Comparison of Two Methods, Lamendin and González-Colmenares, to Estimate Age in Adults *

Comparación de dos métodos, Lamendin y González-Colmenares, para estimar la edad en adultos

Comparação de dois métodos, Lamendin e González-Colmenares, para estimar a idade em adultos

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Abstract:

Background: The estimation of age through tooth study is one of the main tools to guide the identification of a cadaver. This process becomes more complex in adults because dental structures have already completed their development. Several methods for estimating dental age in adults are based on root transparency, being the developed by Lamendin, et al. (1992) one of the most studied worldwide. There is also one method that was developed for Colombian population: González-Colmenares (2007). Purpose: To identify correlations between real age and dentin translucency, real age, and periodontal recession using the Lamendin and González-Colmenares methods by city and combined cities (Bogotá and Medellín, Colombia). Methods: In this experimental, retrospective, and in vitro study, we performed linear regression models. Coefficients of determination (R2), coefficients of multiple connections, and intersection of the regression line with a 95 % confidence were calculated ($p < 0.05$). Results: The Student's t test did not show significant differences between the two methods. The correlation between the biological and the estimated age was slightly more accurate with the González-Colmenares (2 %) than the Lamendin's method. Conclusions: Both methods showed similar accuracy to estimate age in adults.

Keywords: age estimation, dental age, dentistry, forensic dentistry, human identification, periodontal recession, root length, root transparency .

Resumen:

Antecedentes: La estimación de la edad a través del análisis dental es una de las principales herramientas para orientar la identificación de un cadáver. Este proceso se vuelve más complejo en adultos debido a que las estructuras dentales ya han completado su desarrollo. Varios métodos para estimar la edad dental en adultos se basan en la transparencia radicular, siendo el desarrollado por Lamendin, et al. (1992), uno de los más estudiados mundialmente. También existe un método desarrollado para población colombiana: González-Colmenares (2007). Objetivo: Identificar correlaciones entre edad real y translucidez dentinaria, edad real y recesión periodontal utilizando los métodos de Lamendin y González-Colmenares por ciudad y ciudades combinadas (Bogotá y Medellín, Colombia). Métodos: En este estudio experimental, retrospectivo e in vitro, realizamos modelos de regresión lineal. Se calcularon coeficientes de determinación (R.), coeficientes de conexiones múltiples e intersección de la línea de regresión con un 95 % de confianza ($p < 0.05$). Resultados: La prueba t de Student no mostró diferencias significativas entre los dos métodos. La correlación entre la edad biológica y la estimada fue ligeramente más precisa con el método de González-Colmenares (2 %) que con el de Lamendin. Conclusiones: Ambos métodos mostraron similar precisión para estimar la edad en adultos.

Palabras clave: edad dental, estimación de la edad, identificación humana, longitud de la raíz, odontología, odontología forense, recesión periodontal, transparencia raíz.

Resumo:

Antecedentes: A estimativa da idade por meio do estudo dentário é uma das principais ferramentas para orientar a identificação de um cadáver. Esse processo torna-se mais complexo em adultos porque as estruturas dentárias já completaram seu desenvolvimento. Vários métodos para estimar a idade dentária em adultos são baseados na transparência radicular, sendo o desenvolvido por Lamendin, et al. (1992) um dos mais estudados em todo o mundo. Existe também um método que foi desenvolvido para a população colombiana: González-Colmenares (2007). Objetivo: Identificar correlações entre idade real e translucidez dentinária, idade real e recessão periodontal usando os métodos de Lamendin e González-Colmenares por cidade e cidades combinadas (Bogotá e Medellín, Colômbia). Métodos: Neste estudo experimental, retrospectivo e in vitro, realizamos modelos de regressão linear. Foram calculados os coeficientes de determinação (R.), coeficientes de conexões múltiplas e interseção da reta de regressão com 95% de confiança ($p < 0,05$). Resultados: O teste t de Student não mostrou diferenças significativas entre os dois métodos. A correlação entre a idade biológica e a estimada foi ligeiramente mais precisa com o método de González-Colmenares (2%) do que com o método de Lamendin. Conclusões: Ambos os métodos mostraram acurácia semelhante para estimar a idade em adultos.

Palavras-chave: comprimento da raiz, estimativa de idade, idade dentária, identificação humana, odontologia, odontologia forense, recessão periodontal, transparência raiz.

