Accuracy of age estimation using root dentin translucency in Peruvian adults. A pilot study

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KEYWORDS

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ABSTRACT

Introduction: Age estimation is an important forensic resource in human identification. Amongst the different methods of dental age estimation, root dentin transparency (RDT) is considered a reliable parameter, as well as an indicator of chronological age at time of death in human adult remains. The aim of this study was to estimate the age of individuals using the Bang and Ramm method and to derive a new formula suitable for age estimation in the Peruvian population by assessing the length and percentage length of RDT.

Materials and methods: The sample consisted of 248 teeth collected from 124 deceased individuals, between the ages of 30 and 70 years. RDT length was digitally measured from sectioned and photographed teeth. Linear and quadratic regressions were made to derive Peruvian formulae and the new formulae were applied to another group of samples (n=30).

Results: Data showed a significant correlation ($p<0.01$) between chronological age and translucency length (Pearson´s correlation=0.775) and percentage length (Pearson´s correlation=0.778). Linear and quadratic regressions for obtaining Peruvian formulae showed that quadratic equations expressed greater determination coefficients. Comparisons between estimated age using Peruvian formulae showed that dental age from percentage of length of RDT a higher percentage of estimates with errors <± 05 and <± 10 years. The accuracy of the new Peruvian formula using the percentage of length of RDT (MAE=7.83) can be considered acceptable.

Conclusion: As shown in the results, age estimation using the Peruvian formula derived from the percentage of length of RDT has proven to be more accurate than estimates using the Bang and Ramm method. Thus, it could be used in age estimation for Peruvian individuals, as it is the most accurate methods and provides a larger number of acceptable estimates.

INTRODUCTION

Age is a relevant detail in dental and anthropological forensic cases of body identification, especially in cases of massive disasters, genocides and court cases.[1] The importance of age estimation as a forensic resource has been increasing in the recent past, due to the rise of unidentified bodies and human remains. It is even used in cases of living people who cannot prove their real date of birth.[2] There are diverse techniques which have been described and published to estimate

chronological age, including skeletal growth and teeth development. Nevertheless, dental tissue is one of the most resistant parts of the body, remaining intact even in post-mortem stages.[3] Teeth are not affected by the environment or pathological factors and they remain well preserved in cases where the body of the deceased person is decomposed, skeletonized or burnt.[4,5]

Many methods have been used to estimate dental age in deceased adults, through direct assessment of the degree of dental attrition;[6] the extraction of teeth to analyze translucency of dentin, [7] secondary dentin deposits[8] and cementum annulations; [9] or the use of chemical substances.[10] Amongst the different dental parameters used in age estimation, root dentin transparency (RDT) is considered a stable parameter and an indicator of chronological age at death in adult human remains.[11] Gustafson was the pioneer in using RDT as one of the six criteria for age estimation, reporting an increase of the translucency when related to increasing age.[12] Since then, several studies have reported using translucency in age estimation.[13,14] In 1970, Bang and Ramm presented a more detailed method to measure RDT, which was developed through the assessment of 926 teeth from the Norwegian population, establishing different formulae for each specific intact or sectioned tooth.[15]

The aim of this study was to estimate the age of Peruvian individuals using the original Bang and Ramm method and to derive a formula suitable for age estimation in the Peruvian population by assessing the length and percentage length of RDT.

MATERIALS AND METHODS

The sample consisted of 248 teeth. Only lateral and central lower incisors (left and right) were collected from 124 deceased individuals between the ages of 30 and 70 years during a period of 3 months in the Peruvian Institute of Forensic Thanatology (Lima, Peru). Teeth with radicular resorption, radicular cavities, root pathologies and fractures of the crown were excluded. Permission was obtained from the Institute of Legal Medicine. The real age was provided by the National Registry of Identification and Civil Status (RENIEC in Spanish) and treated as an accurate indicator of chronological age at death. Teeth extracted were cleaned with distilled water and soft tissues around the root were removed. Root length of all the sample were measured; then, teeth were sectioned by using a micromotor and placed next to an ABFO scale on a flat-bed scanner for photography. Translucency length was digitally measured from the apex to the coronal extent of the translucency using Adobe Photoshop software. After all procedures, teeth were replaced into their alveolus. According to Bang and Ramm's method, specific equations for each tooth were used to estimate the real age.

