



ORIGINAL ARTICLE

Dental age assessment of Western Saudi children and adolescents



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KEYWORDS

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Abstract *Aim:* The aim of this study was to evaluate the use of the London Atlas of Human Tooth Development and Eruption for age estimation in Saudi Arabian children and adolescents (aged 2–20 years), for forensic odontology application.

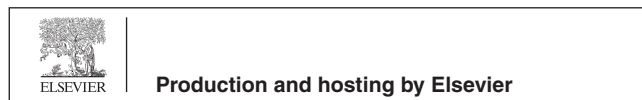
Materials and methods: This cross-sectional survey analyzed orthopantomograms (OPGs) of the complete dentition (including root development) to estimate the deviation from chronological age. Each OPG was de-identified and analyzed individually and classified into age-groups by the lead author, using the methods of the Atlas of Tooth Development.

Results: OPGs from a total of 252 patients [110 (44%) males, 142 (56%) females] aged 2–20 years (24–240 months) were examined in this study. The average estimated and chronological ages of subjects differed significantly $p < 0.001$ (143 ± 55.4 vs. 145 ± 57.9 months). Most (65.5%) estimates were within 12 months of subjects' chronological ages; 19% overestimated and 15.5% underestimated age by > 12 months.

Conclusion: This study, conducted in a sub-population of different origin than the UK sample used for the development of the London Atlas, identified variation in age estimates that may have significant impacts on results. The establishment of a composite international repository of atlas-based data for diverse ethnic sub-populations would be of great value to clinicians across the globe. © 2015 The Authors. Production and hosting by Elsevier B.V. on behalf of King Saud University. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

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1. Introduction

Forensic odontology lies at the intersection of dental science and law, and is used predominantly to assist in the provision of justice in criminal investigations (Seen and Stimson, 2010). The science of forensic dentistry focuses on the analysis of the dentition of living and deceased individuals, with the majority of case work consisting of dental identification and age estimation (Solheim and Kvaal, 2000). The estimation of age at death is very often a starting point in narrowing the

search for possible matching data, retrieved from local, regional, and national missing persons' lists, and it can be useful in limited-population fatal incidents and clustered victim cases. Moreover, age estimation is an important measure in the management of immigration, to help determine the chronological ages of immigrants in the absence of proper documents (Herschaft et al., 2006).

A considerable body of literature pertains to (genetic, sex-based, and ethnic) variation in and environmental influences on tooth development and eruption (Almonaitiene et al., 2010; Suri et al., 2004). Any disturbance of normal growth patterns, such as that caused by nutritional deficiency or chronic illness, introduces a potential source of error in age estimation (Cardoso, 2007a; Franklin, 2010). Differences among local sub-populations must also be considered, and the best estimates are derived from local population-specific standards (Nystrom et al., 1986; Schmeling et al., 2004). The optimal time for dental age estimation is widely acknowledged to be during dental development, which is under strong genetic influence and affected little by environmental factors (Cardoso, 2007a).

Age estimation has been documented to be most accurate in immature individuals, and many dental chart standards are available. Dental age can be estimated by assessing growth in the form of crown and/or root length (Stack, 1967) or crown and root weight (Demirjian et al., 1973), by assessing incremental lines in dental root cementum (Aggarwal et al., 2008), or by using a dental eruption sequence (Nystrom et al., 2001). The strength of using dental developmental stages to estimate dental age is that they provide point estimates based on calculations/mineralization, where estimates for different teeth are averaged or given different weights. However, the use of such methods is limited, as most are based on permanent teeth.

Dental age estimation can also be performed using radiographic evaluation of crown calcification, root and apex development, and tooth emergence patterns (Schour and Massler, 1941; Ubelaker, 1987, 1997). Dental development schemes are simple to use because they are based on direct comparison of radiographs or isolated teeth with illustrations of dental development in a certain age cohort. All existing schemes cover a limited age range, except for those of Schour and Massler (1941) and Ubelaker (1978), which cover dental development from the prenatal period to early adulthood and thus are most widely used. Common drawbacks of previously developed schemes are the lack of uniform age distributions and/or the limited age range, which fail to cover the entirety of dental development. A uniform distribution with similar numbers of children for each year of age reduces variance across the age range. A normal age distribution has high precision around the mean value, but low precision at the extremes (Schour and Massler, 1941; Ubelaker, 1978).

