic odontology

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INTRODUCTION

Estimation of age has been an integral part of forensic dentistry. Teeth have been one of the most stable markers for age estimation as they are the least resistant to environmental factors for their development [1-2] and most stable throughout the life with least turnover of natural structure [3].

Age estimation is essential in various medico-legal cases to differentiate between juveniles and adults, identification of individuals and children of unknown birth records, in scenes of crime and accidents. Exact age estimation is essential in pediatric endocrinology as well as orthodontic treatment planning [4,5].

Various methods have been employed for estimation of age using dental developmental stages as well as elaborated charts of the development of dentition and the specific formation of the tooth crown and root to estimate dental age by comparing radiographs with illustrations [6]. While Demirjian [7,8], Willems [9], Nolla [10], and Häavikko [11] methods utilized the calcification progression of teeth using different stage classification and scoring systems, the London Atlas established age by correlating an orthopantomogram to specific figures of tooth development stage and level of alveolar eruption [12].

London Atlas method was developed by AlQahtani et al. in 2010 [12] that provides charts of tooth development and eruption from 28 weeks in utero to 23 years, for the entire permanent and deciduous dentition. It allows use of software where respective envelopes of dental and alveolar eruption stages for each tooth are entered and the software then compares these stages to its database to generate an estimated age. In 2021, the 2nd edition of the London Atlas was released which was updated into an interactive software version (<https://www.qmul.ac.uk/dentistry/atlas/software-app/>).

This method is easy to use, non-invasive, convenient, and replicable [13,14]. The aim of this study was to assess the accuracy of London Atlas method in estimating chronological age in Pune population. To evaluate dental age from orthopantomogram using London Atlas Method in residents of Pune city.

MATERIAL AND METHODS

Study Design and Ethical Aspects

Study Design

This study employed across-sectional, analytical, observational design. The reporting of epidemiology study was improved by following the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement. Radiographs were solely obtained for diagnostic and treatment planning purposes; no subjects were exposed to ionizing radiation for research purposes. This approach adhered to the World Medical Association's Declaration of Helsinki (2013). The study had obtained institutional ethical approval (EC/NEW/INST/2021/MH/0029).

Participants and Settings

Sample Size: A total of 335 panoramic radiographs were utilized (out of which 168 samples were female participants while 167 samples were males) aged 14 to 23.99 years. The radiographs were retrospectively sourced from the archives of the Department of Oral Medicine and Radiology, Bharati Vidyapeeth University, Pune, captured between March 2021 and December 2022 using a KODAK model number-8000C (Care stream Dental India Pvt Ltd).

Inclusion Criteria: Good quality panoramic radiographs from participants aged 14 to 23.99 years, with good exposure and all teeth in focus.

Exclusion Criteria: Radiographs from individuals above 23.99 years, those with systemic diseases affecting development, oro-dental pathology, gross caries, retained deciduous teeth, impacted teeth, history of orthodontic treatment, or missing birth date and sex information were excluded.

Sample Size Calculation

A minimum sample size of 150 participants was calculated with a 95% confidence level, a standard deviation of 0.5, and a margin of error of 8%. The sample used in the study was used to balance distribution between males and females hence, more individuals were distributed based on age and sex.

A similar sample size has been used in Indian population to estimate dental age using London Atlas method that gave adequate effects between males and females [15].

Radiograph Analysis

Radiographs were analyzed using CST rophy DICOM (KODAK)-63.0.0 (Carestream Dental India Pvt Ltd) dental software. They were viewed on a 15" computer screen.

