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ORIGINAL ARTICLE

Validation of the London Atlas for Dental Age Estimation in an Indian Paediatric Population: A Pilot Study

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Abstract

Background: Dental age estimation is important for treatment planning and medico-legal identification in paediatric dentistry, orthodontics, and forensic odontology. The London Atlas of Human Tooth Development and Eruption is a popular non-invasive method, but its accuracy may vary between populations, and data from Indian children remain limited. This pilot study assessed the accuracy and applicability of the London Atlas in Indian children.

Materials and Methods: A retrospective, cross-sectional analysis was performed on 50 anonymised digital orthopantomograms (25 males, 25 females; aged 3–14 years) from departmental archives. Chronological age (CA) was blinded by coding before assessment. A single calibrated, blinded examiner estimated dental age (DA) using the London Atlas online tool. DA was compared with CA using paired t-tests and Pearson's correlation; significance was set at $p < 0.05$.

Results: Mean CA was 8.92 ± 2.51 years and mean DA 8.74 ± 2.58 years, a non-significant underestimation of −0.18 ± 1.39 years ($p = 0.365$). A strong, significant positive correlation was observed ($r = 0.851$, $p < 0.001$). Neither sex showed a significant CA–DA difference (females $p = 0.849$; males $p = 0.233$). On age-group analysis, the atlas overestimated age in the youngest children (3–6 years, $p = 0.038$) but agreed closely in older groups.

Conclusion: The London Atlas demonstrated good accuracy and strong correlation with chronological age in this Indian paediatric sample, with no significant systematic bias or sexual dimorphism. As a pilot study, these findings warrant validation in larger, multicentric cohorts.

Keywords: Dental age estimation; London Atlas; forensic odontology; orthopantomogram; paediatric dentistry.

Introduction

Age estimation is important in clinical and medico-legal contexts, particularly in growing children. In paediatric dentistry and orthodontics, developmental age aids diagnosis and the timing of interventions for malocclusions related to maxillofacial growth.[1] In forensic medicine, it assists in identifying unknown human remains and in legal matters concerning juvenile culpability, immigration, adoption, and age fraud in sports, especially when reliable birth records are unavailable or disputed.[2,3]

Most dental age estimation methods rely on the radiographic assessment of tooth development and eruption, comparing tooth growth against standardised reference charts derived from large, geographically defined populations.[4,5] Demirjian's method, introduced in 1973, remains widely used and has been tested across diverse ethnic groups, although it has been reported to overestimate age in several populations.[6]

To simplify and improve estimation, AlQahtani, Hector, and Liversidge developed the London Atlas of Human Tooth Development and Eruption in 2010.[7] The atlas evaluates both tooth formation and eruption in relation to the alveolar bone, covering the deciduous and permanent dentitions from 28 weeks in utero to 23 years of age. Subsequent validation has reported favourable accuracy for atlas-based charts relative to earlier estimation systems,[8] and such radiographic approaches are valued as simple, reproducible methods suitable for children and emerging adults.[9]

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Despite its growing use, few studies have evaluated the London Atlas in the Indian population. Earlier Indian work validating a simplified comprehensive chart for the Demirjian method reported limited applicability of the original technique in a north Indian sample,[10] underscoring the need for population-specific testing. A recent Indian pilot study reported that the atlas was more closely aligned with chronological age (CA) than Demirjian's comprehensive chart,[11] and a further retrospective study found it to be the more accurate of the two methods.[12] Given the influence of ethnicity on dental maturation, this pilot study aimed to evaluate the applicability and accuracy of the London Atlas method in an Indian paediatric sample, and to assess whether significant differences exist between CA and estimated ages and between sexes.

Materials And Methods

Study design and ethical considerations

This retrospective, cross-sectional study was conducted in the Department of Paediatric and Preventive Dentistry of a tertiary dental institution in North India. Informed consent for diagnostic radiography and for the future use of records for educational and research purposes was obtained from patients and/or their parents or legal guardians at the time of their original clinical registration at the institution. No radiographs were taken specifically for this study; all OPGs were obtained from departmental archives and were fully anonymised before analysis, with no patient-identifiable information accessed at any stage.

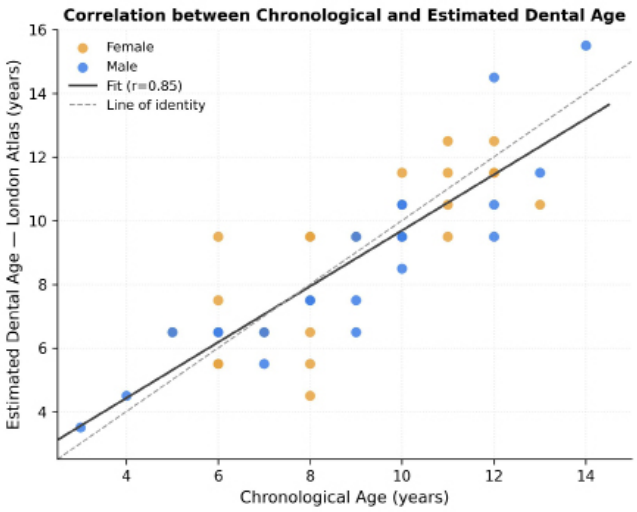


Figure 1: Scatter plot showing the correlation between chronological age and dental age estimated by the London Atlas method, with the line of best fit and the line of identity

