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ORIGINAL ARTICLE

Secondary dentine as a sole parameter for age estimation: Comparison and reliability of qualitative and quantitative methods among North Western adult Indians

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Abstract The indestructible nature of teeth against most of the environmental abuses makes its use in disaster victim identification (DVI). The present study has been undertaken to examine the reliability of Gustafson's qualitative method and Kedici's quantitative method of measuring secondary dentine for age estimation among North Western adult Indians. 196 (M = 85; F = 111) single rooted teeth were collected from the Department of Oral Health Sciences, PGIMER, Chandigarh. Ground sections were prepared and the amount of secondary dentine formed was scored qualitatively according to Gustafson's (0–3) scoring system (method 1) and quantitatively following Kedici's micrometric measurement method (method 2). Out of 196 teeth 180 samples (M = 80; F = 100) were found to be suitable for measuring secondary dentine following Kedici's method. Absolute mean error of age was calculated by both methodologies. Results clearly showed that in pooled data, method 1 gave an error of ±10.4 years whereas method 2 exhibited an error of approximately ±13 years. A statistically significant difference was noted in absolute mean error of age between two methods of mea suring secondary dentine for age estimation. Further, it was also revealed that teeth extracted for periodontal reasons severely decreased the accuracy of Kedici's method however, the disease had no effect while estimating age by Gustafson's method. No significant gender differences were noted in the absolute mean error of age by both methods which suggest that there is no need to separate data on the basis of gender.

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1. Introduction

Aging a dynamic phenomenon is a continuation of physiological processes that takes place from conception to death.[1] Determining age at death is a central issue in correct identification of an unknown body. Teeth are unique in structure and follow a well-defined sequential developmental pattern.[2] Moreover, teeth are most indestructible components of the body because of its resistivity against most of the environmental abuses.[3] In children, age estimation can be achieved on the basis of developmental changes occurring in tooth. But, in adults; changes in dental hard tissues (enamel, dentine and cementum) provide a means for age estimation. Regressive changes like attrition, secondary dentine formation, cementum apposition, and root dentine translucency can be used to estimate age of an individual. For age estimation, factors like attrition and cementum apposition are highly influenced by the life style of an individual so cannot be regarded as reliable parameters. However, secondary dentine deposition and root dentine translucency are found to be reliable by many authors.[4–6] Secondary dentine is a narrow band of dentine bordering the pulp and representing the dentine that is formed after the root completion. Deposition of secondary dentine is continuous but much slower in formation than primary dentine. It has tubular structure which is almost continuous with primary dentine but contains fewer tubules than primary dentine. It is not formed uniformly but is more obvious on the roof and floor of pulp chamber so as to protect the exposure of pulp in older teeth. Whereas, in response to abrasion, caries and increasing age, there is obliteration of the dentinal tubules with mineralized substance that leads to the formation of glass like dentine – transparent or sclerotic dentine.[7] There are many published studies for age estimation based on length of root dentine translucency as a sole factor[7–12] and as well as with the combination of other physiological changes.[13–15] Likewise, secondary dentine has also been used in combination with other parameters by many researchers[16,17] however; a few studies have been conducted to formulate the regression equations using secondary dentine as a sole parameter.[18–20] Estimation of age can be achieved using secondary dentine, qualitatively on ground sections of teeth by employing Gustafson's[21] (0–3) scoring system and quantitatively in the form of micrometric measurements suggested by Kedici et al.[22] However, it is also possible to quantify secondary dentine on radiographs – a technique developed by Kvaal et al.[23]

Published data on age estimation from these morphological changes in Indians are based either on Gustafson's scoring system[6,24–28] or the measurements of pulp/width ratio on radiographs[29–34], whereas; a quantitative measurement of these regressive changes on thin ground sections has yet not been done. Qualitative methods are always subjective in nature so there is need to standardize the quantitative method of age estimation.

Aim of the study: The present study was designed to compare the quantitative and qualitative methods for age estimation using ground sections of teeth among North Western adult Indians.

