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Age estimation of Brazilian individuals using the London Atlas

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ABSTRACT

Objective: The objective of the present study was to evaluate, for the first time, the applicability of the London Atlas method for age estimation on a sample of Brazilian population.

Design: The study consisted of archived dental panoramic radiographs (n = 288) of individuals aged between 5 and 23 years. Radiographs were assessed using the London Atlas method to determine the developmental and eruption stages of all teeth on each sides of each jaw separately, and also to make an age estimation.

Results: There was no significant differences between the right and left sides of the jaws ($p = 0.31$ for males and $p = 0.65$ for females). An overestimation of age occurred more likely in the female sample when compared to the male sample. Three age groups, 20.5, 18.5 and 19.5 years, presented the highest values of mean absolute difference found in the whole sample.

Conclusion: The London Atlas of age estimation performed well in general and good viability in an expert context, with most age groups showing age differences lower than two years of age, however it is necessary that it be applied with caution in certain age groups, especially when the third molar is used as a decision tooth for age estimation. Therefore, it is recommended to use more than one method for assessing the age in those age groups.

1. Introduction

Estimating chronological age from dental biological age, is continually required for judicial proposes when birth date is unknown or disputed (Willems, Olmen, Spiessens, & Carels, 2001). It also aids in identifying unknown human remains, especially in mass disasters (Deitos et al., 2010). Knowing the correct age is relevant in criminal cases to determine whether the accused has reached the age of criminal responsibility or the legal age of majority (Koshy & Tandon, 1998; Maber, Liversidge, & Hector, 2006). Age estimation is also important in civil issues, as in adoption proceedings or situations associated with asylum applications when the person lacks valid documentation (Babshet, Acharya, & Naikmasur, 2010; Cunha et al., 2009; Olze et al., 2010; Schmelling et al., 2008).

Using radiology for dental age assessment has several advantages: it is easily reproduced and interpreted and doesn't require tooth extraction for histological analysis (less invasive). Moreover, it can be used on both the dead as well as living individuals (Priyadarshini, Puranik, & Uma, 2015). The radiological methods for age assessment have two pre-eminent categories: scoring methods, where developmental stages of individual teeth are identified and given a "score" (based on the selected method), which is then used in a linear regression formula, where an age estimation is produced in comparison to standards published in the literature. The second category is by using a direct comparison with dental age diagrams supplied by a chart or an atlas (Ciapparelli, 1992; Sweet, 2001).

AlQahtani, Hector, and Liversidge (2010) developed a comprehensive atlas for age estimation, using both tooth formation and eruption in relation to alveolar bone, for individuals between the ages of 28 weeks in-utero and 23 years. The London Atlas assessed both dentitions, deciduous and permanent until maturity. The method was then tested, along with two other historic charts, on a mixed Bangladeshi and white

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British sample and authors obtained higher agreement coefficients (0,879) and good accuracy measures with standard deviations for all age groups AlQahtani, Hector, & Liversidge, 2014).

The Brazilian population is highly mixed, descending from Native American, Africans and Caucasian Europeans, therefore, there is uncertainty on what method would perform best in age estimation. Moreover, most methods were developed and tested on more homogenous populations of Caucasian decent. The verification of any new methodology on the Brazilian population gives a great contribution to both the forensic and civil disciplines (Mazzilli, Melani, Lascala, Palacio, & Cameriere, 2018). The aim of the present study was to test, for the first time, the performance of the London Atlas of age estimation on a sample of the Brazilian population and assess its reliability and validity.

2. Material and methods

Ethical approval was granted from the Ethics Committee in Research (CAAE: 60999716.5.0000.5414). This was a retrospective study on archived dental panoramic radiographs (OPGs) of individuals between the ages 5 and 23 years, based on the original study design (AlQahtani et al., 2010).

All radiographs included in this study were taken in the course of dental diagnosis and treatment and they were obtained from a radiographic collection that belonged to a specialized radiology institution. Inclusion criteria were good quality radiographs with good exposure with all teeth in focus. Exclusion criteria were any systematic diseases affecting development, oro-dental pathology including gross caries, the presence of retained deciduous teeth, impacted teeth or roots of deciduous teeth reabsorbed by teeth that were not their successor and history of orthodontic treatment or extraction of teeth.