SPSS 26 software was used for statistical analysis. Pearson's correlation coefficient was used to calculate the correlation between chronological age and length/percentage length of RDT. Linear and quadratic regression functions for chronological age and length/percentage length of RDT were performed.

To aid in assessing it, as well as to compare accuracy of the new formula as compared to the Bang and Ramm method, it was applied to a new group of samples (n=30). Paired sample T-tests were run to determine the difference between chronological age and estimated age derived from Bang and Ramm formula and Peruvian formulae, using both length and percentage length of RDT.

To evaluate the accuracy of dental age estimation, the Mean Absolute Error (MAE) was calculated using MS Office Excel Spreadsheet. MAE is the average of the absolute values of the difference between chronological and estimated age.

RESULTS

From 248 teeth collected, 76 incisor teeth were from females and 172 were from males (Table 1). The minimum age was 30 years and the maximum was 70 years (mean age=46.99).

Although results showed a strong correlation between chronological age and length of RDT (0.775), a stronger correlation was found between chronological age and percentage length of RDT (0.778) (Table 2).

Linear and quadratic regressions for obtaining Peruvian formulae showed the relationship between real age and length and percentage length of RDT (Figure 1 and 2). Determination coefficients from quadratic functions were greater than those from linear regressions (Table 3).

Table 1. Distribution of sample according to age groups, sex, and tooth type

Age group (years)	Sex		Tooth				Total
	M	W	LRCI	LLCI	LRLI	LLLI	
30-40	54	22	22	16	24	14	76
41-50	52	34	10	33	14	29	86
51-60	32	12	11	11	9	13	44
61-70	34	8	15	6	13	8	42
TOTAL	172	76	58	66	60	64	248

LRCI: Lower Right Central Incisor; LLCI: Lower Left Central Incisor; LRLI: Lower Right Lateral Incisor; LLLI: Lower Left Lateral Incisor

Table 2. Correlation between age and length and percentage length of translucency

Variables	Pearson's coefficient
Chronological age / Length of RDT	0.775
Chronological age / Percentage length of RDT	0.778

p<0.05

Figure 1. Scatter plot showing the association between age and translucency length