2. Material and methodology

The data were based on 196 samples of extracted teeth (M = 85; F = 111) belonging to different regions of North-Western India ranging in age from 18 to 75 years. The samples were collected from the Department of Oral Health Sciences, PGIMER, Chandigarh, India. Freshly extracted single rooted permanent teeth (incisors, canines and premolars) were selected for the present study. Before sample collection permission of institutional ethics committee was taken. Collected teeth were extracted for the valid clinical reasons like periodontal disease, caries, prosthetic and orthodontic. Single rooted teeth were chosen to reduce the complications that may occur due to difference between morphology, anatomy, and functions of bicuspid and molar teeth. Moreover, in these teeth there is a low incidence of caries and thus tend to survive longer in mouth than other teeth. Grossly decayed, multi-rooted, root canal treated and filled teeth were excluded from the study. Information regarding name, age, sex and reason of extraction was obtained. Before extraction, periodontal status was noted with the help of periodontal probe. The teeth were divided into four age groups with 15 years of interval i.e. ⩽30 years, 31–45 years, 46–60 years and 61–75 years. After fixation, in 10% buffered formalin teeth were cleaned in hydrogen peroxide (for 2 h) and further in running tap water for 24 h.

196 (M = 85; F = 111) samples were examined for scoring secondary dentine as described in Gustafson's method. However, for Kedici's method, 16 teeth were found to be unsuitable to quantify all the 5 micrometric measurements; thus this technique was based on 180 (M = 80; F = 100) samples.

2.1. Section Preparation

Cleaned teeth were sectioned Labiolingually with the help of micro motor up to the thickness of 5 mm which were further thinned down to 2 mm on carborundum stone. Water was used as a coolant to avoid generation of excessive heat and to minimize the damage. Finally, the sections were cleaned in distilled water for 30 s in ultra sonicator. Cleaned and unstained dried sections were mounted on slide using DPX (Diphthalate butyrate xylene). After the preparation of sections, the microscopic analysis was carried out and viewed at 200–400× magnification using light microscope (Olympus CH30). The prepared slides were studied for amount of secondary dentine formation by two methodologies i.e. method 1 – Gustafson's method[21] (Qualitative) and method 2 – Kedici's[22] micrometric measurement method (quantitative).

2.1.1. Gustafson's method

All the prepared sections were scored for the extent of formation of secondary dentin according to Gustafson's 0–3 point scoring system (Cited in Vij, 2002)[35] (Table 1, Fig. 1). These scores were subjected to regression analysis for estimating the age of an individual.

2.1.2. Kedici method

Kedici et al. (2000) studied various age related changes of teeth in the form of 18 micrometric measurements to estimate age of an individual. For the present, out of 18, five (5) measurements representing the amount of secondary dentine formed were chosen (Fig. 2). Measurements were taken under light microscope (Olympus CH 30) using measuring eye piece following Kedici et al. (2000). Finally, the scalar divisions were converted to millimeters and were used to estimate age by formulating multiple regression equation.

Table 1 Gustafson's (0–3) point scoring system.

Parameter	SCORE			
	0	1	2	3
Secondary dentine	No secondary dentine formation	Formation of secondary dentine up to upper part of pulp cavity	Formation of secondary dentine up to 2/3rd of pulp cavity	Diffused calcification of entire pulp cavity