INTRODUCTION

Age estimation is one of the main factors in determining the biological profile of a corpse (1). Teeth, being the most resistant structures in the human body, play a particularly important role in estimating the age of corpses that are difficult to identify. Once the individual reaches physical maturity and body development has finished, age estimation becomes one of the biggest challenges in forensic areas. Although there are several bone indicators to estimate the age of adult individuals, these changes are subject to habits and environmental conditions, unique to each subject, in such a way that *antemortem* changes are highly variable between individuals. Furthermore, given the nature of bone tissue, they are highly susceptible to *postmortem* deterioration processes; however, dental tissue is much more resistant to these deterioration processes and also presents changes associated with age, which continue once the individual reaches maturity; among the factors studied is the transparency of the root dentin (2).

Gustafson in 1950 presented the first scientific technique for estimating age in adults. It was based on longitudinal sections of teeth that were cut through the central zone. The technique consisted of assigning scores from 0 to 3 for the presence and number of age-related changes, such as attrition, periodontal ligament retractions, secondary dentin formations, root translucency, and root resorption. The author aggregated scores were aggregated and performed a regression analysis with age (3).

The methods developed to estimate age can be categorized as morphological/histological systems and biochemical/radiographic techniques. Gross studies can be performed on sectioned or non-sectioned teeth and are based on regressive changes to which teeth are subject over time. These studies are used primarily to estimate the age of adult subjects and are partially influenced by functional and pathological processes resulting in considerable variability in both the intensity and rate of these changes: this results in estimates of adulthood less accurate with respect to techniques that use developmental stages (4).

Several methods have been used to assess apical translucency and its relationship with age. Among the traditional methods for estimating age in adults, the morpho histological parameters suggested by Gustafson (5) continue to show widespread use. Of the variables suggested by Gustafson, dentinal translucency is perhaps the easiest to assess and is relatively accurate in predicting age (5).

Root dentin becomes translucent in the apex around age 30. This phenomenon was first described by Bradford and was further investigated by other authors, such as Miller (micro radiographic studies) and Schroff (electron microscopic studies). Regarding the differences in dentin translucency by sex, some authors maintain that it has little significance. Prince and Ubelaker, however, considered it necessary to create two different formulas for the two sexes in order to calculate age using the two variables of dentin translucency

and clinical attachment loss (4). The translucency of root dentin has been probed and used in different studies as a reliable indicator to estimate dental age since its introduction by Gustafson (6).

Lamendin, *et al.*, (1992) formulated a new method based on the analysis of root translucency and gingival recession. The Lamendin method has received considerable attention in forensic science because its application does not require special facilities, experience in biochemistry laboratories, dental preparation, or special training (7). The method is fast and easy to learn and use (8). The technique developed was applied to teeth with a single root and consists of the analysis of two dental variables (periodontosis and transparency) and three height measurements (periodontosis, transparency, and root), applying a multiple regression analysis from the measurement of dental variables and using the Mann-Whitney U test for the comparison of means, and consists of the following formula:

A (age) = (P x 0.18) + (T x 0.42) + 25.53.

Where, P = (height of periodontosis x 100)/ root height; and T = (transparency height x 100)/ root height.

This method is a good option to use in forensic cases (9). A study was conducted on a sample of 306 teeth of known age, sex and race. The measurements were taken in millimeters and on the labial surface since on this surface T is usually higher and P is less susceptible to be affected by pathological factors such as infections. Periodontosis was defined as the maximum distance between the cement-enamel junction and the soft tissue insertion line. Dentin transparency was defined as a physiological characteristic that never appears before the age of 20 and is due to the deposition of hydroxyapatite crystals within the dentin tubules; the measurement was taken from the root apex to its root greater extension on the labial surface. Root length was defined as the distance between the root apex and the cement-enamel junction. They found that the mean error between the real and the estimated age was +10 years in the work sample, the upper incisors showed better precision than the other single-rooted teeth, and the precision was not related to sex (10).

Subsequent studies focused on evaluating the performance of Lamendin's proposal in different populations (11-18). An interesting investigation was conducted in the Terry collection on 400 teeth of 359 adult individuals (166 women and 193 men between the ages of 25 and 99 years). It concluded that periodontal recession cannot be used as a univariate age indicator due to its low correlation with chronological age, unlike apical translucency that showed a high correlation with chronological age, being therefore an important indicator of age (12). Other studies also confirm the relevance of dentin translucency as an indicator of age of the Lamendin method (19).