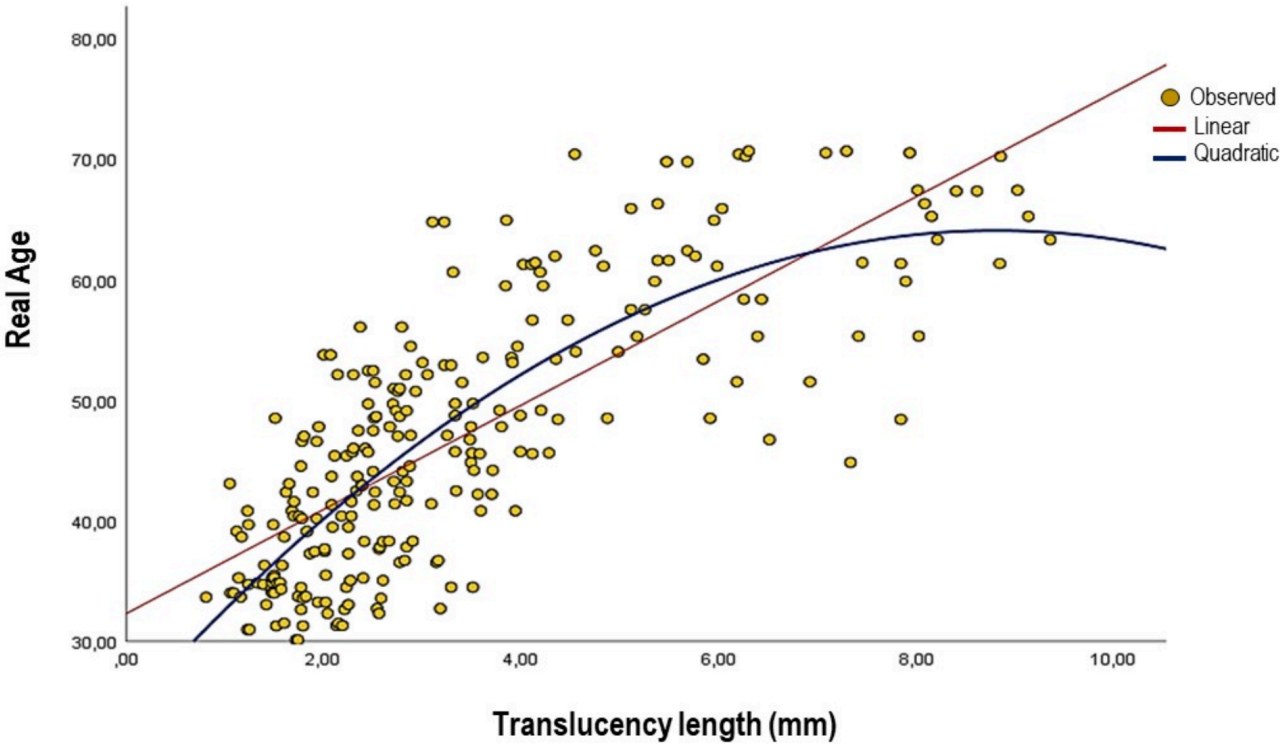

Figure 2. Scatter plot showing the association between age and percentage of translucency length

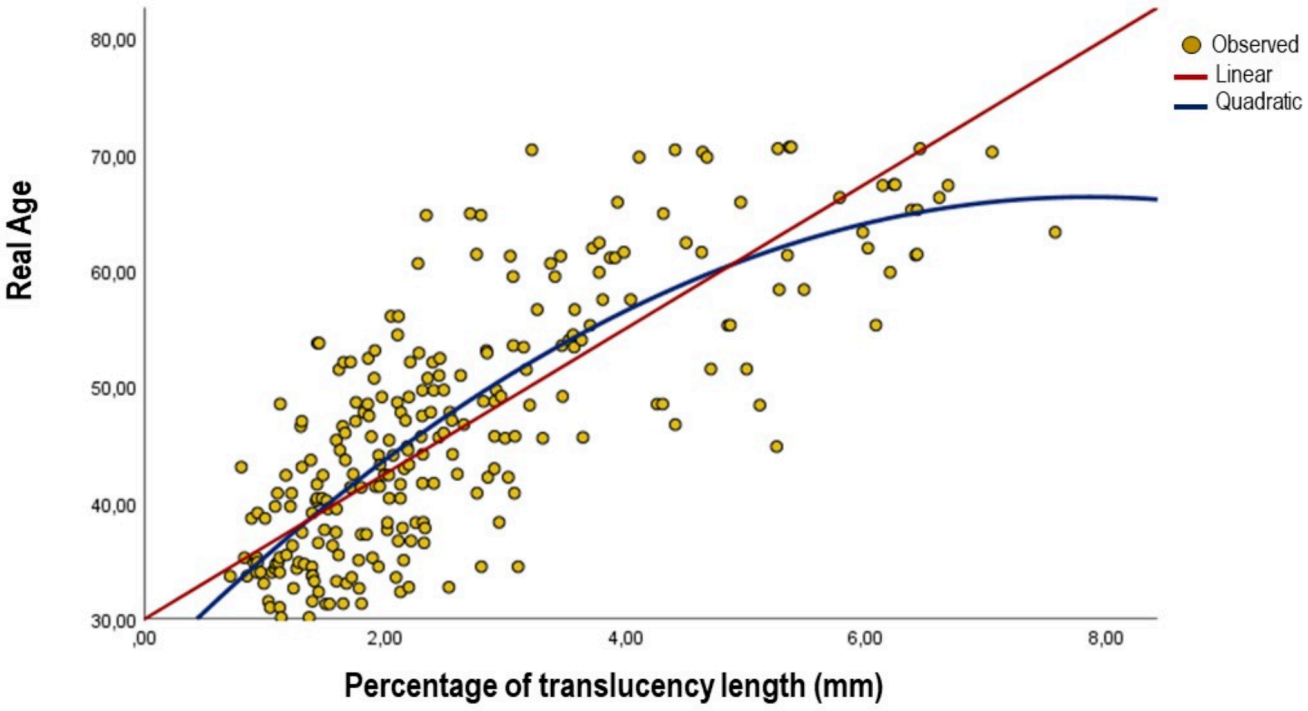

Table 3. Regression analysis, coefficients and formulae derived for length and percentage length of translucency

Variables	Regression analysis	R	R^2	Regression equation/formula
Chronological age / Length of RDT	Linear regression	0.775	0.600	Age= 32.294 + 4.323×T
	Quadratic regression	0.800	0.641	Age= 24.028 + (9.090×T)+(-0.516×T^2)
Chronological age / Percentage length of RDT	Linear regression	0.778	0.605	Age= 31.913 + 0.569×P
	Quadratic regression	0.793	0.629	Age= 25.623 + (1.037×P)+ (-0.007×P^2)

