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TECHNICAL NOTE

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Age Estimation by a Dental Method: A Comparison of Lamendin's and Prince & Ubelaker's Technique

ABSTRACT: Lamendin et al. (J Forensic Sci 1992;37:1373) developed a general technique to estimate age of adults at death using two dental features: periodontosis and translucency of the tooth root. Prince and Ubelaker (J Forensic Sci 2002;47:107) modified this method, creating a formula for each sex and for different ancestries, and obtained more precise age estimations. In the present study, the validity of each method was tested in 45 males and 34 females of Spanish Caucasian origin, and a novel formula, based on Prince and Ubelaker method, was specifically developed for a population of mixed racial origin (mestizo) from Colombia, and findings obtained were again compared with those yielded by Lamendin adult dental aging technique. The Prince and Ubelaker method proved more accurate than the Lamendin technique in the Spanish Caucasian population, and our Prince and Ubelaker-based formula was also more accurate than the Lamendin et al. In both populations, the Lamendin method showed a higher mean error in estimations of the age of youngest and oldest individuals. These findings confirm the need to create specific formulas for each human group in order to obtain more accurate age estimates.

KEYWORDS: forensic science, physiological age, adults, teeth, Lamendin

Estimation of age at death is one of the most important issues in the identification of human remains, both in forensics and anthropology. Estimations of the age of subadult individuals at death are currently based on the synostosis of secondary ossification centers and the development and eruption status of the teeth. However, determination of the age of adults is more complex. Current techniques are based on changes or bony remodeling of pelvis, sternal end of fourth rib, or symphyseal surface of the pubis, on degree of closure of sutures, or on dental wear or changes in dental structure, among other approaches (1). All of these methods were developed in different populations, hampering comparisons of their accuracy (2). The use of multiple age indicators offer superior results (2,3); but, when these methods are evaluated individually, those based on dental structure offer greater precision when estimating age (2).

Gustafson (4) was the first in formulating a method to age estimation, based on six characteristics of the dental structure: attrition, periodontosis, secondary dentine, cementum apposition, apical resorption, and translucency tooth root. Modifications of this method were later developed, including the technique of Lamendin et al. (5), based on translucency of the tooth root and periodontosis. Tooth root translucency, also known as sclerosis of root dentine, does not appear before the age of 20 results from deposition of hydroxyapatite crystals in dentin tubuli. Translucency can be observed on the whole tooth by using a negatoscope. The translucency shows a clear relationship with age (6). Periodontosis, or gingival regression, is produced by degeneration of soft tissue around the tooth from neck to root apex. It can be observed as a smooth yellowish area below the enamel that is darker than this but lighter than the rest of the root (5). Both parameters can be easily measured on the dental surface. In a French sample, Lamendin et al. (5) related these parameters to the overall height at the root and applied multiple regression analyses to generate the following equation for determining age at death independently of ancestry or sex: $A = 0.18 \times P + 0.42 \times T + 25.53$, where A = age in years, P = Periodontosis height $\times$ 100/root height, and T = Translucency height $\times$ 100/root height.

Prince and Ubelaker (7) evaluated this technique and suggested that sex and ancestry should be considered when estimating age at death based on translucency of the tooth root and periodontitis. This proposal has been supported by other studies (8). Prince and Ubelaker (7) created specific formulas for different subpopulations, classified as black females, black males, white females, and white males. They also included root height in the multiple regression analysis for the equations they developed. The mean difference between real and estimated age was reduced with this novel approach, especially in young and elderly individuals, age groups in which the Lamendin formula (5) showed a higher mean error.

The aims of the study were to compare the accuracy of the Prince and Ubelaker (7) and Lamendin group (5) formulas in the age estimation of a Spanish Caucasian population, and, based on results obtained, to develop a new specific formula for application in a racially mixed (mestizo) population in Colombia and compare accuracy with the results of using the Lamendin formula.