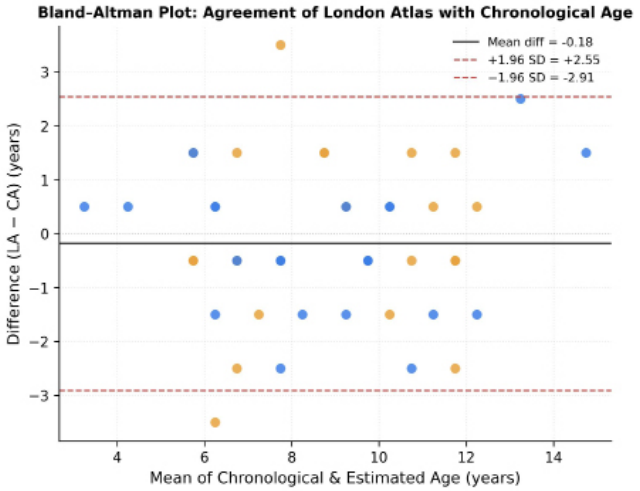


Figure 2: Bland–Altman plot showing the agreement between London Atlas estimated dental age and chronological age, with mean difference and 95% limits of agreement

Sample

The sample comprised 50 archived digital OPGs of Indian paediatric patients (25 males, 25 females; aged 3–14 years), originally acquired for routine diagnosis and treatment; none were taken for the purpose of this study. The sample size of 50 was based on previous pilot studies of dental age estimation in Indian children, which used samples of comparable size. [10,11,13]

Inclusion and exclusion criteria

High-quality OPGs of Indian children with adequate exposure, optimal contrast, clear visualisation of developing structures, and a known date of birth and radiograph date were included. OPGs of poor diagnostic quality, or with developmental anomalies, congenitally missing teeth, pathology affecting tooth development, a history of orthodontic treatment or extraction, or partially visible teeth precluding reliable staging, were excluded.

Blinding and anonymisation

To eliminate observer bias, all OPGs were assigned anonymous alphanumeric codes by an independent

Table 1: Comparison between chronological age (CA) and London Atlas estimated dental age (DA), overall and by sex

Group	*n*	*Mean CA ± SD*	*Mean DA ± SD*	*Mean Diff ± SD*	*p-value*
Females	25	8.88 ± 2.30	8.82 ± 2.43	−0.06 ± 1.56	0.849
Males	25	8.96 ± 2.75	8.66 ± 2.78	−0.30 ± 1.22	0.233
Combined	50	8.92 ± 2.51	8.74 ± 2.58	−0.18 ± 1.39	0.365

Table 2: Karl Pearson correlation between chronological age and London Atlas estimated dental age.

Group	*Pearson r*	*p-value*
Females (n=25)	0.784	<0.001
Males (n=25)	0.902	<0.001
Combined (n=50)	0.851	<0.001

coordinator not involved in age estimation, and each patient's CA was concealed during assessment. CA was unblinded only after all estimations were complete. Assessments were carried out by a calibrated observer to ensure internal consistency in the application of the London Atlas.

Age estimation and statistical analysis

Chronological age (CA) was calculated by subtracting the date of birth from the radiograph date. Dental age (DA) was estimated using the London Atlas online tool (www.atlas.dentistry.qmul.ac.uk), matching the developmental and eruption stages of each quadrant to the closest atlas age category. The difference between estimated and chronological age was recorded for each patient, with positive values indicating overestimation. Data were analysed using the paired t-test, with the Wilcoxon signed-rank test applied as a non-parametric confirmation; the Karl Pearson correlation coefficient assessed the association between CA and DA, and the independent samples t-test was used for sex-related differences. To examine performance across development, participants were further divided into age subgroups (3–6, 7–9, 10–12, and 13–14 years) and analysed separately. Agreement between CA and DA was additionally assessed using Bland–Altman analysis. A p-value < 0.05 was considered significant.

Results

Fifty OPGs of Indian children aged 3–14 years (25 males, 25 females) were analysed. The overall mean CA was 8.92 ± 2.51 years and mean estimated DA was 8.74 ± 2.58 years, a non-significant underestimation of −0.18 ± 1.39 years ($p = 0.365$), indicating close agreement (Table 1); the Wilcoxon signed-rank test concurred ($p = 0.35$). Neither sex showed a significant difference between CA and DA, and estimation error did not differ between sexes ($p = 0.548$), indicating no marked sexual dimorphism. The atlas overestimated age in 21 cases (42%) and underestimated it in 29 (58%), with a mean absolute error of 1.12 years.