The London Atlas of Human Tooth Development and Eruption, introduced by AlQahtani et al. (2010), is now freely available in numerous languages (www.atlas.dentistry.qmul.ac.uk) and as software. AlQahtani et al. (2014) recently reviewed and assessed the accuracy of the London Atlas and previously developed dental age estimation methods. This atlas covers dental development and eruption sequences from the ages of 1–23 years, with illustrations depicting the midpoint of each chronological year. Eruption in this atlas refers to the emergence of a tooth from the alveolar bone, in contrast

to Ubelaker's (1978) definition of tooth emergence through the gingiva. Allowance should be made for gingival eruption when using this atlas in the presence of oral soft tissues. In situations in which gingival tooth emergence is used, simple oral examination is all that is needed. The London Atlas is a well-developed, comprehensive, evidence-based method of age estimation using dental development and alveolar eruption. Its ease of use and accuracy in age estimation makes the London Atlas more preferable than Schour and Massler (1941) and Ubelaker (1978). What is more, in mass disaster situations, the use of a method involving comparison of a radiograph showing dental development and eruption with an atlas illustration or computer software to estimate chronological age is ideal (AlQahtani et al., 2010, 2014).

No systematic standard for estimation of the chronological ages of sub-adults (children and adolescents) in the Saudi Arabian population is available. Many studies have tested the accuracy of different age estimation techniques based on dental development, with varying results (Bhat and Kamath, 2007; Cardoso, 2007b, 2009; Cruz-Landeira et al., 2010; Griffin et al., 2009; Halcrow et al., 2007; Liversidge, 1994; Maber et al., 2006; Shi et al., 2009; Tao et al., 2007). However, very few studies have tested the accuracy of diagram-based techniques (Smith, 2005; Smith et al., 2006). The aim of this study was to assess the congruence of age estimates for Saudi children and young adults aged 2–20 years using AlQahtani et al.'s (2010) method, to determine the applicability of this method to this sub-population. In addition, we examined whether division of the sample by sex increased the overall accuracy of the standard.

2. Materials and methods

2.1. Materials

This cross-sectional survey involved the analysis of orthopantomograms (OPGs) showing the complete dentitions (including roots) of 252 subjects aged 2–20 years using the London Atlas, to estimate deviation from chronological age. Radiographs from healthy Saudi individuals were collected from the Dental Centre of King Fahd Hospital, Jeddah, Saudi Arabia, and the Pedodontics-Orthodontics clinic. The completed sample was from both institutions, divided into the following age groups: 2–3, 4–6, 7–9, 10–12, 13–15 and ≥ 16 years.

Subjects were from various socioeconomic strata and diverse geographic localities within Saudi Arabia. The Dental Centre, managed by the Ministry of Health, accepts Saudi patients referred from primary (general practice) dental clinics for specialized treatment. OPGs are obtained from all patients for clinical examination, diagnosis, and treatment planning.

Consistent with previous studies, OPGs were used because they are easily obtained (especially in young children) and because visualization of the mandibular region suffers little distortion (Demirjian et al., 1973).

In the case of unilateral hypodontia or first molar extraction, we evaluated the contralateral tooth. The assessment of age estimation was performed using all (present) teeth on the right side of the dental arcade, including primary/permanent teeth, or mixed teeth, except when the right tooth was missing in which case this was substituted by the same tooth on the left

side, as there is a high degree of lateral symmetry (Demirjian et al., 1973).

A single trained and calibrated examiner blinded to subjects calculated the ages estimated using the radiographs.

2.2. Methods

All the OPGs were de-identified individually, classifying them into age groups using the London Atlas of Human Tooth Development and Eruption (AlQahtani et al., 2010). This atlas method has resolved problems associated with developmental variation among individual teeth, and estimates produced using it have been shown to differ significantly from those produced using the original atlas of Schour and Massler (1941) and Ubelaker (1978). Advantages of the London Atlas method include its non-destructive nature and ease of use because dental maturity can be compared to a total of 31 reference illustrations of dental development at median ages ranging from 30 weeks *in utero* to 23.5 years. In addition, it does not require the use of specialized equipment other than X-ray equipment. London Atlas illustrations were used to compare crown/root lengths. Assessment of OPGs was conducted with the naked eye, consistent with the specifications for atlas use. All data analysis, was performed using Excel 2003 software (Microsoft Corporation, Redmond, WA, USA), and SPSS (version 15.0; SPSS Inc., Chicago, IL, USA). Paired *t*-tests were performed, with statistical significance set to the 95% level ($p \leq 0.05$).

3. Results

OPGs from a total of 252 patients [110 (44%) males, 142 (56%) females] aged 2–20 years (24–240 months) were examined in this study. The average estimated and chronological ages of subjects differed significantly $p < 0.05$ (143 ± 55.4 vs. 145 ± 57.9 months). Most (65.5%) estimates were within 12 months of subjects' chronological ages; 19% overestimated and 15.5% underestimated age by > 12 months.

3.1. Accuracy of estimates varied by age

Age estimation were most accurate (80% within 12 months) for 10–12-year-olds, and least accurate for those aged ≥ 16 years (50% within 12 months). The rate of overestimation was highest (20–29%) among 7–9-year-olds and lowest (4–7%) among 10–12-year-olds. The rate of underestimation was highest (25–42%) among 13–15-year-olds and lowest (0–7%) among 7–9-year-olds.