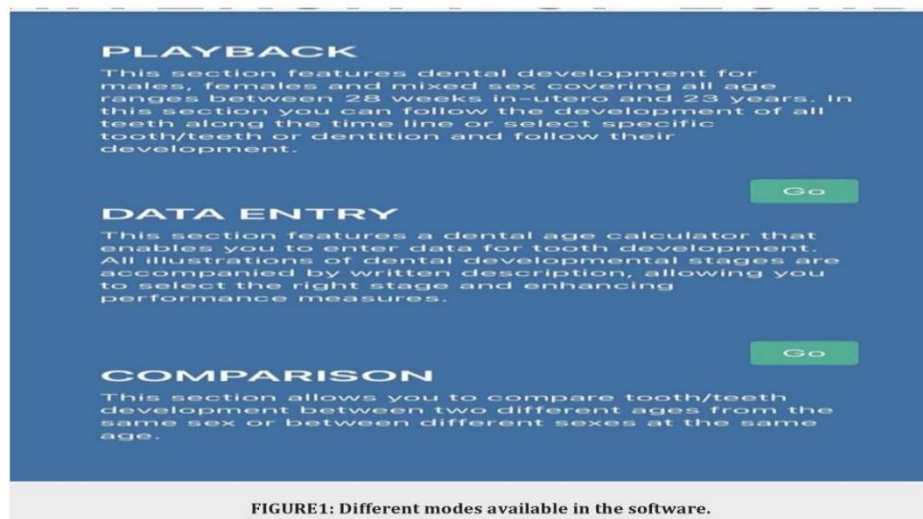
Data Source and Variables

Sex, chronological and estimated ages of the participants were variables taken into consideration. Two of the researchers selected the radiographs that fulfilled the inclusion criteria. The selected radiographs were stored in a separate folder and given an identification number. All the details including participant's sex, date of birth and the date on which radiograph was taken were recorded in excel spreadsheet (version 16.0.7571.7095, Microsoft, Redmond, Washington, USA).

Chronological age (real age), for each individual was calculated by subtracting the date on which the OPG was taken from the date of birth. For in depth analysis the data was categorized into 10 age groups; 14-14.99 yrs, 15-15.99yrs, 16-16.99yrs, 17-17.99yrs, 18-18.99yrs, 19-19.99yrs, 20-20.99yrs, 21-21.99yrs, 22-22.99yrs and 23-23.99yrs.

Coding was done for all the participants and the observer was blinded to the or actual age. To calculate the estimated age, London atlas software app 2nd edition was used.

The software has three options: play back mode, data entry mode and comparison mode as shown in Figure 1.



Play back mode: provides development of all teeth or a specific tooth along the timeline

Data entry mode: this is the dental age calculator. All data with respect to tooth developmental stages and eruption status are entered in table to calculate dental age.

Comparison mode: provides comparison between two different ages or between males and females at the same age.

Dental age calculation

Radiographs were analysed under standard viewing conditions and not more than 15 radiographs were analyzed per day. This method utilizes the Moorrees et al [1] stages of tooth eruption and modified Bengston's [16] tooth developmental stages as depicted in fig.2[12].

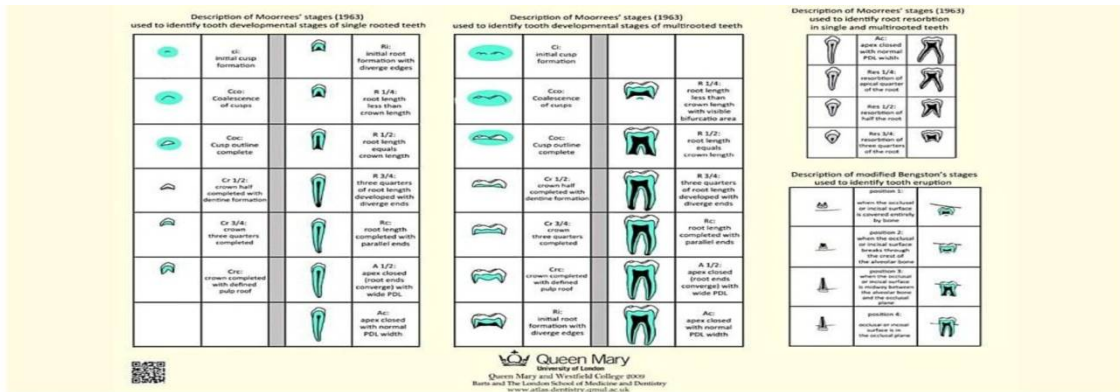


FIGURE 2: Illustrations showing Moorrees's stages of tooth development and modified Bengston's stages of tooth eruption.