All radiographs were collected along with the date of birth and the date the radiograph was taken. Chronological age (real age), for each individual, was calculated by subtracting the date on which the OPG was taken from the date of birth. The age was then converted to a decimal scale (Eveleth & Tanner, 1990).

The main examiner received the radiographs without any other information and did the dental age assessment being blind of chronological age throughout the execution of the method. Assessment was done under natural light, using a notebook (model NP270E4E, Samsung, Seoul, South Korea) and image viewer (Picasa, Google, California, USA). The gender of participants was known to the examiner, because it did not constitute any bias relevant to the purpose of the study.

Intra-examiner reliability test was done by re-analyzing 10 % of the total sample (29 radiographs) that were randomly selected two weeks after the initial assessment. Weighted Kappa coefficient was used to assess the intra-rater agreement.

Statistical analysis was done using the R program (The R Project for Statistical Computing, Free Software Foundation, Boston, Massachusetts, USA). Paired sample Student's T-tests was used to compare the sides of the jaws (right and left), estimated age and real age, and also comparing the performance of the method between males and females. Descriptive measures, such as bias (mean difference: Estimated Age – Real Age), standard deviation, bias by age groups and absolute mean difference were also calculated. The level of significance for the hypothesis tests was set at $\alpha = 5$ %.

All mean comparison tests, as well as mean difference and absolute mean difference assessments were conducted within total sample (dentally mature and immature individuals combined) and secondly on dentally immature sample (only individuals without fully developed teeth).

3. Results

Total number of radiographs analyzed was 288 (155 females and 133 males), and the distribution for each age groups by sex is presented in Table 1.

Table 1
Descriptive sample statistics. Age ranges correspond to all individuals who fall within the possible ages covered by the range (mid-point was selected to represent the age group: for example, 10.5-year age group comprises individuals from 10.00 to 10.99 years).

Age group	Sex		Total
	Male	Female	
5,5	3	0	3
6,5	6	2	8
7,5	13	5	18
8,5	9	8	17
9,5	4	14	18
10,5	4	10	14
11,5	7	6	13
12,5	9	9	18
13,5	17	11	28
14,5	10	9	19
15,5	3	9	12
16,5	5	8	13
17,5	3	9	12
18,5	12	6	18
19,5	8	6	14
20,5	11	7	18
21,5	11	7	18
22,5	9	5	14
23,5	11	2	13
Total	155	133	288

The weighted Kappa value obtained was 0.873, which shows excellent agreement (Landis & Koch, 1977).

There was a statistically significant difference between males and females when estimated age was assessed from each right and left jaws and both sample groups (total and immature) ($p < 0.001$). However, there was no significant differences between these variables within the same sex group ($p = 0.31$ in males and $p = 0.65$ in females) (Fig. 1). Looking at age estimation, The London Atlas overestimated the age of females more than the males (Figs. 2 and 3).

Table 2 shows the bias (mean difference between estimated and real age) by age group of both sides of the maxilla and mandible, of the whole sample, and in dentally immature individuals separately. There was a total of 23 individuals that had their teeth fully developed, and they were at least 18 years old or more. Mean differences and p-values in these cases can be also observed in Table 2.

In the sample with both mature and immature individuals included, higher overestimation of age was found at the age of 16.5 years for both sides, with a value of 1.68 years (SD ± 2.31 years). The second largest mean overestimation, for the right side, was found at the age of 11.5

Fig. 1. Difference between left and right side age estimates for females and males. Age estimates differences are represented in years. Pink colored dots are female and blue colored ones are male individuals (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

