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Forensic Anthropology Population Data

Age estimation in Indians from pulp/tooth area ratio of mandibular canines

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ABSTRACT

In India, age estimation of living individuals is gaining importance, particularly in cases of child labour, ascertaining majority status and to assess disputed age in criminals. Previous studies on adult age prediction in Indians have focused on histological parameters, which are invasive in nature and not feasible in the living. Methods for age estimation in living adults make use of radiographs to indirectly measure the rate of secondary dentine deposition and studies have focused on ratios of linear measurements rather than absolute dimensions per se. Recently, the ratio of the pulp/tooth area of canines was suggested by a group in Italy who developed regression formulas for age estimation [10]. The present study has assessed the usefulness of one of the formulas on an Indian sample and also examined the use of an India-specific equation in age prediction. Intraoral periapical digital radiographs of mandibular canines were obtained from 143 individuals (aged 20–70 years) using the paralleling technique; pulp and tooth areas were measured using a commercially available computer software programme and the pulp/tooth area ratio was computed. Age was calculated using the Italian formula which revealed a mean absolute error (MAE) of 11.01 years in Indians, an error recognisably greater than the 4.38 years reported in the Italian sample. The divergence may be explained on account of population differences that exist between Italians and Indians as well as variation in the pattern of secondary dentine deposition in Indians. The Indian formula derived (age = 64.413 − (195.265 × PTR), where PTR is the pulp/tooth area ratio) was applied on a control group of 35 radiographs. The Italian formula was also applied on the control sample to ascertain if the Indian formula markedly improved age prediction. No apparent difference was observed between the two (MAE was 10.76 and 11.58 years, respectively, using the Indian and Italian formula) however, the Indian formula had a tendency to produce more 'stable' age estimates. This could be on account of low correlation ($r = -0.34$) between secondary dentine deposition and age in Indians and the consequent large pulp/tooth area ratio in some cases; such cases would invariably result in very low age estimates using the Italian formula, unlike the Indian formula which had factored in the low correlation.

1. Introduction

Age estimation of adults may be essential in postmortem identification, verifying age in immigrants and refugees with disputed birth records, or in persons of criminal antecedents reluctant to reveal their age. It is relevant not only in routine casework but also in mass fatalities resulting from natural phenomena (e.g. tsunami) and man-made catastrophes (e.g. terror attacks). Dental age prediction in adults is usually accomplished using a number of methods, most notable being Gustafson's parameters [1] and Johanson's [2] grading, dentinal translucency [3] and cementum annulations (e.g. Ref. [4]). Recent developments in biochemistry have allowed very precise age estimation [5,6]. However, these techniques require extraction of teeth and, usually, tooth sectioning/processing, which may not be feasible in living adults or for that matter in certain jurisdictions that prohibit tissue collection from human remains. Kvaal et al. [7] introduced a method that did not require tooth extraction—they indirectly measured secondary dentine deposition on radiographs (by measuring pulp radiolucency) and correlated it to age. These authors proposed a number of length and width measurements of the tooth and pulp. Cameriere et al. [8] put forth a similar method for age estimation which, however, measured the tooth in two dimensions, specifically the tooth and pulp *area*. The method originally examined the maxillary canine but subsequently included the second molar [9] and mandibular canine [10]. While the authors obtained high levels of accuracy in age prediction (mean error ~3–4.5 years), they advised that future research should investigate "the effect of race and culture in model parameters" [10]. Indeed, others have also advocated the verification of age estimation methods on independent samples [7] and some have concluded that best results are derived when

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population-specific formulas are used [11]. The purpose of this study, therefore, was to test one of the Cameriere's formulas [10] on an Indian sample and ascertain whether the original formula predicted age accurately or if population-specific equation improved age assessment.

2. Materials and methods

One-hundred and seventy-eight adults of Indian origin (110 males, 68 females) visiting the Department of Oral Medicine and Radiology in our institution for consultation and diagnosis were included as study subjects. Subjects' age ranged between 20 and 70 years and was well-distributed across different age-groups (Table 1). Subjects were divided into a base sample of 143 individuals and a control group of 35, taking care to ensure that age-distribution was similar in both groups. Intraoral periapical digital radiographs of mandibular canines (either left or right side) were made using the paralleling technique. The radiographic images were saved as high resolution JPEG files on a desktop computer and imported to Adobe Photoshop CS2 image-editing software programme (Adobe Systems Inc., Mountain View, CA, USA) wherein the tooth's long axis was aligned vertically using the measure tool. Next, eleven horizontal lines were marked on the tooth using Photoshop's in-built line tool (Fig. 1). The lines were marked at the cusp tip, at two levels corresponding to the maximum curvature of crown on the mesial and distal side, as well as the cemento-enamel junction (CEJ); from the CEJ, lines were marked apically at every one-eighth increments up to the root apex, the exception being the one-eighth increment immediately apical to the CEJ. Marking of the lines, particularly the ones based on root length, allowed for designation of points at specific regions of the tooth and pulp perimeters on all radiographs. The images were again saved as high resolution JPEG files and opened in AutoCAD 2004 software programme (Autodesk Inc., San Rafael, CA, USA). Twenty points were then marked on the outline of the tooth, at the junction of the marked horizontal lines, using the point tool on AutoCAD's Draw Toolbox; a minimum of 10 points were also marked on the pulp outline although up to 18 points were marked in some cases. The points were connected using the line tool, also on the Draw Toolbox, and area obtained for both tooth and pulp. Repeat measurements were undertaken and the values subjected to a paired *t*-test to assess potential intra- and inter-observer error. All measurements were made without prior information about personal data of the subjects.