Materials

In the first phase of the study, the sample comprised 79 teeth from 45 males and 34 females with known full name, all of whom were from Granada in southern Spain and belonged to the Mediterranean group (Table 1). Forty-five of the teeth were from a collection

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TABLE 1—*Distribution of samples by age, sex and ancestry.*

Age category	Spanish sample females	Spanish sample males	Colombian sample females	Colombian sample males
25–35	3	5	1	21
36–45	8	3	5	23
46–55	2	5	1	15
56–65	7	17	-	4
66–75	9	13	-	5
≥76	5	2	-	3
Total	34	45	7	71

of recent skeletal remains and thirty-four had been recently extracted from live subjects in dental clinics of the city of Granada (Spain). Their age at death/extraction was known and ranged from 25 to 90 years. We took teeth from recent skeletal remains and live subjects in order to evaluate of the effect of taphonomic changes on dental structures. Except for first and third upper molars, all types of teeth were included to explore the utility of different tooth types in age estimation.

In the second phase of the study, the sample comprised 78 teeth from 71 males and 7 females of a Colombian mestizo population (Table 1) undergoing autopsy at Colombian Legal and Forensic Medicine Institute. Their age at death was known and ranged from 25 to 87 years. Because upper incisors, lower incisors, and premolars offered greater accuracy in the first study phase, only these three tooth types were included in the sample.

Methods

Teeth were separated from their alveoli, washed with water, digested for 5 min in 0.05% solution of sodium hypochlorite, dried, and placed in plastic bags. A digital caliper (precision of ±0.02 mm) was used for measurements (in millimeters), following Lamendin technique recommendations. Periodontosis height was defined as the maximum distance between cemento-enamel junction and soft tissue attachment line (5). Root height was the distance between root apex of the root and cemento-enamel junction (5). These measurements were made on the labial surface of the tooth without sectioning it. Translucency height, measured with the aid of a negatoscope from the root apex, on labial and distal surfaces and recording the higher measurement of the two, as the translucency was occasionally higher on distal surface. This represents a modification of the procedure used by Lamendin et al. (5), in which translucency height was only measured on labial surfaces.

Bang and Ramm (9) reported that root dentine translucency is measured more accurately in sectioned teeth or in a tooth section than in the whole tooth. In order to explore this issue, we measured translucency in 12 longitudinally sectioned teeth and compared these data with those obtained by measurements in the whole tooth.

In the Spanish Caucasian sample, we applied the general equation of Lamendin et al. (5) ($A = [0.18 \times P] + [0.42 \times T] + 25.53$) and the equations of Prince and Ubelaker (5) for white males ($A = [0.16 \times RH] + [0.29 \times P] + [0.39 \times T] + 23.17$) and white women ($A = [1.10 \times RH] + [0.31 \times P] + [0.39 \times T] + 11.82$), where RH = root height. SPSS for Windows version 12.0 (SPSS Inc., Chicago, IL) was used for the statistical analysis, dividing the sample by age (age group 1 = 25–35 years, 2 = 36–45 years, 3 = 46–55 years, 4 = 56–65 years, 5 = 66–75 years, and 6 = > 75 years), sex, and tooth type. Nonparametric statistics were used unless otherwise indicated, as some variables (e.g., periodontosis) did not meet parametric test requirements. The Wilcoxon-matched pair test was used to compare estimated age with real age, and the Spearman ranks test was used to establish correlations of each dental parameter with age. The mean difference between real and estimated age is expressed as mean error with standard deviation and standard error of the mean.

In the Colombian sample, translucency of the tooth root, periodontosis, and root height, i.e., the Prince and Ubelaker method variables, were entered in a multiple regression model in order to establish a new formula for this type of population that did not exist until now. Then, the multiple regression models calculated a mathematical formula that related the dental traits measured with age, as it was performed by Prince and Ubelaker method (7). Results were analyzed as described above for the Spanish population.