The applicability of a Bayesian model using an international dental database (Forensic International Dental Database), including the height of the translucency of the root and the height of periodontosis as a method to estimate age in adults combined became a generalizable model for age estimation in adult cadavers, offering optimal results in any human population (20). González-Colmenares (2007) (15) proposed a single formula for the mestizo population from Colombia, given the non-existence of a specific formula for this population group and following the modifications of Prince and Ubelaker (2002), eliminating sex as a discriminating factor. A multiple regression analysis to establish the following equation:

A = 0.87 x RH + 0.18 x P + 0.47 x T +11.22

Where, A = age in years, RH = root height, P = height of periodontosis x 100/ height of the root and T = height of the transparency x 100 / height of the root

The study by Gonzalez-Colmenares (15) was conducted with 78 teeth that were extracted from cadavers of 71 males and 7 females, who were Colombian mestizos, with a known age ranging from 25 to 87 years and who were admitted for autopsy to the Colombian Institute of Legal Medicine. Incisors and upper and lower premolars were taken since they showed greater precision. Measurements were expressed in millimeters. For the height of the periodontosis, the maximum distance from the cement-enamel limit to the level of the bone crest was measured. The total height of the root was measured from the cement-enamel limit to the root apex. These measurements were taken on the vestibular surface of the tooth without sectioning it. The height of transparency was measured from the root apex of the tooth over the vestibular and distal surface,

taking the highest extension of the two. This as variation of the original technique by Lamendin, *et al.*, who only measured the vestibular surface. The results obtained showed that the new formula proposed is more precise than that of Lamendin, *et al.* For the Colombian mestizo population, the formula of Lamendin, *et al.*, increased the error of the estimate for the extremes of age of the population (15).

A study similar to the one we are reporting here compared the González-Colmenares and Lamendin formulas with the Mexican population in fifty corpses. They found out that the González-Colmenares method offers a small margin of error, but it is more frequent. Lamendin, on the other side, has a greater margin of error, but in a small number of times, which makes it more precise (21).

The present study compares two methods considering the equations proposed by Lamendin, et al., and González-Colmenares, through the examination of 153 single-rooted teeth that were extracted from cadavers initially in unidentified condition, They were later identified through the methods typified in article 251 of the Colombian Law No. 906 of 2004, such as dactyloscopy, genetics, and dentistry. The following research question is posed: Which of the two methods to estimate age in adults (Lamendin, *et al.*, or González-Colmenares) presents the best correlation with real age in a Colombian sample of 153 single-rooted teeth from the cities of Medellin and Bogota?

Colombia presents a high number of victims of forced disappearance, 80,674 between the years 1958 and 2021, according to the Observatory of Memory and Conflict (22). A corpse in an unidentified condition constitutes a potential missing person, so the estimation of an age range is an essential factor to guide its identification, as well as to carry out technical cross-checks between unidentified corpses and people disappeared, determining which of the two methods (Lamendin, *et al.*, or González-Colmenares) is the most accurate to apply in the cities of Medellín and Bogotá and is very useful in the Search for Disappeared Persons, taking into account these cities represent a high percentage of the autopsies that are performed throughout the country.

MATERIALS AND METHODS

This was a retrospective, experimental, and *in vitro* study. One hundred and fifty three (n = 153) healthy single-rooted teeth from the same number of unidentified cadavers were analyzed. The bodies were necropsied in the cities of Bogotá and Medellín (Colombia). Through identification we estimated the deceased were in the 22 and 93 year age range, with a mean of 46.26 years and a standard deviation of 17.55. Fifteen of the bodies corresponded to females and 138 to males. Corpses of foreign citizens were not included in the sample (the aim was to analyze the precision of the two methods for the Colombian population and/or the teeth needed to be free of pathologies such as caries or periodontal to validate the methods in healthy teeth). The cases analyzed were admitted to the National Institute of Legal Medicine and Forensic Sciences between 2011 and 2019.

For each tooth, three measurements in millimeters were taken with a Mitutoyo® digital caliper: 1) root translucency or transparency throughout the length of the transparent area (reference of root dentin from the buccal surface extending from the apex and transmitting a lumen through the intact tooth); 2) periodontal recession (distance between the cement-enamel junction and the periodontal attachment level); and, 3) root length (distance between the apex and the cement-enamel junction). All the measurements were made on healthy teeth, not sectioned. After completing the measurements, the teeth were repositioned in their respective alveoli and then the equations proposed by Lamendin, *et al.*., and González-Colmenares were applied to estimate age.