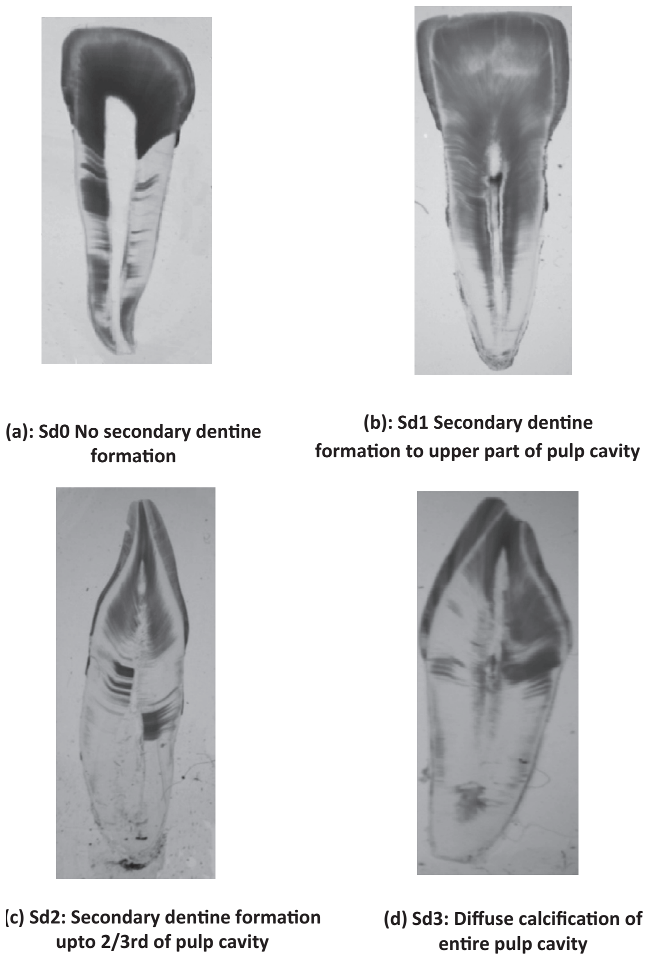

Figure 1 (a–d) Stages of secondary dentine formation.

Following measurements were taken to evaluate the morphological changes occurring in pulp cavity because of the formation of secondary dentine (Fig. 2)

(1) Cervical total thickness (CTT): it is the total distance between cementum–enamel junction at labial and lingual ends.
(2) Pulp height from cervical line (PH): it is the total height of pulp over cervical line.
(3) Pulp width at cervical line (PW): it is the width of the pulp at cervical line.
(4) Height of predentine over pulp tissue (HPD): height of predentine was taken as its distance from cervical line to its extent within the pulp cavity.
(5) Labiolingual pulp width at 5 mm above root apex (LLPW): Labiolingual pulp width was measured as a width of pulp tissue at 5 mm from root apex.

3. Statistical analysis

For statistical analysis, the data were entered and analyzed on MS Office 2007 Excel spreadsheet (Microsoft Corp. Redmond, WA) and SPSS 17.0 statistical program (SPSS Inc. Chicago, IL). Correlation was found between amount of secondary dentine formation and actual age using Pearson's correlation coefficient and line of best fit or "trend" line (is a straight line that best represents the data on a scatter plot) was calculated. Regression analysis was performed for age estimation. For comparison purposes, Data were divided on the basis of age groups, reason of extraction and sex of an individual. Absolute mean error of age was calculated as absolute value of difference between actual and estimated ages. An independent *t*-test was used to confirm the presence of significant difference in absolute mean error of age in periodontal and non periodontal diseased teeth as well as in two sexes. ANOVA was used to evaluate potential difference of absolute mean error in different age groups. Further, post hoc test (Student–Newman–Kuels) was used to identify the samples differing significantly from each other. A value of $p < 0.05$ was set as statistically significant. In order to assess intra-observer variations, scores of thirty teeth were repeated at the interval of 15 days. It was found that there were no intra-observer variations in all the repeated scores and measurements of secondary dentine.

4. Results

The trend line (Fig. 3) clearly indicated that mean values for secondary dentine increase as the age advances. Keeping this trend in view, age was estimated by formulating linear (Fig. 3) and multiple regression equations for pooled data using methods 1 and 2 respectively. Gustafson's method showed a value of 0.441 as coefficient of determination whereas, it was found to be 0.164 for Kedici's method. Gustafson's method reported a standard error of estimate as 12.62 while in Kedici's method it was noted as 16.11 (Table 2, Fig. 4). As is evident from Fig. 4, there were a few scattered points that showed a marked difference between the actual and estimated age. In pooled data, significant correlation coefficients (method 1: $r = 0.664$ ($p < 0.05$); method 2: $r = 0.405$ (< 0.05)) were obtained between actual age and amount of secondary dentine by both methods. No significant differences were obtained between actual and estimated ages of pooled data by means of *t*-test (Table 3). In Gustafson's technique (method 1) absolute mean error was found to be ± 10.42 years which increased to ± 13.71 years on applying Kedici's technique (method 2). *t*-Test showed that statistically significant difference was observed between the absolute mean errors calculated from two methods ($p < 0.05$) (Table 4). On the basis of age groups, significant correlation coefficient ($p < 0.05$) was observed in age group I by method 1 and in age groups