SE: Standard Error T: Transparency length P: Transparency length/Root length×100

The mean of differences between real and estimated age from Bang and Ramm formula (-6.701) pointed out an overestimation of chronological age. Nevertheless, the mean of differences from Peruvian formula (percentage length of RDT) showed better results (-5.999), which also represented an overestimation of chronological age. In relation to age groups, differences from all three formulae do have significant variations in the ranges of 30-40 and 41-50 years old ($p<0.05$) (Table 4).

The assessment of errors among chronological and estimated age revealed that quadratic functions derived from both Peruvian formulae produce smaller MAEs in comparison to estimates using Bang and Ramm formula (MAE=8.97). Thus, percentage length of RDT presented more errors with regards to age estimates at <±5 years and <±10 years (Table 5).

Table 4. Paired t test evaluating the mean of differences between real and estimated age across age groups

Paired samples	Age group	N	r	Mean	95% CI		t	sig
					Inferior	Superior		
Chronological age / Bang and Ramm formula	30-40	10	0.621	-8.508	-14.890	-2.125	-3.015	0.015
	41-50	9	0.583	-10.054	-15.610	-4.499	-4.174	0.003
	51-60	9	0.403	-3.168	-11.219	4.884	-0.907	0.391
	61-70	2	1.000	1.519	-66.370	69.408	0.284	0.824
	Total	30	0.606	-6.701	-10.134	-3.269	-3.993	0.000
Chronological age / Peruvian formula (T)*	30-40	10	0.546	-9.986	-14.937	-5.034	-4.562	0.001
	41-50	9	0.568	-9.228	-14.641	-3.815	-3.931	0.004
	51-60	9	0.328	-1.003	-7.250	5.245	-0.370	0.721
	61-70	2	1.000	3.352	-57.651	64.354	0.698	0.612
	Total	30	0.564	-6.174	-9.317	-3.032	-4.018	0.000
Chronological age / Peruvian formula (P)**	30-40	10	0.555	-9.466	-13.334	-5.597	-5.535	0.000
	41-50	9	0.491	-8.548	-14.246	-2.851	-3.460	0.009
	51-60	9	0.273	-1.395	-7.372	4.583	-0.538	0.605
	61-70	2	1.000	2.088	-22.188	26.365	1.093	0.472
	Total	30	0.627	-5.999	-8.853	-3.145	-4.299	0.000

*using Transparency length
**usingTransparency length/Root length×100

Table 5. Accuracy of the original method of Bang ad Ramm and Peruvian formulae

Formula	MAE	Error <± 05 years	Error <± 10 years
Original Bang and Ramm formula	8.97	36.7% (11/30)	63.4% (19/30)
Peruvian Formula (T)*	8.40	33.3% (10/30)	63.3% (19/30)
Peruvian Formula (P)**	7.83	46.7% (14/30)	70% (21/30)

*using Transparency length
*using Transparency length/Root length×100

DISCUSSION

Root dentin transparency (RDT) is described as the appearance of translucency on the external tooth root surface when the tooth is observed through a source of light.[16]

Since Gustafson first employed root dentin transparency as one of six parameters for age estimation in adults,[12] several studies using RDT have been published.[13,14] Nevertheless, Bang and Ramm were the ones who reported the largest sample of teeth, assessed, and made different formulae for sectioned and/or unsectioned teeth.[15] Although the first attempts at measuring the length of RDT were made manually,[17] current studies report digital approaches for more reliable measurements than those obtained by using calipers.[18,19] Additionally, digital images allow for easier storage and thus allows the

samples to be used again in the future if required.[20] In this study, digital copies of tooth images were made by uploading the images to Adobe Photoshop, in concordance with previous articles which used the same software program.[20,21]

Although intact teeth can be used for the macroscopic assessment of the transparency of root dentin, better details are provided by sectioned teeth.[15] This is the reason why the current study only used sectioned samples, because better evidence of the RDT is obtained and its measurement is made faster in comparison to the entire tooth. Furthermore, Soomer et al. reported greater accuracy and precision in sectioned as opposed to intact teeth using Bang and Ramm's method.[22]