The Mitutoyo® digital caliper met the preventive maintenance requirements established institutionally through the Instructions for Preventive Maintenance Service for Intermediate Technology and Electromechanical Equipment (Code DG-A-I-144). The measurements were taken by two forensic dentists

in Bogotá and Medellín. As mentioned above, the measurements were performed for the variables of transparency (T), root length (RH), and periodontal recession (P). Data were entered into a spreadsheet in Excel that included information on number of the necropsy protocol, sex of the corpse, result of the measurement for each variable, the scores obtained with the two methods, and the real age of the corpse after identification.

Data analysis comprised the Student's t-test to compare averages between the two methods, linear regression models to evaluate the correlations between the real age and dentin translucency, real age and periodontal recession, the statistical relationship of each method by city and the integrated relationship by joining both cities for each method. In addition, coefficients of determination (R2), multiple correlation coefficients, and intersection of the regression line with 95 % confidence (95 % CI) were calculated. Values of $p < 0.05$ were considered significant. Statistical analysis of the data was performed using R and Excel.

RESULTS

The correlation between the dental age estimated through the equations proposed by Lamendin, *et al.*, (10) and González-Colmenares (15) and the real age of the cadavers after identification was studied to establish which of the two methods better predicts age in Colombian population. Before applying the hypothesis test, it was necessary to test if the variances are the same or different, using the var.test function of the R software. We obtained a p value of 0.1073, which is greater than the 5 % significance level. We inferred that the variances of both methods were similar.

Once the variances were deemed similar, we proceeded to test whether there were differences between the two methods with Student t-test ($p = 0.05$). From that analysis, we obtained a p-value of 0.6133; therefore, we inferred that there are no significant differences between the two methods. The error range obtained for the 153 cases analyzed with the equations proposed by Lamendin, *et al.*, and by González-Colmenares are shown in table 1.

TABLE 1
Error Range

Years	Number of Cases. Lamendin	Number of Cases. González-Colmenares
< 5	63	70
6 -10	54	51
10 - 15	18	18
> 15	18	14

Figure 1 shows a scatter diagram showing the relationship between real age and dentin translucency, showing a trend from the lower left to the upper right, showing a positive relationship. No relationship was found between actual age and periodontal recession.

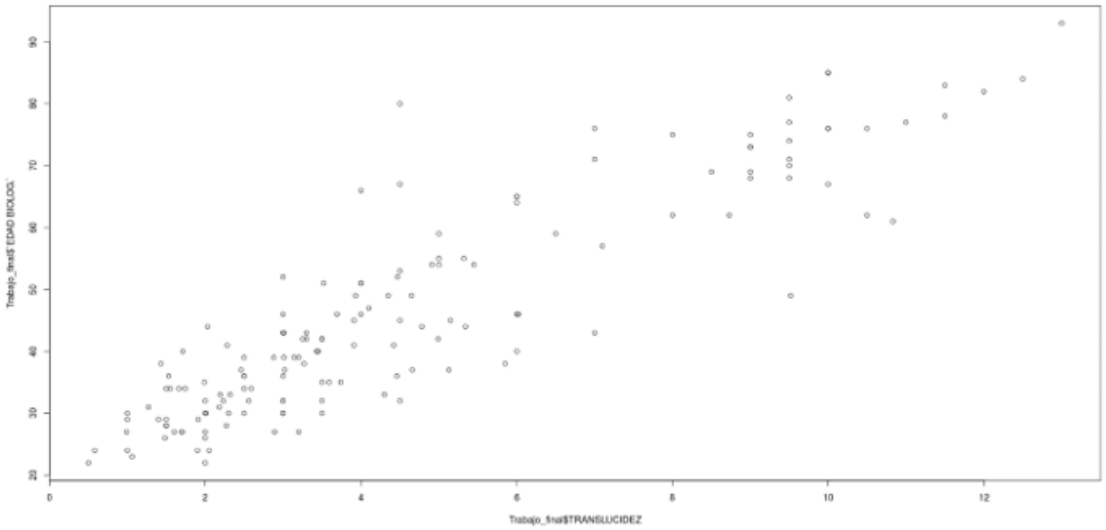

FIGURE 1
Scatter diagram showing the relationship between real age and dentin translucency

We found that, for the sample from the city of Medellín, the relationship between Lamendin, *et al.*, (10) and biological age was 84 %, with an intercept on the Y axis of 17.38 and a slope or inclination of the curve of 0.57. Likewise, the determination coefficient was 0.7135, which shows that the equation explains the Lamendin's variation by 71.35 % (Figure 2).