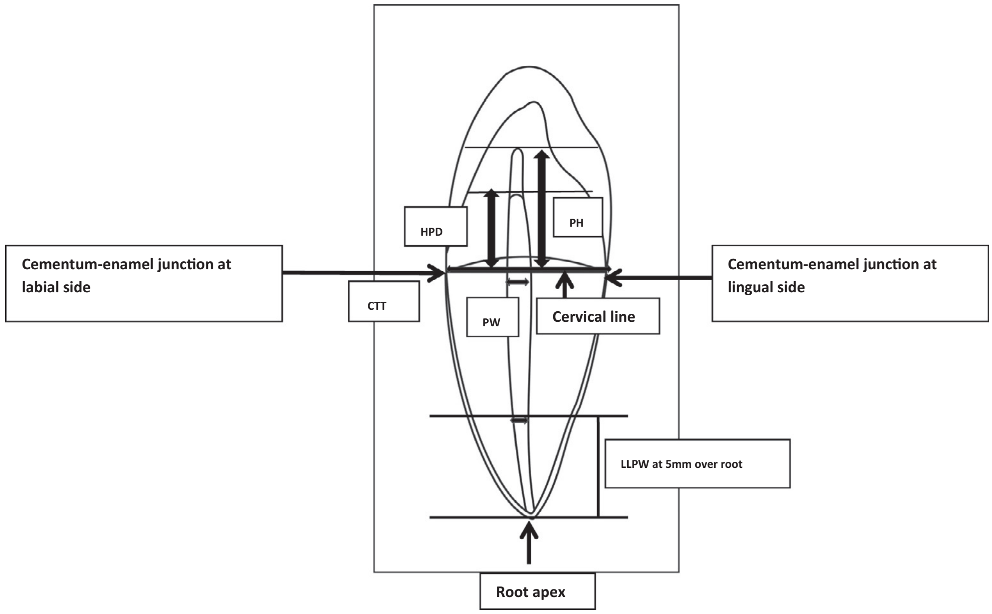

Figure 2 Micrometric measurements of tooth-cervical total thickness (CTT), pulp height from cervical line (PH), pulp width at cervical line (PW), height of predentine over pulp tissue (HPD) and Labiolingual pulp width at 5 mm above root apex (LLPW).

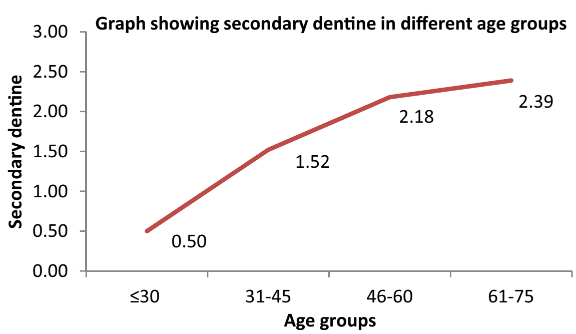

Figure 3 Line graph showing the trend of secondary dentine in different age groups in method 1 (Gustafson's method).

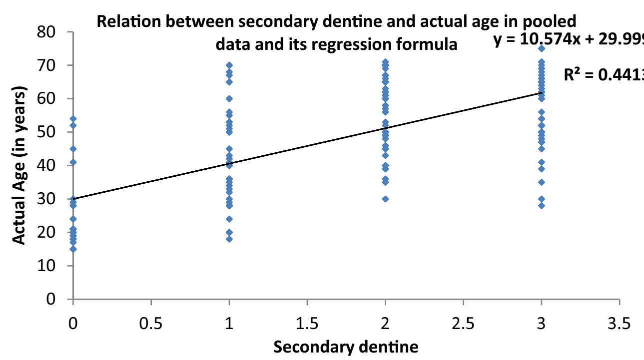

Figure 4 Scatter plot showing the linear regression analysis using age as dependent variable and secondary dentine as independent variable in method 1 (Gustafson's).