Regarding the quantification of RDT, it is important to point out that reports have calculated it by measurements of length,[13] area;[23] length expressed as percentage of total root length[24] and area expressed as percentage of total root area.[25] However, most studies have prefered to use the length of RTD as a variable, showing a varied range of coefficients' correlation with real age, from r values less than 0.15[26] to a coefficient higher than 0.90.[27]

In this study we decided to employ the length and the percentage length of RDT. Pearson's coefficients for correlation between real age and length and percentage length of RDT shows strong correlations (r=0.775 and r=0.778 respectively). Even though Thomas et al. conducted a study using the same variables involved in our study (i.e. length (r=0.59) and percentage (r=0.583) of RDT),[24] we found similar results with the research of Whittaker et al. (r=0.797) in Caucasian individuals.[28] In addition, Whittaker et al. reported that higher correlation coefficients were obtained using percentage length of RDT compared with percentage area of RDT.[28] Furthermore, Sengupta et al. quantified and assessed four variables which included the length and area of root dentin translucency; the percentage of length and percentage of area of RDT, showing that correlation coefficients were improved when length and area of RDT were expressed as percentages.[29]

Considering the population used, the sample consisted of 248 teeth, which is the largest Peruvian sample which has been reported to date. Although a previous study using RDT height for age estimation in Peruvian population showed a correlation with real age of r=0.69,[30] a better coefficient of correlation between real age and length of RDT was found in this study (r=0.775).

Though a universal formula for dental age estimation was proposed due to the ease of use in forensic cases,[19] Ubelaker et al. have pointed out that a maximum accuracy for estimating age in adults is obtained with population specific formulae.[31] Additionally, Lucy et al. reported the need to fit the original Bang and Ramm method and obtain new suitable formulae for different populations.[32] Concerning the above, we completely agree with the mentioned statements. Thus, linear and quadratic regressions have been made following Bang and Ramm's methodology to find appropriate coefficients and determine a more accurate formula for the Peruvian population.

Similarly, Acharya et al. performed both linear (r^2=0.55) and quadratic (r^2=0.60) regressions demonstrating better results in terms of larger coefficient of determination for quadratic equations.[11] In our study, regression analysis expresses an improvement in coefficients of quadratic regressions, using both length and percentage length of RDT (Table 3). Results about r squared mean that the proportion of data to predict real age in function of the length of RDT is 64.1% and 62.9% in function of the percentage of length of RDT.

Bang and Ramm noted a bias for transparency length to slow down principally after 60 years.[15] Furthermore, Acharya et al.,[11] in concordance with our study (Fig. 1 and 2), found that length of RDT begins to decrease approximately after 60 years. This fact, added to larger coefficients for quadratic equations, suggests the presence of a curvilinear relationship between real age and length of RDT. Consequently, in this study we decided to focus on quadratic rather than linear regressions and compare those determinants.

Regarding the mean of differences between chronological and estimated age, results involving the percentage of length of RDT express the lowest mean of difference and tend to overestimate in 5.999 years (Table 4). According to Shruthi et al., estimated age using translucent dentine had a mean difference of -5.6 years (overestimation) with its lowest value in the 6675 year-old group.[33] As for the Peruvian population, a previous study showed the lowest mean errors of age estimation in the group of 30–39 years old.[31] However, in this study differences between real

and dental age from all three formulae do present a significant variation ($p<0.05$) and show their lowest value for the 30-40 and 41-50 age group.

As a measure of accuracy of age estimation methods, the present study used the MAE. Results show that the Peruvian formula (percentage of length of RDT) is more accurate than the Bang and Ramm method because of lower MAE (7.83), with more percentage of estimates with errors <±5 years (46.7%) and <±10 years (70%). The Indian formula used by Acharya et al. produced larger MAE (>8 years) and less age estimates with errors <±10 years than ours.[11] A further study in the Indian population showed a larger percentage of estimates with errors <5 years (61.4 %) and less result for <10 years (12.9%) in comparison to ours.[34] As for the Peruvian population, Ubelaker et al. obtained a lower mean error of 6.29 years.[31] Solheim et al. consider that errors <± 3 years are excellent, while errors <± 10 years are acceptable in dental age estimation.[35] Therefore, MAEs from the Peruvian formula using percentage of length of RDT can be considered acceptable.

It is important to point out that the sample in this study was collected from the region of Lima. In order to prove the suitability of the Peruvian formula, further studies should include teeth from other regions.

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