Patterns of the accuracy of age estimation also differed between sexes: a larger proportion of estimates was accurate in males (80%) than in females (63%) among 7–9-year-olds, whereas this proportion was larger in females (62.5%) than in males (58.8%) among 13–15-year-olds. For subjects aged ≥ 16 years, 57.1% of estimates for males and 47.6% of estimates for females were accurate. The rate of overestimation was higher for females (16.2% ≥ 13 months) than for males (Table 1).

Most estimates for the age groups of 4–6, 7–9, and 10–12 years were within 6 months of chronological age. In the 13–15-year group, 22.4% of estimates were 1–6 months younger than chronological age. Among those aged ≥ 16 years, 24.3% of estimates were 19 months younger than chronological age.

The lowest frequencies of deviations in age estimates by age group were: 4–6 years, ≥ 19 months overestimation (7.7%); 7–9 years, 13–18 and ≥ 19 months underestimation (1.9%); 10–12 years, ≥ 19 months underestimation (3.7%); 13–15 years, 7–12 months and ≥ 19 months overestimation (both 2.0%); and ≥ 16 years, 7–12 months

overestimation and 13–18 months underestimation (both 4.3%; Table 2). Overall, differences between estimated and chronological ages were not significant in the 4–6-, 10–12-, and ≥ 16 -year age groups. However, significant differences were observed in the 7–9-year (estimated 98.1 ± 12.5 vs. chronological 93.5 ± 10.7 months; $p < 0.001$) and 13–15 year (estimated 158.5 ± 17.1 vs. chronological 165.5 ± 9.8 months; $p < 0.001$) age groups (Table 3).

4. Discussion

The accuracy of the London Atlas must be tested in a variety of populations to ensure that it is a universal, practical, valid, and comprehensive method. To date, it has been used for age estimation only in Western populations (in Portugal, the Netherlands, the United States, Canada, France, and the United Kingdom) (AlQahtani et al., 2010, 2014).

Comparing results from older dental development charts (Schour and Massler, 1941; Ubelaker, 1978) with those from the London Atlas (AlQahtani et al., 2014) has indicated that the London Atlas produces more accurate and precise age estimates.

Although all three methods result in some underestimation of age, the performance of the London Atlas was superior to that of the Schour and Massler (1941) and Ubelaker (1987) methods in all measures. The mean differences (mean difference refers to the average difference between dental age and chronological age) for the Schour and Massler (1941) and Ubelaker (1987) methods were 0.76 ($n = 1,227$, SD 1.27) and 0.80 years ($n = 1,227$, SD 1.27), respectively, whereas that for the London Atlas was 0.10 years ($n = 1,429$, SD 0.97 – AlQahtani et al., 2014).

The accuracy of estimates at the midpoints of age intervals, obtained using the London Atlas, was superior to that of point estimates derived from the most widely used methods (AlQahtani et al., 2014; Liversidge et al., 2006). The results of the present study indicate that the London Atlas (developed with a UK sample) could be utilized in a sample of children and young adults from Saudi Arabia with similar levels of accuracy.

The primary aim of this study was to apply the age estimation techniques of the London Atlas to Saudi Arabian children and young adults, to assess the applicability of this method in this sub-population. The average estimated and chronological ages were 143 ± 55.4 and 145 ± 57.9 months, respectively. The majority (65.5%) of estimates were within 12 months of chronological age. In this single sub-population of different origin than the original UK population, this study identified variation that may have significant impacts on results. Although deviations in age estimates were small among 4–6-year-old males and females, these deviations became significant after 7 years of age; the greatest observed discrepancy was 7 month underestimation at the age of 13–15 years.

All atlas-based methods have limitations, such as the inability of illustration series to represent all cases, and failure to update to account for variability in the timing of tooth formation and eruption stages. In addition, the disadvantage of using tooth eruption or emergence is related to the assessment of this single event for each tooth. Eruption is also affected by early extraction, tooth crowding, tooth impaction, and missing teeth. Moreover, tooth eruption (excluding third molars) is applicable only to certain age groups (6–24 months and

Table 1 Frequency of estimated from real age deviation range by gender and age group.