Results

Spanish Sample

Tooth root translucency and periodontosis significantly increased with higher age ($r_s = 0.92$ and 0.72, respectively; $p < 0.001$; $n = 79$) but root height did not ($r_s = 0.17$; $p = 0.13$; $n = 79$). With respect to sex, the correlations were very similar between sexes; the correlation coefficients for translucency were: females, $r_s = 0.93$ and males, $r_s = 0.92$; $p < 0.001$ for both cases; and for periodontosis were: females, $r_s = 0.78$, males and $r_s = 0.66$; $p < 0.001$ for both; and neither sex showed association between root height and age at death/extraction (females, $r_s = 0.20$ and men, $r_s = 0.19$; $p > 0.20$ for both).

In the Spanish sample, the Lamendin technique showed a mean difference between real and estimated age of +1.29 years, standard deviation 3.09, and standard mean error 0.35. The age estimated by Lamendin's method differed significantly from the real age (Wilcoxon test, $z = 3.44$; $p = 0.001$). The Prince and Ubelaker method showed a mean difference between real and estimated ages of −0.33 years, standard deviation 3.11, standard mean error 0.35; these age estimates did not differ significant from the real ages ($z = 1.75$, $p = 0.08$). The difference in age estimations between the two methods was significant ($z = 5.98$; $p < 0.001$). With respect to age groups, both techniques showed a difference of +1.5 years in groups 1 and 2 and a lower difference of +1 years in groups 3 and 4. In age groups 5 and 6, a discrepancy of −6 years was shown by the Lamendin method and of −2 years by the Prince and Ubelaker method (Fig. 1).

The Prince and Ubelaker method showed a lower mean error in both sexes (7). For females, the error with the formulas of Lamendin et al. (5) was +1.56 years ($z = 2.32$; $p = 0.02$), while with the method of Prince and Ubelaker was −0.93 years ($z = 2.15$; $p = 0.03$). The error also decreased for males from 1.08 years, with the formulas of Lamendin et al. ($z = 2.41$; $p = 0.02$), to 0.12 years with those of Prince and Ubelaker ($z = 0.20$; $p = 0.84$). In each sex, the difference in age estimation between the Lamendin and Prince and Ubelaker methods was highly significant ($z > 4.20$; $p < 0.001$).

It was equally possible to observe and quantify tooth root translucency in teeth from skeletal remains and those extracted from live individuals. The Prince and Ubelaker method proved equally accurate in both types of sample (Mann–Whitney U-test, $z = 0.62$; $p = 0.53$; Fig. 2*b*), whereas estimations of age by the Lamendin method were less accurate in modern skeletal remains than in live subjects ($z = 3.46$; $p = 0.001$; Fig. 2*a*). Regarding tooth types, it was easier to measure the translucency of the tooth root in incisors and premolars, and they produced more accurate estimates

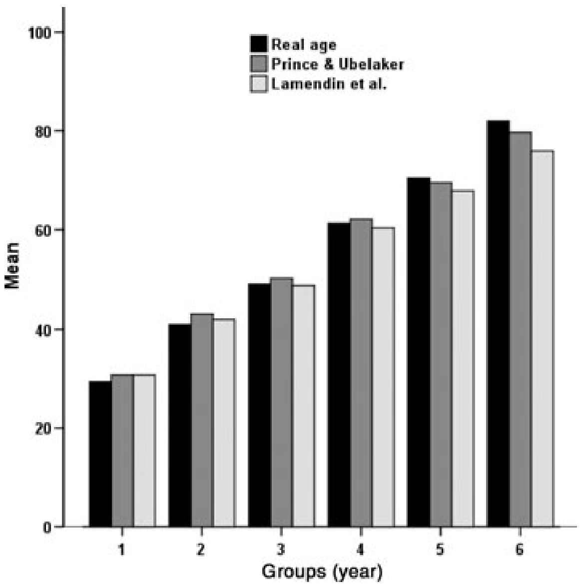

FIG. 1—*Real age and age estimated by Lamendin method and Prince and Ubelaker method by age group (Spanish Sample).*

versus molars. Although the mean errors were relatively low in all three tooth groups by both methods (Figs. 3*a* and 3*b*), they were lower with the Prince and Ubelaker method (Kruskal–Wallis test, $H = 3.25$; $p = 0.20$) than with the Lamendin method ($H = 12.72$; $p = 0.002$).