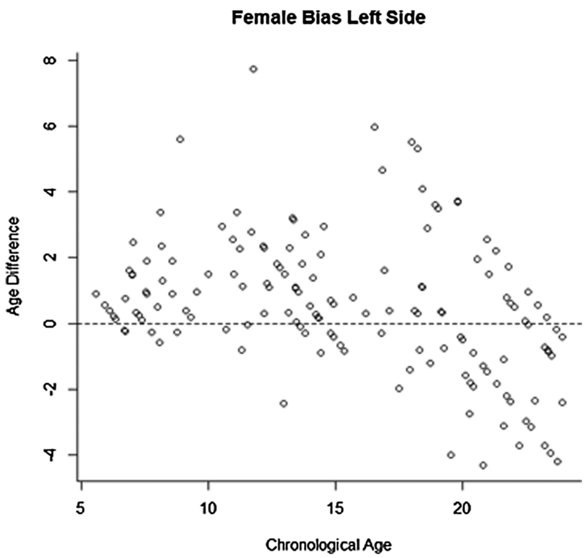

Fig. 2. Mean differences between real and estimated ages in the left side of maxilla and mandible, Female sample.

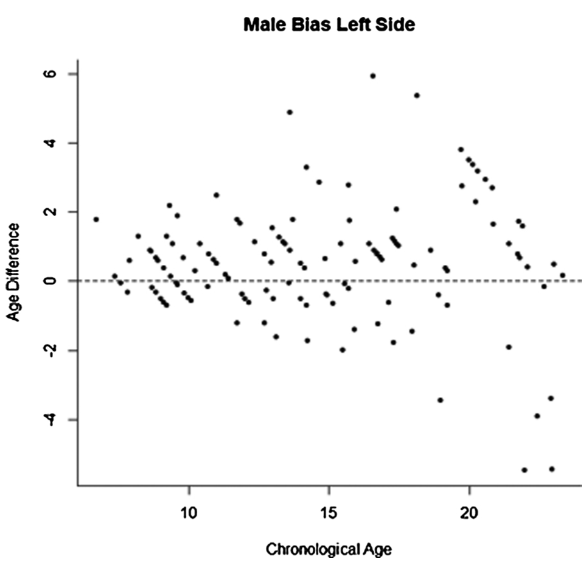

Fig. 3. Mean differences between real and estimated ages in the left side of maxilla and mandible, Male sample.

years (Bias: 1.59 years, SD ± 2.27 years), while for the left side it was at the age of 18.5 years (Bias: 1.46 years, SD ± 2.59 years). The greatest underestimation of the age was −1.61 years for both sides at the age of 22.5 years (SD ± 2.14 years) followed by the age 23.5 years (Bias: −1.30 years, SD ± 1.60 years), for both sides as well. The lowest value of age underestimation was at 17,5 years old group, for both sides (Bias: −0,01 years, SD ± 1,46 years). For age overestimation, lowest values were found at the age groups of 15,5 years and 20,5 years old.

When only immature individuals were analyzed, mean differences in the 18 and 19 years age groups were lower, while the 20, 21, and 23 year old groups presented higher mean differences values than when the mature individuals were included. The 20 year old age group presented an underestimation value instead of an overestimation one, when considering only immature individuals.

The absolute mean differences, which are the actual differences between estimated and real age regardless of underestimation or overestimation of the actual age, are described in Table 3, by age group, for each side of the jaw. The greatest difference was at the age of 20.5 years (2.24 years for the right side and 2.18 years for the left side), followed by the age 18.5 years (2.19 years for both sides), then the age of 22.5 years (1.97 years for both sides). On the other hand, lowest differences were found at the age groups of 6,5 and 9,5 years old (0,67 and 0,68 for both sides, respectively). The 5,5 years age group had an insignificant sample size and was not considered here.

When considering only the dentally immature sample, the absolute mean difference also presented some changes, seen also in Table 3. In the age groups of 18, 19 and 20, the absolute mean difference presented lower values, while the 22 and 23 years age groups had greater values than before. The 21 year age group remained unaltered.

When the sample was combined (males and females), higher mean difference was observed in older ages, specially from 16 years and older, as well as some younger ages, i.e. 11 years old (Fig. 4). This age groups also presented higher standard deviations as well.

4. Discussion

The London Atlas method (AlQahtani et al., 2010) has a clear diagram with written description of each stage of tooth development and eruption including the internal details of teeth, allowing the visualization and accurate recognition of these stages. To reduce variability, a uniform distribution of each age group was done (AlQahtani et al., 2014). The tooth developmental stages were illustrated in the London Atlas separately in order to facilitate the applicability of the method in both panoramic radiographs and direct observation. Hence, the analysis of the sample in this study was based on the direct observation and comparison of the stages of tooth formation in the panoramic radiographs with the stages described in the London Atlas and its illustrated diagrams.