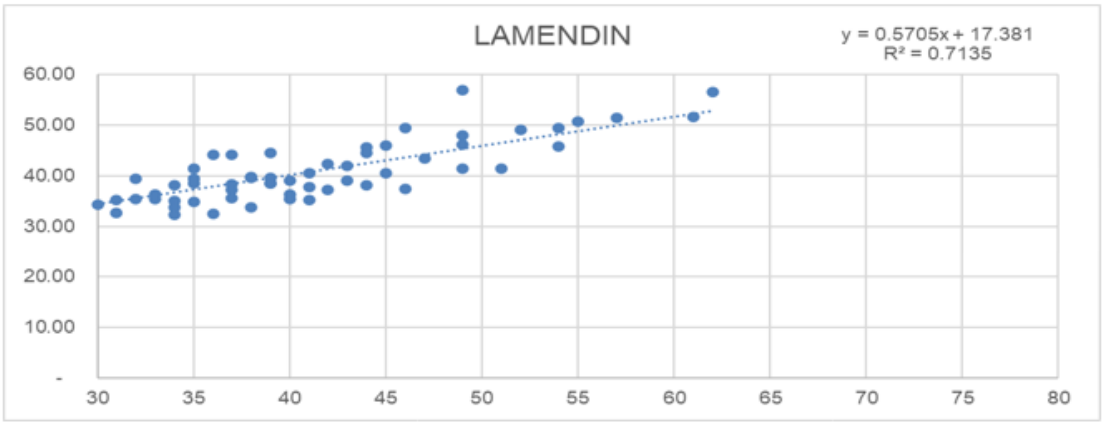

FIGURE 2
Relationship between Lamendin, *et al.*, (10) and biological age in the city of Medellín.

For the city of Bogotá, the relationship between biological age and the one estimated with Lamendin, *et al.,* (10) formula was 87 % with an intercept of 22.88 and a slope of 0.46. In this case, the equation explains the variation of Lamendin, *et al.*, (10) in 76.21 %. (Figure 3).

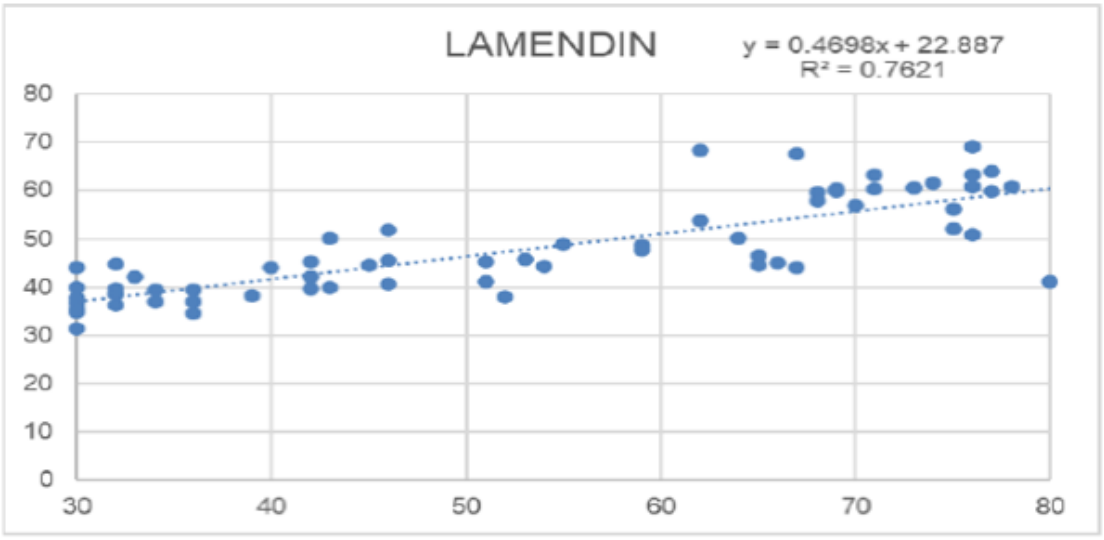

FIGURE 3
Relationship between Lamendin, *et al.*, (10) and biological age in the city of Bogotá

It is important to consider that, when combining both populations corresponding to the cities of Medellín and Bogotá, the relationship was 88 % with an intercept on the Y axis of 20.594 and a slope or inclination of the curve of 0.5027, and a coefficient of determination of 0.79. We inferred equation explains the variation of Lamendin, *et al.,* (10) by 79 %. (Figure 4).