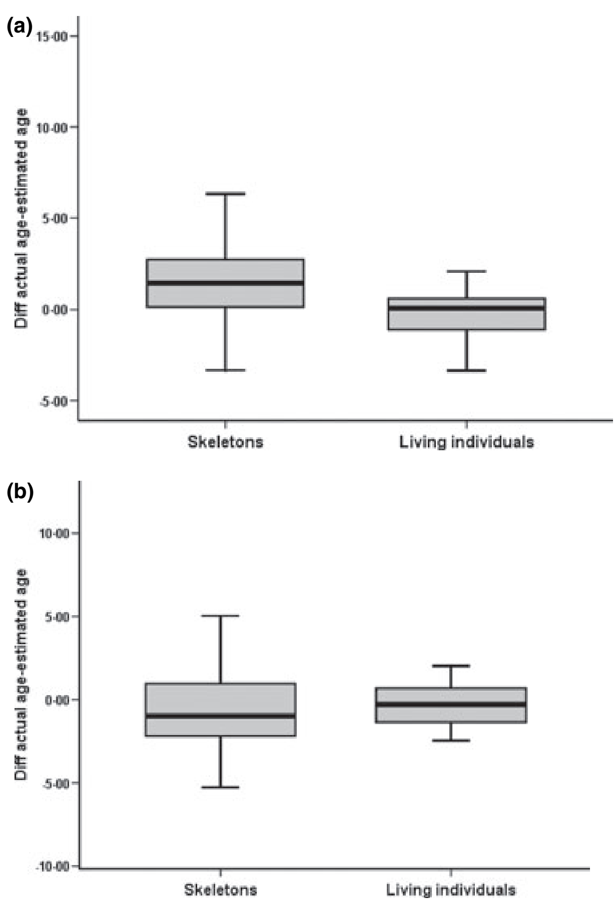

FIG. 2—*Effect of origin of samples (skeletons vs. living individuals) on age estimation by (a) Lamendin method and (b) Prince and Ubelaker method (Spanish Sample).*

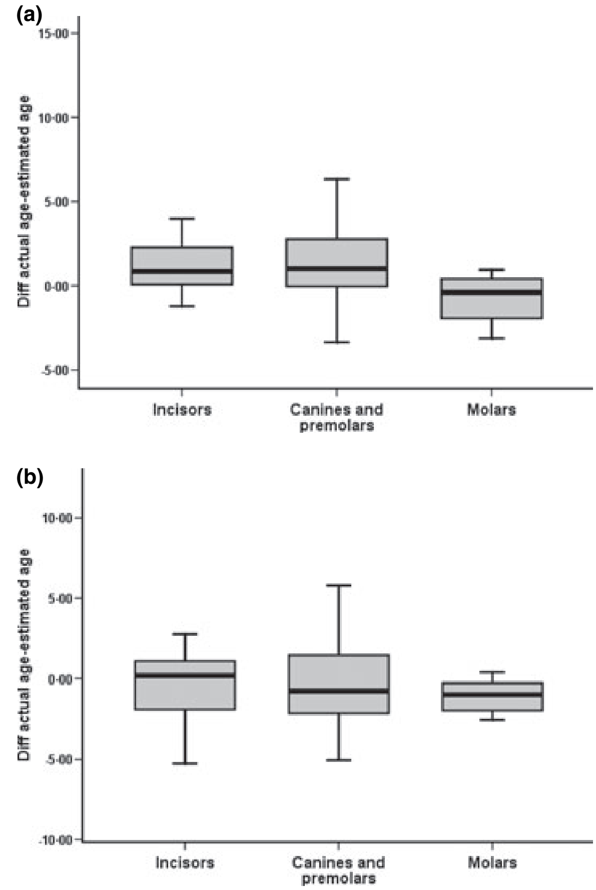

FIG. 3—*Effect of type of tooth on age estimation by (a) Lamendin technique and (b) Prince and Ubelaker technique (Spanish Sample).*