PDL refers to "period on talligament space".

Using the data entry function, sex of each individual was selected followed by selection of permanent dentition. Each tooth on right side of quadrant in OPG was assigned tooth developmental stage and eruption status respectively in the table provided by the software as shown in Figure 3B.

After all the teeth in right quadrant were assigned the values, pictorial representation of tooth specific stages were provided by the software and estimated age was selected from the best possible age match, shown in figure 3C.

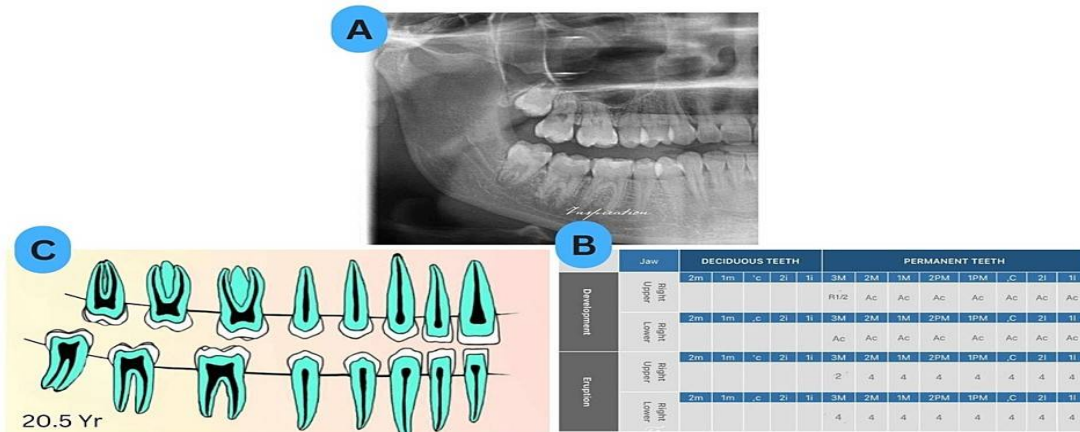


FIGURE3: Illustration depicting age estimation using the London Atlas Software Application.

- A) Mandibular and maxillary right permanent teeth were analysed with respect to Moorrees et al. [1] tooth development and modified Bengston's tooth eruption stages[15]
- B) In data entry mode, each tooth was assigned the respective developmental and eruption stage

In case of multiple estimates provided by the software, the inter mediate estimate was selected. If there were only 2 possibilities of age match, the lower value was selected.

REPRODUCIBILITY

The main examiner was a Radiologist with more than 15 years of experience in the field of oral medicine diagnosis and radiology. Inter and intra examiner agreement was assessed by taking 20 radiographs

(randomly selected sub sample) of main sample and evaluating them with time interval of 15 days from the main analysis. The data was quantified using Cohen Kappa test.

STATISTICAL ANALYSIS

Stata 15 software developed by Stata Corp Texas, USA was used for analysis. Descriptive statistics, including measures of central tendency and dispersion (such as minimum, maximum, mean, and standard deviation(SD), were applied to chronological and estimated ages data. The error in the method was presented as difference between estimated age and chronological ages wherein the positive values were considered as overestimates and negative values as underestimation. Radiographs were categorized as having estimated ages with in 12 months (-1to+1year) or over 12 months (>1year,<-1year) of the chronological age. Chronological and estimated ages for the entire sample were compared using a paired t-test ($p < 0.05$ was considered statistically significant). Pearson's correlation coefficient was used to measure the association between estimated and chronological age.

RESULTS

Cohen's kappa for intra observer agreement was 0.889 whereas for inter observer agreement it came out to be 0.834. This suggests almost perfect agreement in accordance to Landis and Koch guidelines.

A total of 335 radiographs were analyzed. It was separated by age group and gender (167 males and 168 females) as represented in table 1.