Age group (in years)	Gender	Age deviation range (in months)			Total
		-12 to +12 months <i>N</i> (%) [*]	≥13 months <i>N</i> (%) [*]	≤-13 months <i>N</i> (%) [*]	
2-3	M	1 (100)	0	0	1
	F	0	0	0	0
4-6	M	9 (64.3)	3 (21.4)	2 (14.3)	14
	F	8 (66.7)	2 (16.7)	2 (16.7)	12
7-9	M	20 (80.0)	5 (20.0)	0 (0)	25
	F	17 (63.0)	8 (29.6)	2 (7.4)	27
10-12	M	20 (80.0)	1 (4.0)	4 (16.0)	25
	F	24 (82.8)	2 (6.9)	3 (10.3)	29
13-15	M	10 (58.8)	0 (0)	7 (41.2)	17
	F	20 (62.5)	4 (12.5)	8 (25.0)	32
16+	M	16 (57.1)	7 (25.0)	5 (17.9)	28
	F	20 (47.6)	7 (16.7)	15 (35.7)	42
Total	M	76 (69.1)	16 (14.5)	18 (16.4)	110
	F	89 (62.7)	23 (16.2)	30 (21.1)	142
	All	165 (65.5)	39 (15.5)	48 (19.0)	252

^{*} Percentage of gender in each age group.

Table 2 Estimated age deviation (from real age) frequency by age group.

Age deviation (in months)	Age group (in years)						Total
	4-6 <i>N</i> (%) [*]	7-9	10-12	13-15	16+		
0-6	8 (30.8)	20 (38.5)	15 (27.8)	7 (14.3)	10 (14.3)	60 (24.2)	
-1 to -6	5 (19.2)	9 (17.3)	9 (16.7)	11 (22.4)	9 (12.9)	43 (17.1)	
7-12	4 (15.4)	5 (9.6)	10 (18.5)	1 (2.0)	3 (4.3)	23 (9.1)	
-7 to -12	0	3 (5.8)	10 (18.5)	11 (22.4)	14 (20.0)	38 (15.1)	
13-18	3 (11.5)	9 (17.3)	3 (5.6)	3 (6.1)	5 (7.1)	23 (9.1)	
-13 to -18	4 (15.4)	1 (1.9)	5 (9.3)	6 (12.2)	3 (4.3)	19 (7.5)	
>19	2 (7.7)	4 (7.7)	0	1 (2.0)	9 (12.9)	16 (6.3)	
<-19	0	1 (1.9)	2 (3.7)	9 (18.4)	17 (24.3)	29 (11.5)	
Total	26 (100)	52 (100)	54 (100)	49 (100)	70 (100)	251 (100)	

^{*} Percentage in each age group.

6-13 years), and methods based on gingival emergence are not applicable to skeletal remains. Other limitations include the overlap in maturity stages, lack of differentiation by sex (resulting in a high degree of variability, particularly from mid-childhood through adolescence), and the tendency for higher degrees of inter-observer disagreement and higher error rates than other tooth formation and development assessment techniques (AlQahtani et al., 2014; Irish and Nelson, 2008; Liversidge et al., 2006; Seen and Weems, 2013). When estimating age using atlas methods, researchers are forced to choose the illustration that most closely matches the dentition of the individual being assessed. The application of a universal atlas-based age estimation method in forensic dental science is clearly not appropriate. The results of research like the present study can provide a basis for atlas adjustment to allow application in diverse sub-populations. The establishment of a composite international repository of atlas-based data for

Table 3 A comparison of real age and estimated age (according to AlQahtani) across genders.

Age group (in years)	<i>N</i>	Mean estimated age in months (SD)	Mean real age in months (SD)	Mean difference in months (SD)	<i>p</i> -Value
4-6	26	60.9 (14.4)	58.2 (10.5)	2.7 (10.8)	0.213
7-9	52	98.1 (12.5)	93.5 (10.7)	4.5 (9.5)	0.001 [*]
10-12	54	123.5 (15.3)	125.3 (10.1)	-1.8 (9.5)	0.171
13-15	49	158.5 (17.1)	165.5 (9.8)	-6.9 (12.3)	0.000 [*]
16+	70	213.6 (29.5)	218.3 (25.9)	-4.7 (21.4)	0.068

^{*} *t*-Test, *p* < 0.05.

diverse ethnic sub-populations would be of great value to clinicians across the globe. Future research in Saudi Arabia should also involve increased sample sizes, geographic diversity, and

age ranges to establish new maturity scores and logistic regression curves for this population group.

Studies of dental mineralization patterns have shown that whereas the early stages of tooth development are almost the same in both sexes, sexual dimorphism in developmental rates occurs around the crown completion stage and continues to increase during the root development stage. Girls reach the majority of developmental stages before boys. These findings suggest that tooth formation follows the pattern of general growth and may be affected by hormonal changes (Blenkin and Taylor, 2012).

5. Conclusion

These differences highlight the need to develop separate charts for each sex, with dental developmental stages coinciding with hormonal changes and growth spurts. More research should be conducted to determine whether tooth formation stages are associated with or affected by hormonal changes.

Ethical statement

Ethics approval from the Dental Centre of King Fahd Hospital, Ministry of Health, Jeddah, Saudi Arabia (H-02-J-002) and The University of Western Australia Human Research Ethics Committee was obtained prior (RA/4/1/4875) to commencing this study.

Conflict of interest statement

None declared.

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