Mean age of each side of the jaw was compared to verify any possible statistically significant difference between left and right sides when age assessment is applied. This study showed that there are no statistically significant differences between both sides, therefore, in a scenario where the left side is unavailable or unsuitable for analysis, the right side can be used without prejudice. Moreover, the examiner can use teeth from any side depending on clarity of the radiograph. These results coincide with a study done on the Portuguese population, where they observed similar results (Pavlovic, Pereira, & Santos, 2017).

It was noticed, while analyzing results of the present study, a trend of the method to overestimate age, since positive differences indicate overestimation. This lead to conducting, *a posteriori*, paired t-tests with a modified alternative hypothesis of difference of the means being greater than 0, instead of equal to 0, and evidence for this trend was observed in both sexes and sides ($p < 0.001$).

Another noticeable result was observed when comparing the development of the third molar within our sample with the tables described by the original research of AlQahtani et al. (2010). In the male sample, n = 61 individuals from various age groups presented prematurely developed third molar stages, while in the female sample, this number reached n = 37 individuals. This means that these individuals had third molar developmental stages reached before the maximum values reported by the original article tables, which described minimum, median (used for Atlas construction) and maximum values for each tooth within each age group. This indicates probable evidence of regional influence in tooth development.

In our sample, overestimation happened more within females than in males, in general, which implies that females develop at an earlier time (Blenkin & Taylor, 2012), specifically in age cohorts of 7.5–13.5 years old. This phenomenon may have a direct influence of sexual dimorphism, whereby growth is first achieved by female subjects, something observed as well in other studies, within other populations as well (Alshiri, Kruger, & Tennant, 2015; Esan & Schepartz, 2018; McCloe, Marion, Fonseca, Colvard, & AlQahtani, 2018). On the other hand, in age cohorts of 6.5, 17.5, 20.5 and 23.5, males showed advanced dental formation compared to the female sample. Hence,

Table 2
Mean difference (Bias) in years, between estimated age and real age, by age group, with Standard Deviation (SD) in years. Values between parentheses are associated with dentally immature sample.

Age Group	n	Mean Difference Left Side	Standard Deviation (±)	p	Mean Difference Right Side	Standard Deviation (±)	p
5,5	3	0,73	0,24	*	0,73	0,24	*
6,5	8	0,55	0,78	*	0,55	0,78	*
7,5	18	0,79	0,80	< **0,01**	0,79	0,80	< **0,01**
8,5	17	1,16	1,5	< **0,01**	1,16	1,5	< **0,01**
9,5	18	0,38	0,85	0,07	0,38	0,82	0,07
10,5	14	0,98	1,11	< **0,01**	0,98	1,11	< **0,01**
11,5	13	1,44	2,27	**0,03**	1,59	2,18	**0,03**
12,5	18	0,53	1,28	0,09	0,53	1,28	0,09
13,5	28	1,15	1,34	< **0,01**	1,11	1,34	< **0,01**
14,5	19	0,57	1,38	0,08	0,57	1,38	0,08
15,5	12	0,11	1,36	0,92	0,02	1,36	0,92
16,5	13	1,68	2,31	**0,02**	1,68	2,31	**0,02**
17,5	12	−0,01	1,46	0,95	−0,01	1,46	0,95
18,5	18 (14)	1,46 (0,62)	2,59 (1,98)	**0,03** (0,24)	1,46 (0,62)	2,59 (1,98)	**0,03** (0,24)
19,5	14 (10)	1,18 (0,18)	2,36 (2,04)	0,08 (0,26)	1,18 (0,18)	2,36 (2,04)	0,08 (0,26)
20,5	18 (12)	0,25 (−0,88)	2,44 (1,97)	0,76 (0,14)	0,19 (−0,96)	2,50 (2,02)	0,76 (0,14)
21,5	18 (13)	−0,30 (−0,96)	2,17 (2,08)	0,56 (0,12)	−0,30 (−0,96)	2,17 (2,08)	0,56 (0,12)
22,5	14 (12)	−1,61 (−2,01)	2,14 (2,05)	**0,01 (< 0,01)**	−1,61 (−2,01)	2,14 (2,05)	**0,01 (< 0,01)**
23,5	13 (9)	−1,30 (−2,06)	1,60 (1,50)	**< 0,01 (*)**	−1,30 (−2,06)	1,60 (1,50)	**< 0,01 (*)**

Bold values represent statistically significant differences.
* Significance not assessed due to small sample size.