TABLE1: Distribution of samples based on age and sex

Age Group (in years)	Gender	Mean difference	Abs. mean difference	SD	Total
14-14.99	F	0.150	0.225	0.161	16
14-14.99	M	0.133	0.267	0.118	15
15-15.99	F	0.112	0.206	0.103	17
15-15.99	M	0.172	0.194	0.155	18
16-16.99	F	0.100	0.188	0.136	16
16-16.99	M	0.138	0.213	0.120	16
17-17.99	F	0.026	0.153	0.135	19
17-17.99	M	0.150	0.194	0.147	18
18-18.99	F	-0.011	0.211	0.191	18
18-18.99	M	0.047	0.216	0.157	19
19-19.99	F	0.159	0.250	0.276	22
19-19.99	M	0.059	0.195	0.156	22
20-20.99	F	-0.095	0.347	0.524	19
20-20.99	M	0.090	0.280	0.177	20
21-21.99	F	0.140	0.367	0.337	15
21-21.99	M	-0.182	0.491	0.394	11
22-22.99	F	-0.208	0.454	0.350	13
22-22.99	M	0.064	0.421	0.391	14
23-23.99	F	-0.055	0.200	0.148	11
23-23.99	M	0.008	0.208	0.180	13

Differences between chronological age and age estimated by London Atlas method are represented in table 2.

TABLE 2: The accuracy of the London Atlas for male and female age groups.

Age(inyears)	Male	Female	Total
14-14.99	16	16	32
15-15.99	18	18	36
16-16.99	16	17	33
17-17.99	18	18	36
18-18.99	19	19	38
19-19.99	22	21	43
20-20.99	18	18	36
21-21.99	14	14	28
22-22.99	11	12	23
23-23.99	15	15	30
Total	167	168	335

Male subjects had a smaller mean difference (chronological and estimated age) when compared to female subjects. In general, underestimation of age in the age groups 18-18.99 yrs,20-20.99yrs, 22-22.99yrs and23-23.99yrs for female subjects. There was statistical significant difference for male participants [P=0.008] while no statistical significant difference was observed for females [P=0.170]

Table 3 represents that there is slight over estimation in the age groups from 14 year still 21.99years of age followed by underestimation in the age groups from 22years till 23.99years.

TABLE 3: The accuracy of London Atlas for the age groups.

Age group(in years)	N	Mean difference	Abs. Mean difference	SD	SE Mean	P value
14-14.99	31	0.142	0.245	0.141	0.046	0.007
15-15.99	35	0.143	0.200	0.131	0.033	0.000
16-16.99	32	0.119	0.200	0.127	0.037	0.003
17-17.99	37	0.086	0.173	0.141	0.034	0.016
18-18.99	37	0.019	0.214	0.172	0.045	0.679
19-19.99	44	0.109	0.223	0.223	0.045	0.019
20-20.99	39	0.000	0.313	0.383	0.080	1.000
21-21.99	26	0.004	0.419	0.360	0.109	0.507
22-22.99	27	-0.067	0.437	0.365	0.112	0.793
23-23.99	24	-0.021	0.204	0.163	0.054	0.702

Highest standard deviation were found in age groups 20-20.99 yrs [SD +/- 0.383], 21-21.99 yrs [SD +/- 0.360] and 22-22.99 yrs [SD +/- 0.365]. Pearson’s correlation demonstrated a positive correlation between chronological age and estimated age where R square=0.9649 as seen in Fig.2.