When translucency was measured in the sectioned tooth according to the technique of Bang and Ramm (9), the age estimated by the Lamendin et al. formula was highly similar to that estimated from measurement of the whole tooth ($r = 0.98$; $p < 0.001$). The two estimations were also very closely correlated when the formula of Prince and Ubelaker was used ($r = 0.97$; $p < 0.001$). These findings demonstrate the reliability of the method based on the whole tooth, with no need for sectioning teeth, as the data contributed by both techniques are in practice the same.

Colombian Sample

Translucency of the tooth root and periodontosis significantly increased with higher age ($r_s = 0.62$, $r_s = 0.33$, respectively; $p < 0.005$; $n = 78$), but root height did not ($r_s = -0.17$; $p = 0.12$; $n = 78$).

After multiple regression analysis, the following equation was developed as the basis of a formula for this population: (Table 2)

$$A = (0.87 \times RH) + (0.18 \times P) + (0.47 \times T) + 11.22$$

where A = Age in years, RH = Root height, P = Periodontosis height × 100/root height, and T = Transparency height × 100/root height.

This difference between the real and estimated ages was smaller with this novel formula than with the Lamendin formula, although the differences between the age estimated with new formula and that estimated with the formula of Lamendin et al. were not

TABLE 2—*Results of the multiple regression model for the new formula for the Colombian population.*

Summary of Fit				
R-square				0.850
R-square Adj.				0.455
Root Mean Square Error				5.223
Source	**DF**	**Sum of squares**	**Mean square**	***F*-ratio**
Analysis of Variance				
Model	3	1,1448.51	3816.17	139.87
Error	74	2018.99	27.28	$p > F$
C Total	77	1,3467.50		<0.0001
Term	**Estimate**	**SE**	***t***	***p*-value**
Parameter estimates				
Constant	11.22	6.49	1.73	0.088
Root HT	0.87	0.40	2.15	0.035
Calc. P	0.18	0.07	2.36	0.021
Calc. T	0.47	0.03	17.25	0.000

statistically significant ($z = 1.09$, $p = 0.28$). Thus, the new formula obtained a mean error of −0.23 years, standard deviation 5.12, and standard mean error 0.58, which, again not differ significantly from the real age ($z = 0.64$, $p = 0.53$), and the Lamendin method obtained a mean error of −0.36 years, standard deviation 5.33, and standard mean error 0.60, also a nonsignificant difference ($z = 0.87$, $p = 0.38$). The new formula gave a closer estimate in all age groups with the exception of group 2 (Fig. 4).

Discussion

One of the advantages of dental methods for age determination is that they can be applied to adults of all ages. Most skeletal methods, except for the auricular surface method of Lovejoy et al. (10), have an upper age limit of 45 years, after which skeletal change becomes more influenced by pathologic changes and less by increasing age (11). The advantage of the Lamendin technique is its simplicity. It does not require complicated equipment, it can be very easily applied on an extracted tooth (2), and it does not destroy the tooth.