The Karl Pearson correlation coefficient showed a strong, statistically significant positive correlation between CA and DA for the combined sample ($r = 0.851$, $p < 0.001$), which was stronger in males ($r = 0.902$) than in females ($r = 0.784$), both statistically significant (Table 2). This relationship is illustrated in Figure 1.

Age-subgroup analysis

When analysed by developmental age group (Table 3), the London Atlas significantly overestimated age in the youngest children (3–6 years; mean difference +0.90 years, $p = 0.038$). In the 7–9 year group a non-significant underestimation was observed (−0.68 years, $p = 0.060$), while the 10–12 year group showed the closest agreement (−0.20 years, $p = 0.456$). The oldest group (13–14 years) contained only three participants and showed a non-significant underestimation (−0.83 years, $p = 0.560$). Positive correlations with CA were seen across all subgroups.

Agreement analysis

Bland–Altman analysis (Figure 2) showed a mean difference of −0.18 years, with 95% limits of agreement of approximately +2.55 to −2.91 years. The points were distributed evenly about the mean line without a marked systematic trend across the age range, indicating acceptable overall agreement between the London Atlas and chronological age, with wider individual variation at the extremes of the age range.

Discussion

This pilot study tested how well the London Atlas estimates dental age in Indian children. Overall it performed well. The atlas underestimated chronological age by a mean of just 0.18 years — about two months — which was neither statistically nor clinically meaningful, and its estimates correlated strongly with chronological age ($r = 0.851$). A mean absolute error of 1.12 years, taken together with this small bias, suggests the atlas gives a usable age estimate in this population, and it does so quickly, simply, and without any additional radiographic exposure.

Table 3: Age-subgroup comparison between chronological and estimated dental age. *p < 0.05

Age group (yrs)	*n*	*Mean CA ± SD*	*Mean DA ± SD*	*Mean Diff*	*p-value*
3–6	10	5.30 ± 1.06	6.20 ± 1.64	+0.90	0.038*
7–9	17	8.06 ± 0.75	7.38 ± 1.62	–0.68	0.060
10–12	20	10.80 ± 0.89	10.60 ± 1.45	–0.20	0.456
13–14	3	13.33 ± 0.58	12.50 ± 2.65	–0.83	0.560

The clearest signal from the subgroup analysis was at the youngest end: the atlas significantly overestimated age in 3–6 year-olds, while staying accurate in the older groups. This likely reflects the pace of early dental development. Tooth formation and eruption move quickly in young children, so even small mismatches between the atlas reference population and Indian children translate into proportionally larger apparent errors at these ages. As the atlas draws on a demographically mixed reference sample, Indian children in the early mixed-dentition stage may look slightly less dentally advanced than it expects, which pushes estimates upward. This matters practically. Age estimates for very young children should be read with extra caution, whereas those in the 10–12 year range — the band most often at issue in medico-legal questions of majority — were the most reliable in our sample.

Our results sit comfortably alongside earlier Indian work. Chowdhry et al. found London Atlas estimates closer to chronological age than Demirjian's comprehensive chart,[11] and Krishna and Manoharan reached the same conclusion about the atlas being the more accurate of the two.[12] Priya's South Indian pilot of the Willems method is a useful comparison too: she reported an underestimation of roughly four months and judged the method suitable for the population,[13] which is the same direction and a similar order to our own mean bias of about two months. The strong correlation and small bias we observed reinforce the atlas as a dependable tool for Indian children. Where some earlier atlas-based and Demirjian studies leaned towards overestimation, we saw a slight underestimation instead. Differences like this are usually put down to genuine ethnic and environmental variation in dental maturation, and to the different reference populations each method was built on.[1,6]

We found no significant difference in estimation error between the sexes, so there was no marked sexual dimorphism in how the method performed here, though the correlation with chronological age was a little stronger in boys. On agreement, the Bland–Altman limits (roughly ±2.7 years) are in line with those reported for other radiographic age-estimation methods. That level of spread is generally acceptable in forensic practice, where age is reported as a range with a stated confidence interval rather than a single exact figure. The estimate can reasonably support a medico-legal decision, provided its uncertainty is stated and, where a specific legal threshold is at stake, it is backed up by other evidence.

A few limitations should temper how these findings are read. This was a pilot, with a modest sample from a single centre, so the results cannot be generalised to the wider Indian population. The oldest subgroup held only three children, and its estimates should be treated as indicative at best. The retrospective design also gave us little control over the original radiographic technique. Building on what we found here, future work should recruit larger, multicentric samples across India's diverse ethnic groups, cover all age bands adequately, and compare the London Atlas head-to-head with other established methods.

Conclusion

Within the limits of a pilot study, the London Atlas estimated dental age well in this Indian paediatric sample, correlating strongly with chronological age, carrying only a small and non-significant bias, and showing no marked sexual dimorphism — all of which support its use in this population. The important caveat is age: the atlas overestimated in the youngest children (3–6 years) and was most accurate at 10–12 years, so it should be applied with age- and population-specific caution. Because these are preliminary findings from a single centre, they need confirming in larger, multicentric studies with formal reliability testing before the atlas is adopted for routine forensic age estimation in Indian children.

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