Table 3
Mean absolute difference (accuracy, by years) between estimated age and chronological age by age group. Values between parentheses are associated with dentally immature sample.

Age Group	n	Absolute Mean Diff. Left Side	p	Absolute Mean Diff. Right Side	p
5,5	3	0,73	*	0,73	*
6,5	8	0,67	*	0,67	*
7,5	18	0,86	< **0,01**	0,86	< **0,01**
8,5	17	1,31	< **0,01**	1,31	< **0,01**
9,5	18	0,68	0,07	0,64	0,07
10,5	14	1,12	< **0,01**	1,12	< **0,01**
11,5	13	1,79	**0,03**	1,82	**0,03**
12,5	18	1,15	0,09	1,15	0,09
13,5	28	1,34	< **0,01**	1,30	< **0,01**
14,5	19	1,07	0,08	1,07	0,08
15,5	12	1,07	0,92	1,06	0,9
16,5	13	1,92	**0,02**	1,92	**0,02**
17,5	12	1,30	0,95	1,30	0,95
18,5	18 (14)	2,19 (1,51)	**0,03** (0,24)	2,19 (1,51)	0,03 (0,24)
19,5	14 (10)	2,02 (1,35)	0,08 (0,26)	2,02 (1,35)	0,08 (0,26)
20,5	18 (12)	2,19 (1,87)	0,76 (0,14)	2,25 (1,95)	0,76 (0,14)
21,5	18 (13)	1,81 (1,81)	0,56 (0,12)	1,81 (1,81)	0,56 (0,12)
22,5	14 (12)	1,97 (2,17)	**0,01 (< 0,01)**	1,97 (2,17)	**0,01 (< 0,01)**
23,5	13 (9)	1,43 (2,06)	**< 0,01 (*)**	1,43 (2,06)	**< 0,01 (*)**

Bold values represent statistically significant differences.
* Significance not assessed due to small sample size.

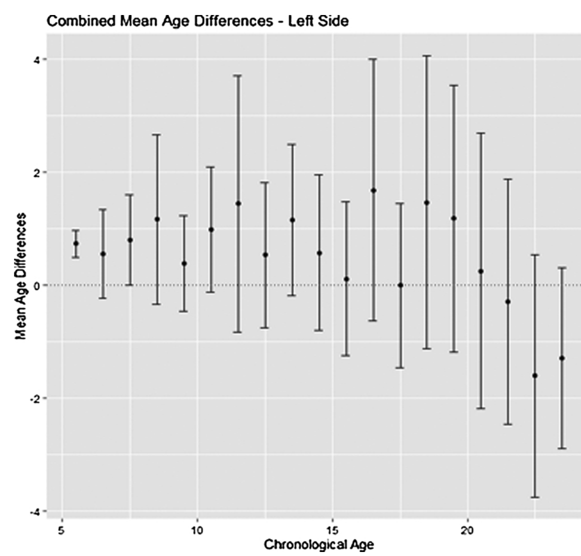

Fig. 4. Combined (male and female) mean age differences between real and estimated ages, per age group, in the left side of maxilla and mandible, with respective Standard Deviations (vertical lines).

differences between sexes observed in this study should be looked up with caution, as they could've been observed due to different numbers of males/females within a certain age cohort or due to low sample number, as in younger age groups, where panoramic radiograph exams are more unlikely to be produced.

Conducting two separate analyses; one with all the individuals gathered in the sample and another with only the ones with an incomplete dental development, allowed more interpretations. Although there was a statistically significant difference between real and estimated age in both cases, removing dentally mature individuals from the sample lowered bias in the 18 and 19 year age groups and increased it in the 20, 21, 22 and 23 age cohorts. Accuracy was also better, in this case, in the age groups of 18, 19 and 20 years old, while it got lower in the age groups of 22 and 23 years old.