Age was calculated using the linear regression equation developed by Cameriere et al. [10] for mandibular canines. The radiographs were decoded and actual age was ascertained. The difference between actual and predicted age (the 'error') was tabulated using Microsoft Office 2007 Excel spreadsheet (Microsoft Corp., Redmond, WA, USA). The absolute value of the errors was tabulated and its average calculated. This is the 'mean absolute error' or MAE. The MAE depicts the average magnitude of error in the age predictions and has been used as a measure of accuracy of age estimation methods [6,12]. In addition to the MAE, the number/percentage of estimates with errors $< \pm 10$ years were also tabulated. Errors $< \pm 10$ years is considered by some as "acceptable" in forensic age prediction [13]; it is also the interval given most often in forensic age estimation and the error usually associated with postmortem age assessments [14]. The number of estimates with errors $< \pm 10$ years and the MAE was compared to those reported in the original study [10]. This approach of quantifying error was used in a recent age estimation study on Indians [15] and using a similar approach here possibly allows some form of comparison of the usefulness of various age estimation methods in Indians.

Regression analysis was performed on the pulp/tooth area ratio data and an Indian formula derived (SPSS 10.0, SPSS Inc., Chicago, IL, USA). The regression equation was applied on the control sample ($n = 35$) to ascertain whether the population-specific formula enhanced age prediction. A control group was utilised since applying the equation on the base sample of 143 cases from which it was derived may have resulted in biased age estimates. To compare the accuracy of the Indian formula to that of Cameriere's formula [10], the latter was also applied on the control group.

Table 1
Sample distribution across age-groups and sexes.

Age-group (years)	Males	Females	Total
Base sample			
20–30	16	11	27
31–40	19	14	33
41–50	14	12	26
51–60	16	12	28
>60	25	4	29
Total	90	53	143
Control group			
20–30	4	3	7
31–40	4	3	7
41–50	4	3	7
51–60	4	3	7
>60	4	3	7
Total	20	15	35
Grand total	110	68	178

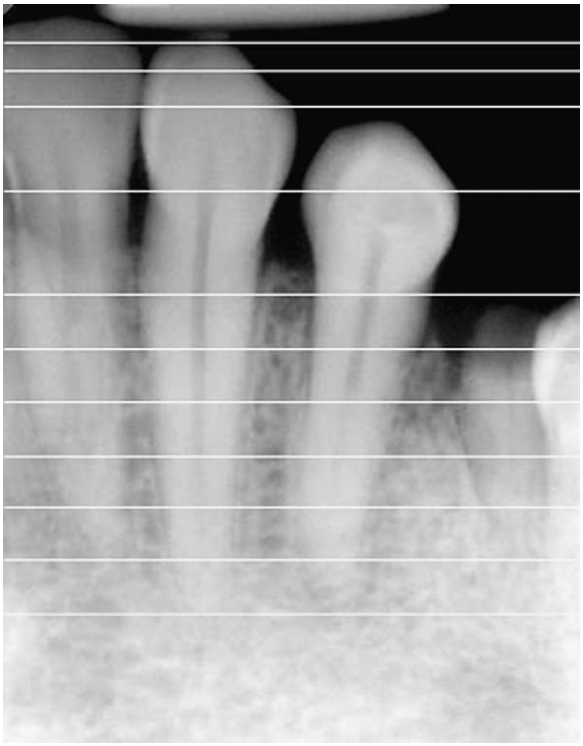

Fig. 1. The tooth's long axis is aligned vertically and horizontal lines drawn on the crown and root using Adobe Photoshop. Using AutoCAD, points were marked at the junction of these lines and the perimeters of the tooth and pulp.

Table 2
Paired *t*-test evaluating intra- and inter-observer variation in measuring pulp/tooth area ratio.

Examination	*n*	*t*-Value	*p*
Intra-observer	25	−0.777	0.45
Inter-observer	10	−1.839	0.10

3. Results

The paired *t*-test to evaluate intra- and inter-observer error revealed no significant differences ($p > 0.05$) (Table 2). Test of Cameriere's formula produced an MAE of 11.01 years (Table 3); in 79/143 cases (55.24%), age estimation was within ±10 years of actual age. Regression analysis for the Indian sample produced a statistically significant albeit low correlation between pulp/tooth area ratio and age ($r = -0.34$; $p < 0.001$). The following linear regression equation was derived: age = 64.413 − (195.265 × PTR), where PTR is the pulp-to-tooth area ratio. Application of this formula on the control group yielded an MAE of 10.76 years with 19/35 cases (54.3%) producing "acceptable" age estimates (i.e. error $< \pm 10$ years of actual age). The use of Cameriere's formula produced an MAE of 11.58 years with age in 20/35 cases (57.14%) being estimated to within "acceptable" limits.

4. Discussion

Several anatomical structures can be used to estimate age of human remains [16–19]. The advantage of teeth, however, is that