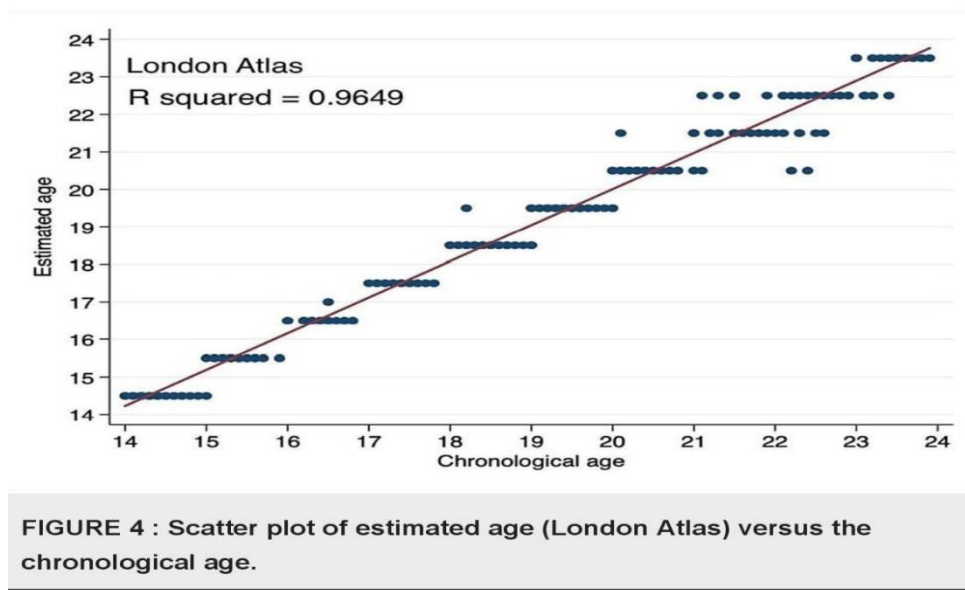


TABLE 4: Frequency of estimated from real age deviation range by sex and age group.

Age Group(inyears)	Gender	Age deviation range			Total
		"	"-1to1"	">1"	
14-14.99	F	0	16	0	16
14-14.99	M	0	15	0	15
15-15.99	F	0	17	0	17
15-15.99	M	0	18	0	18
16-16.99	F	0	16	0	16
16-16.99	M	0	16	0	16
17-17.99	F	0	19	0	19
17-17.99	M	0	18	0	18
18-18.99	F	0	18	0	18
18-18.99	M	0	19	0	19
19-19.99	F	0	21	1	22
19-19.99	M	0	22	0	22
20-20.99	F	2	17	0	19
20-20.99	M	0	20	0	20
21-21.99	F	0	14	1	15
21-21.99	M	1	10	0	11
22-22.99	F	0	12	1	13
22-22.99	M	0	13	1	14
23-23.99	F	0	11	0	11
23-23.99	M	0	13	0	13

Three hundred twenty eight radiographs (97.9%) were estimated between -1 and +1 year, three radiographs were underestimated and four radiographs were over estimated. Most of the estimates were lying between -1 and +1 year (Table 4).

DISCUSSION

Those of various ethnicities frequently have diverse tooth growth patterns where as those within the same ethnic group generally have comparable dental developmental patterns. Hence, age estimation methods were suggested for testing and practicing in varied populations.

Sousaetal. [17] also stated that“ more studies on different populations using the London atlas would be fund a mental to test how it performs in different population groups.”

There are two main strategies to test the applicability of the London Atlas: by assessing the deciduous and permanent dentition among individuals below the age of 16years [18], and by assessing the development of third molars among individuals between 16 and 23 years [19]. Rarely any studies have been conducted on Indian population using London Atlas Method in age groups be yond 15.99years.

A significant portion of the Indian population does not have substantial records such as birth certificates that prove their age. According to The International Labour Organisation, 12.9 million Indian children are engaged in work that includes hazardous occupation including mining, inflammable substance, and explosive related work [20]. With respect to The Child Marriage Restraint Act,1978, the minimum legal age of marriage is 18 years in women and 21years in men. However, atleast1.5 million girls under 18 years get married in India [21]. With the ever-increasing sexual abuse cases in India and so many un law full activities challenging the victims age [22,23], an accurate method of age estimation becomes essential. Hence, we decided14-23.99years of age a sour target population.

Various age estimation methods have been employed to Indian population such as study conducted on Indian children concluded that Willem’s method was the most accurate followed by Demirjian and Chaillet’s methods [24]. However, studies involving non-invasive techniques of age estimation such as London Atlas Method has been hardly done on Indian population. Hence, we assessed the accuracy of London AtlasMethod in Indian population (14-23.99 years). Our study revealed that there was statistically significant difference [P<0.05] for age groups 14-14.99years, 15-15.99years, 16-16.99years, and 17-

17.99years which is congruent with the study conducted on white and Bangladeshi populations where in the authors observed minimum variation during in fancy but most variability after 16years [12].