We included dentally mature individuals in our sample not to estimate their age, but to observe how the method would behave analyzing dentally mature individuals in our population and test the 23 years old individuals, so depending on the results obtained, it could be possible to associate a fully developed dental state to a minimal age of 23 years old, or at least closer to 23. Looking at our results, dental development completion is not necessarily correlated with an age of 23 or close, and the London Atlas chart does not predict the ending of dental development in this population.

When the London Atlas method was applied to Hispanic children, the 7-year old and 11- to 14-year old age groups showed a statistically significant value of overestimation (McCloe et al., 2018), being similar to what we observed in our study, in which the age of 11.5 years obtained the second highest overestimate mean value of 1.59 years for the right side. On the left side, the second largest positive mean difference was found at 1.46 years, at 18.5 years. In contrast, when applied to the Portuguese population, the female sample had overestimated values close to zero, whilst in the male sample, it was significant only in one age group (Pavlovic et al., 2017).

Alshiri et al. (2015) studied the applicability of the London Atlas method on children and adolescents in Saudi Arabia, and Pavlovic et al. (2017) tested the methodology in the Portuguese population. Both concluded that there were significant differences between sexes. Therefore, it is feasible to state that although the London Atlas method is not yet primarily separated by sex in its original illustrations, analysis should be done separately for better results. This coupled with the results found in our study, reinforces the suggestion of sample separation. On the other hand, recently developed software was created with separated sexes, and future researches might start using it in order to obtain improved results (AlQahtani et al., 2014).

Pinchi, Vitale, Pradella, Farese, and Focardi (2018) used the London Atlas methodology in a study with individuals between 4.49 and 19.8 years, who had chromosomal syndromes, with a paired control group of individuals of the same age, who did not have any syndrome. After analyzing the results, they verified a tendency of the method to overestimate the age for both study samples, as observed in our study. However, it was not found statistically significant differences between real and estimated age in their sample, as well as dental maturation levels between studied groups, with the method working consistently. They concluded that the London Atlas could be used to estimate age in individuals with chromosomal syndromes, despite the slight overestimation occurring.

Ismail et al. (2018) tested the accuracy of the London Atlas method in Malaysian children, in the age groups of 5–5.99, 10–10.99 and 15–15.99 years old. It demonstrated age underestimation values in the 10- and 15-year groups and overestimation in the 5-year group. On the other hand, in our study, the highest mean values of underestimation of age occurred in the age range of 22.5 years and 23.5 years. The highest overestimation mean value, for our sample, occurred at 16.5 years.

When testing the London Atlas and Smith (1991) methods in Iranians aged 5–15 years, Ghafari, Ghodousi, and Poordavar (2019) identified that the mean absolute differences for both methods in the age range of 8–13 years were distinct, with the London Atlas presenting a lower error and superior in its simplicity of use. Differently, our findings showed that the London Atlas methodology obtained lower mean biases at 6.5 and 9.5 age groups years, respectively. However, our results show that The London Atlas overestimated the age in both sexes and sides coincide with the results from the Iranian population.

The biggest difference between estimated and real age was observed in ages that had only the third molar still in development, which reflects the variability of that tooth. As previously mentioned, this variability of the third molar development is highlighted in our study as there was a high incidence of third molars in our sample that began their development before than the reported in The London Atlas (AlQahtani et al., 2010), which also coincide with the great population variability found in Brazil (Deitos et al., 2010; Mazzilli et al., 2018). However, comparing our findings with the table in the original article (AlQahtani et al., 2010) that presents minimum, median and maximum developmental stage per age cohort, we noticed that the third molar appears in the age group of 7.5 years in the AlQahtani et al. paper, which corresponds to our findings as there was no evidence of third molar below that age group.

In age groups over 16.5 years, only the third molar is still in development, and when age estimation is limited to a single tooth, which has high variability in angulation, onset of development and morphology within the same population fraction (Deitos et al., 2010), it leads a more pronounced over or under estimation of age. These biological differences related to the third molars were evident in individuals of the same chronological age (McCloe et al., 2018). There is evidence in this sense also when other age estimation methods are applied without third molar analysis, obtaining slightly better results (da Luz et al., 2019).