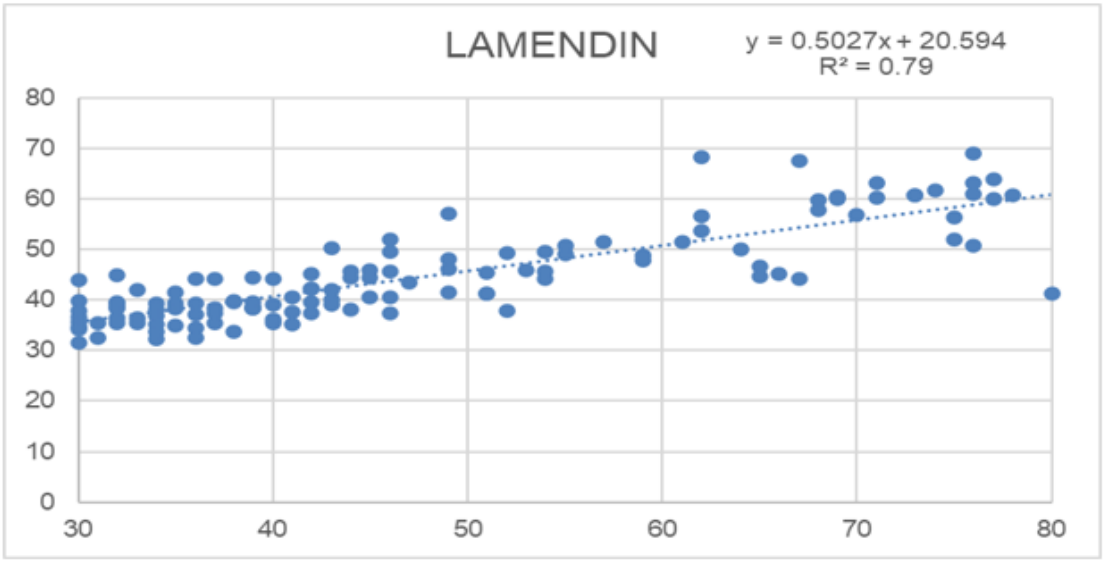

FIGURE 4
Relationship between Lamendin, *et al.*, (10) and biological age in the cities of Medellín and Bogotá

When carrying out the calibration or adjustment process of the data in Excel, the intercept was close to zero and Beta or slope was equal to 1, which allowed us to deduce that with the calibration, it is possible to achieve a more adjusted correlation between the biological age and the age determined by Lamendin, *et al.*, (10) adjusted or calibrated, reaching a relationship coefficient of 84 % for Lamendin, *et al.*, (10) adjusted Medellín, 87 % for Bogotá and 88% with Lamendin, *et al.* (10). When calibrated by combining both populations, then,

we established that for each additional year of biological age, Lamendin will increase age by one more year, which indicates an adequate correlation between biological age and age adjusted with Lamendin, *et al.* (10).

Regarding the application of the González-Colmenares's formula (15), an 85 % relationship with biological age was found for the sample from the city of Medellín, with an intercept on the Y axis of 12.37 and a slope o inclination of the curve of 0.66 and a coefficient of determination of 0.7256. Therefore, it showed that the equation explains the variation of González-Colmenares (15) by 72.56 % (Figure 5).