Alshihri et al, 2015 [14,25] conducted study on Saudi Arabian children and adolescents 2-20years old while Pavlovićetal[1] conducted on Portuguese population between 3-24years for age estimation using London Atlas method. They found a significant difference between mean estimated and actual age. Also, there was significant difference in the accuracy of age estimation between males and females. The observation of our study is in agreement where in the over all $P < 0.05$.

Additionally, there was no statistically significant difference between chronological and estimated ages In female. However, significant difference in samples coming from males ($P < 0.05$). This is in agreement with the study conducted by Pavlovićetal.[1].

However, it is in contrast with the studies carried out in Iranian population [13] and Indian population [15] indicating high accuracy with no significant differences between the mean chronological age and mean dental ages. This difference in results could possibly be due to difference in age groups included in the study where in study on Indian population as well as Iranian population was conducted on 5-15.99yrs of age.

Underestimation of age was a common observation in Saudi [14] and American populations [26]. Our study showed over all over estimation of age as was seen in studies conducted on Portugal population[27,28].

Over estimation of age specially 18 years and younger can have legal implications in India.

According to Majority Act of 1875 consider 18 years as age of majority as there is a separate juvenile legislation for under age population. Juvenile Justice Act [29]states that children in conflict with the law are not treated as criminals rather individuals who need care and protection. Hence, over estimation of age would affect the legal conditions. Even though London Atlas method is simple to use, non-invasive and involves both permanent and deciduous teeth, this method provides age as an average i.e., 11.5 yrs depicts mean of 11 to 11.99 years. Therefore, there could be error of 6 months with this method and bias being over stated[30].

Another limitation involves either memorizing a series of tooth developmental pictures or using are ference for tooth eruption and developmental stages to utilize this method.

Sometimes the atlas provides multiple age estimates as evaluated teeth coincide with multiple age estimates. Adams et al. [19] suggests to conduct more studies in order to understand which teeth are more stable during development. Since accuracy is a primary criterion for age estimation methods [31], age predicted by London atlas method showed statistically significant difference between actual and estimated age.

Even though 90% of tooth development process is affected by genes with very less environmental influence [32], factors such as nutrition, customs, and sun light exposure could still affect the developmental process. We were unable to record potential factors for each subject thereby limiting the casual analysis in further exploration.

CONCLUSIONS

Estimation of age is essential for both forensic and criminal cases if it is within six to twelve months of the chronological age. Considering the results of this study the accuracy of London atlas method for Indian population above 14yrs was questionable. There is a need for carrying out more studies in these age groups in Indian population to assess the precision of London atlas method.

The difference between genders indicate a need to have separate representation of tooth developmental stages for females and males considering the impact of hormonal changes and growths purts. More studies should be conducted to prove its practicality and validity.

A comprehensive global data base of atlas-based data for diver se ethnic sub populations would be very useful for clinicians worldwide.

ADDITIONAL INFORMATION

Human subjects: Consent was obtained or waived by all participants in this study. Bharati Vidyapeeth (Deemed to be University) Dental College and Hospital, Pune, India, Institutional Ethics Committee issued approval EC/NEW/INST/2021/MH/0029. This is to certify that the study titled 'Estimation of Chronological Age in Local Population using London Atlas Method' by Miss Pavni Chawla and Miss Rakshita Sinha ,Principal Investigators from the Department of Oral Pathology and Microbiology has been approved by the Institutional Ethics Committee (Registration number EC/NEW/INST/2021/MH/0029) during a meeting held on 21-06-2022 and 22-06-2022.

Animal subjects: All authors have confirmed that this study did not involve animal subjects or tissue.

Conflicts of interest: In compliance with the ICMJE uniform disclosure form, all authors declare the following: Payment/services info: All authors have declared that no financial support was received from any organization for the submitted work.

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