Due to the Brazilian population being quite mixed, descending from Native Americans, Africans, and Europeans (Tinoco, Lima, Delwing, Francesquini-Júnior, & Daruge-Júnior, 2016), we obtained moderately divergent results, in the dental development aspect in relation to the AlQahtani et al. (2010) original results as well as their performance measures (AlQahtani et al., 2014). The London Atlas was developed based on a sample of Bangladeshi and white British populations that are more homogeneous compared to the Brazilian population (Deitos et al., 2010). In agreement with McCloe et al. (2018) and Pavlovic et al. (2017), we also emphasize that more studies on different populations using the London Atlas would be fundamental to test how it performs in different population groups.

This populational variance can be also observed when different methods are applied. For example, Cameriere's method (Cameriere, Ferrante, & Cingolani, 2006) was tested on a sample of 612 panoramic radiographs of Brazilians from the southeast of the country, although Mazzilli et al. (2018) concluded that the methodology could be applied successfully in these individuals, they reinforced that there were variations in age estimation in specific age groups and the use of population specific formula may be pertinent for a more accurate result, demonstrating the importance of establishing parameters and specific databases according to the studied population. In contrast, recently, other age estimation methods had been applied comparing Brazilians to more homogenous populations and did not observed populational differences (da Luz et al., 2019).

In another situation, WITS Atlas (Esan & Schepartz, 2018) was created to establish a reliable method for application in South Africa, based on the method of Demirjian, Goldstein, and Tanner (1973) associated with clinical analysis to determine the level of the dental eruption. When comparing the dental development illustrated in the London Atlas with that of the Wits Atlas, great contrasts were noticed among them, starting with the established methodology, since the London Atlas is based on medians obtained while the Wits Atlas uses modal values of the sample to be built. Nevertheless, at 21.5 years the third molar is formed and erupted according to AlQahtani et al. (2010), whereas this same stage of development is observed at age 17 in the WITS Atlas. This variability in the formation stage of the third molar could be observed in our study as well, where it was completely formed at approximately 20.5 years. Esan and Schepartz (2018) support that, in order to be precise, the parameters used for the estimation of age should be established concerning the individual whose age is disputed.

Some limitations of our study must be addressed, in order to take up results obtained with scrutiny. Firstly, it was not possible to obtain an even sample distribution for sex and age groups, as noticed in Table 1. Additionally, some age groups, especially younger ones, are underrepresented here, as radiographic examinations, especially good quality ones are scarce in those age groups.

From the obtained results, we verified that despite the ancestry differences found among the population in which the London Atlas method was developed and the Brazilian one, and besides the overestimation of the age in some age groups, the data obtained showed good accuracy and viability of the method except for ages 11.5, 16.5, 18.5 and 20.5 groups, and especially when the third molar is used as a decision tooth for age estimation.

5. Conclusion

From the results obtained with the London Atlas methodology in the Brazilian sample, it is possible to conclude that it showed good performance measures with good viability in the expert context, with most age groups showing age differences lower than two years of age. However it is necessary that it be applied with caution in certain age groups groups, and especially when only the third molar is still in development. Therefore, using more than one for age assessment is advisable.

Author's contributions

Sousa, AMS: Data acquisition, article drafting, final approval of submission version.

Jacometti, V: Data analysis and interpretation, article drafting, final approval of submission version.

Silva, RHA: Conception and design of the study, article critical revision and final approval of the submission version.

AlQahtani, S: Conception and design of the study, article critical revision and final approval of the submission version.

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CRediT authorship contribution statement

Aline Maria da Silveira Sousa: Conceptualization, Methodology, Investigation, Writing - original draft, Visualization. **Victor Jacometti:** Conceptualization, Methodology, Formal analysis, Data curation, Writing - review & editing. **Sakher AlQahtani:** Conceptualization, Methodology, Project administration, Writing - review & editing. **Ricardo Henrique Alves da Silva:** Conceptualization, Methodology, Resources, Supervision, Project administration, Funding acquisition, Writing - review & editing.

Declaration of Competing Interest

None.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.archoralbio.2020.104705.

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