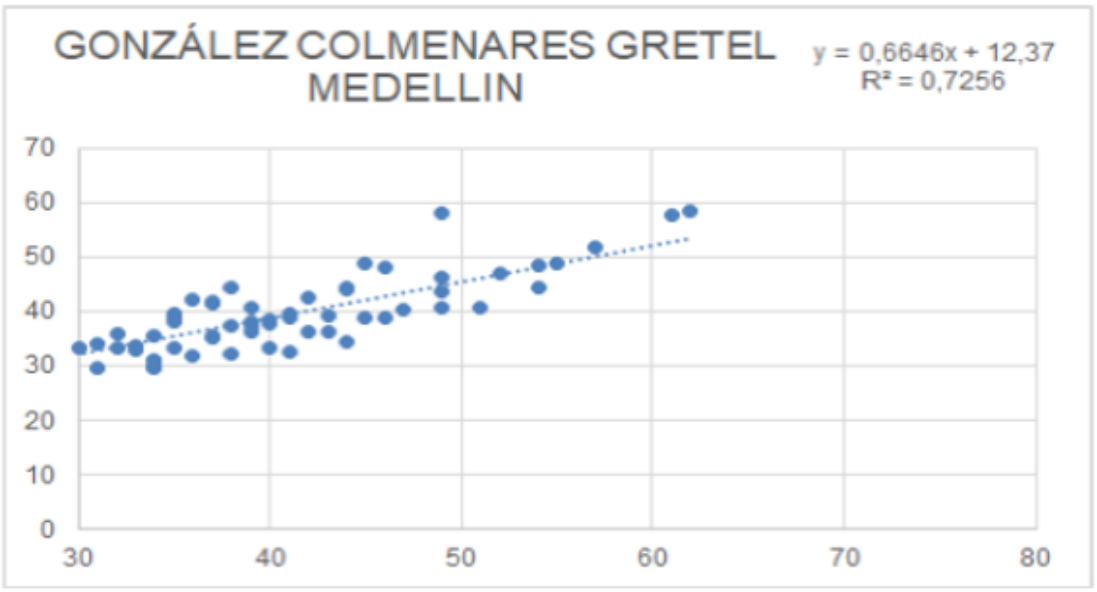

FIGURE 5
Relationship between González-Colmenares (15) and biological age in the city of Medellín

For the city of Bogotá, the relationship was 89 % with an intercept of 19.15 and a slope of 0.54. Therefore, the equation explained the variation of González-Colmenares (15) by 79.89 % (Figure 6).

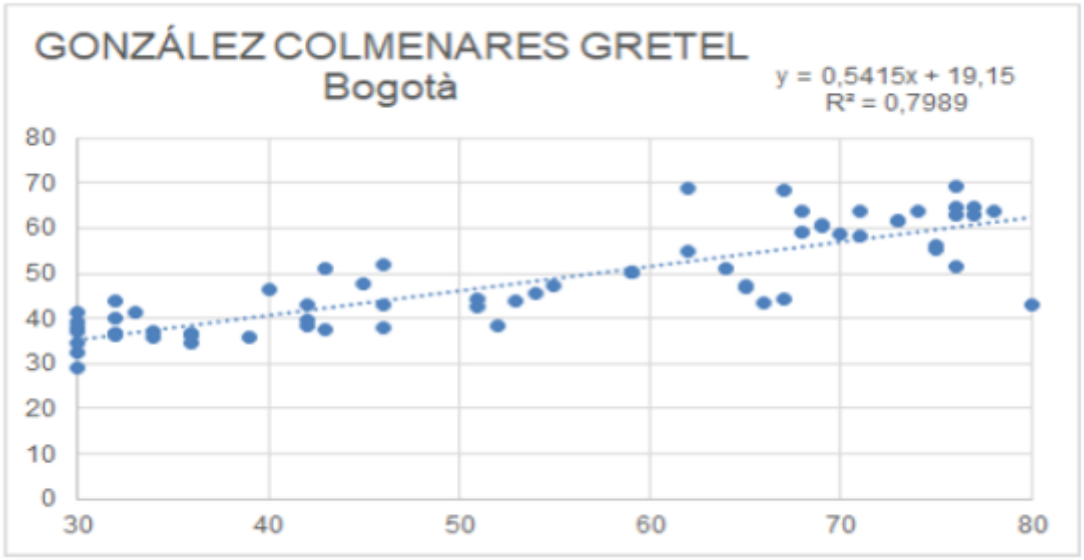

FIGURE 6
Relationship between González-Colmenares (15) and biological age in the city of Bogotá

When combining both samples from the cities of Medellín and Bogotá, the relationship was 90 % with an intercept on the Y axis of 16.29 and a slope or inclination of the curve of 0.5823 and a coefficient of determination of 0.8156. We found out that the equation explained the variation of González-Colmenares (15) by 81 % (Figure 7).