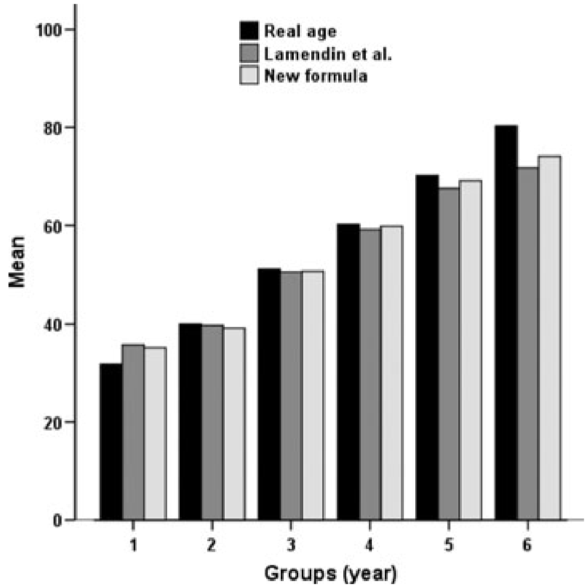

FIG. 4—*Real age and age estimated with Lamendin method and with new formula by age group (Colombian population).*

In previous studies, the dental parameter most closely related to age has been translucency of the tooth root (4,5,8,9,12,13). In the present study, this parameter showed the highest correlation coefficient in relation to age, similar to that reported by other authors (r = 0.65–0.87; 9,12,14–16). However, this relationship is not linear, as translucency develops more slowly in older individuals, possibly due to a delay in this process at the coronal part of the root (9). This would explain the underestimation of age in older subjects found with the two techniques under study.

Whereas the technique of Prince and Ubelaker was equally accurate between teeth from live subjects and recent skeletal remains (Figs. 2*a* and 2*b*), the Lamendin method was less accurate in the latter. Translucency was equally observable and quantifiable in both types of tooth sample. Obliterated translucency root dentine (pinkish tinge throughout the dentine) has been described in some teeth from a medieval skeletal collection (11) but was not observed in teeth from modern skeletal remains in the present study. Studies of skeletal collections from different periods are required to ascertain possible taphonomic changes in translucency of the tooth root.

When root translucency was measured in the sectioned tooth, no appreciable increase in accuracy was achieved compared with its measurement in the whole tooth, hence the work and handling involved in sectioning is not justified.

All tooth types studied appeared to contribute valid data, the most precise age estimations were obtained from incisors (Figs. 3*a* and 3*b*), confirming findings by Lamendin et al. (5). For this reason, incisors were selected for investigation in the second phase of the study. This does not mean that incisors ate to be used exclusively and that other teeth cannot be used, but they are preferable for the greater accuracy they offer and the easy of the data collection.

Although there are some ancestry-related variations in tooth eruption, morphology (17), and tooth size (18), Prince and Ubelaker (7) found that ancestry had no significant effect on estimation of age by the Lamendin technique. Nevertheless, their new equations for different sex and ancestries enabled them to reduce the mean error in each group. In both the Spanish and Columbian samples in the present study, the mean error was also smaller with the Prince and Ubelaker method or our new formula than with the Lamendin technique (Figs. 1 and 4). However, our new formula has only been tested in this single sample, therefore caution is warranted. We highlight the lesser overestimation of age in younger groups and the even greater reduction in the underestimation of age in the older groups. These findings may be related to variations in the apical extension of the translucency between the different ancestry groups. Hence, the ancestry should be taken into account when a regression is made to determine the age on the basis of translucency of the tooth root (8).

Prince and Ubelaker (7) obtained more accurate age estimations when they took account of the sex of individuals in their application of Lamendin's technique, as also found in the first phase of the present study, when age determination was again improved by the use of specific formulas for each sex in the Spanish population.

Conclusions

This study demonstrates the utility and applicability of dental characteristics in forensics and anthropology to determine the age of adults at death. Our results support that the ancestry and sex should be taken into account in the estimation of age on the basis of dental characteristics. A higher accuracy was demonstrated by the Prince and Ubelaker (7) formula in the Spanish Mediterranean population and by the new formula in the Colombian population compared with the use of the Lamentin method. Results obtained confirmed that translucency of the tooth root shows the closest correlation with age.

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