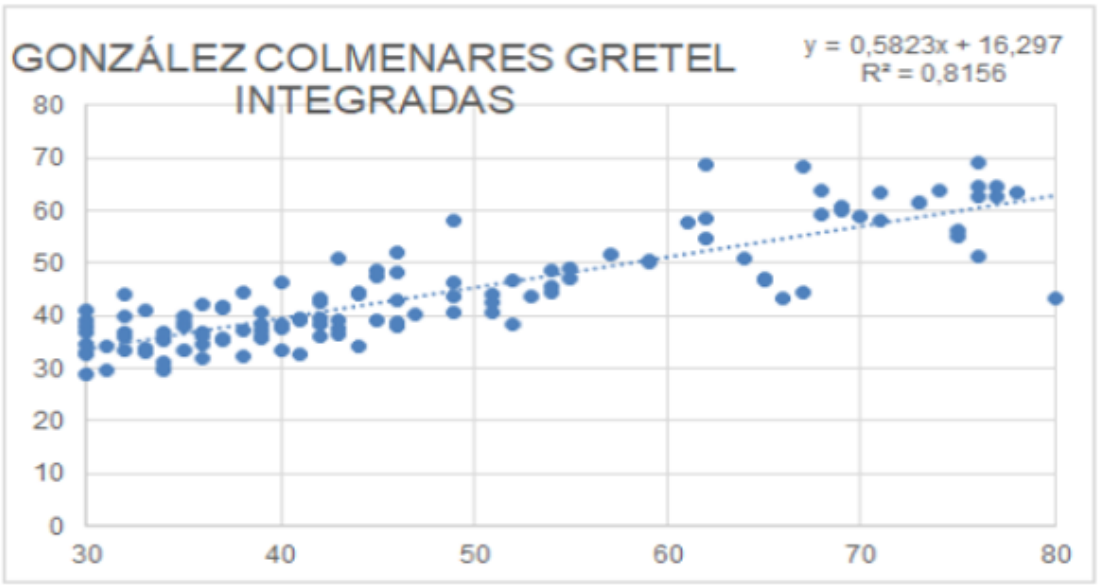

FIGURE 7
Relationship between González-Colmenares (15) and
biological age in the cities of Medellín and Bogotá combined

When performing the data calibration process, the intercept was close to zero and Beta or slope was equal to 1. This allows us to infer that when carrying out the calibration or adjustment of the data in Excel, it

is possible for that correlation to be more adjusted between the biological age and the age determined by González-Colmenares (15), adjusted or calibrated. We obtained then a correlation coefficient of 85 % for Medellín, 0.89 % for the Bogotá and, when combining both cities, the correlation coefficient increased to 90 %, indicating that for each additional year of biological age, González-Colmenares will increase the age obtained by one more year.

DISCUSSION

As reported in most related studies, root transparency was found to be the most accurate measure within the parameters cited by Gustafson (i.e., wear, secondary dentin, cement apposition, root resorption, and gingival retraction). Consequently, there is an increase in root translucency as age advances. This physiological marker of aging is very rarely influenced by internal and external factors; however, it could be impacted by bacterial agents that produce a similar appearance of translucency (23).

On the other hand, even though this study did not find a positive relationship between real age and periodontal recession, some studies have reported a positive correlation. Unlike translucency, this variable is more influenced by internal and external factors that could affect the precision of the method (23). Thus, it is not recommended as a univariate variable in age estimation methods. Some authors argue that periodontal disease tends to be related to age. Parra, *et al.*, (20) found an important coefficient of determination for this variable R2 0.59, contributing to a better performance of the methods derived from the Lamendin technique.

The Lamendin, *et al.*, (1992) method conducted out with a French population, while the González-Colmenares method was developed specifically for the Colombian mestizo population. The first method is reported in research as the most widely used and well-known worldwide; thus, it was necessary to know which of the two showed a better correlation with the real age of the corpse, in order to offer more precise age ranges, which allow guiding human identification and the search for Missing Persons in Colombia.

CONCLUSIONS

This study showed the usefulness of the dental methods of Lamendin, *et al.*, (10) and González-Colmenares (15) to estimate the age of unidentified adult corpses. No statistically significant differences were found in the application of both methods in the cities of Bogotá and Medellín. A positive relationship was found between root transparency and real age, but the same was not the case between periodontal recession and real age.

The correlation between the biological age and the estimated one is slightly tighter with the González-Colmenares method (2 %) than with the Lamendin method. For each more year of biological age that an individual has, González-Colmenares and Lamendin, *et al.*, will increase one more year, if the formula is adjusted or the data is calibrated.

RECOMMENDATIONS

More studies are recommended to observe the precision of both methods in periodontally compromised teeth and/or with pathological processes such as caries. It is also necessary to observe the precision of both methods in specific ethnic groups of the Colombian population.

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Notes

* Original research.

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