I and IV by method 2. In all other age groups, non-significant correlation coefficients were found between actual age and amount of secondary dentine formed. Significant differences were indicated by *t*-test between actual and estimated ages in age groups I, III and IV in method 1 and in all the age groups in method 2. It was seen that absolute mean error ranged from approximately ±8 years to ±12 years and ±6 years to ±20 years in method 1 and method 2 respectively. But, both the methods disclosed the minimum error in age group III i.e. 46–60 years. Although, in method 1, no significant differences were noted in absolute mean errors between different age groups by a one way ANOVA, in method 2 a one way ANOVA showed significant differences in absolute mean errors among different age groups ($p < 0.05$) (Table 5). Further, Student–Newman–Kuels test revealed that absolute mean error of all the age groups differed significantly from each other (Table 6).

Table 2 Regression equations, coefficient of determination and standard error of estimates for pooled data by method 1 (Gustafson's) and method 2 (Kedici's).

	Gustafson's method		Kedici's method	
	Regression Equation	R^2, SEE	Regression equation	R^2, SEE
Pooled Data	$y = 10.574$ * score of sec. dentine + 29.999	0.441, 12.628	$Y = 55.86–0.062$ * CTT-0.194 * PH − 5.478 * PW + 3.1 * HPD − 0.259 * LLPW	0.164, 16.114

In the above regression equations, *Y* is the estimated age.

Table 3 Correlation coefficient (r), actual age vs estimated age in pooled data by methods 1 (Gustafson's) and 2 (Kedici's).

Gustafson (N = 196)				Kedici (N = 180)		
		t	p		t	p
r	0.664	–	0.000*	0.405	–	0.000*
Actual age (years) Mean ± SD	48.99 ± 16.90	0.000	0.999	47.74 ± 17.38	−0.000	0.999
Estimated age (years) Mean ± SD	48.99 ± 11.27			47.75 ± 7.04		

* $p < 0.05$.

Table 4 Absolute mean error of age in pooled data by methods 1 (Gustafson's) and 2 (Kedici's).

Method	Absolute mean error (in years) (absolute difference b/w actual and estimated age)	t-Value	p-Value
Method 1 (Gustafson (N = 196))	±10.42	4.232	0.000*
Method 2 (Kedici (N = 180))	±13.71		

* $p < 0.05$.

Table 5 Correlation coefficient (r), actual age vs estimated age and absolute mean error of age in different age groups by methods 1 (Gustafson's) and 2 (Kedici's).

	Gustafson's method				Kedici's method			
	Age groups				Age groups			
	⩽30 (N = 42)	31–45 (N = 29)	46–60 (N = 57)	61–75 (N = 68)	⩽30 (N = 41)	31–45 (N = 30)	45–60 (N = 51)	61–75 (N = 58)
r (p value)	0.510 (0.000*)	0.064 (0.372)	−0.196 (0.005)	0.012 (0.867)	0.756 (0.000*)	0.507 (0.181)	0.179 (0.909)	0.438 (0.043*)
Actual age (years) mean ± SD	23.00 ± 4.94	39.34 ± 3.91	52.02 ± 3.91	66.41 ± 3.69	22.17 ± 4.78	38.60 ± 3.89	52.12 ± 3.96	66.71 ± 3.68
Estimated age (years) mean ± SD	35.23 ± 8.21	46.03 ± 8.80	53.05 ± 9.08	66.41 ± 3.69	41.88 ± 8.37	49.70 ± 3.15	49.45 ± 6.33	49.38 ± 5.86
t value, p value (actual vs est. age)	−8.276, 0.000*	−3.739, 0.000*	−0.782, 0.435	11.516, 0.000*	−13.089, 0.000*	−12.142, 0.000*	2.547, 0.012*	19.083, 0.000*
Absolute mean error (absolute difference b/w actual and estimated age)	±12.24	±9.07	±8.91	±11.10	±19.87	±11.10	±6.16	±17.33
F value, p value	2.160, 0.094				53.651, 0.000*			

* $p < 0.05$.

Table 6 Student–Newman–Kuels in absolute mean error of age in age groups by method 2 (Kedici).

Post hoc-SNK					
Age group	N	Subset for alpha = 0.05			
		1	2	3	4
46–60	51	6.1604			
31–45	30		11.1047		
61–75	58			17.3298	
⩽30	41				19.884

Data were also analyzed on the basis of reason of extraction of teeth i.e. non-periodontal (caries, prosthetic and orthodontic) and periodontal. Significant correlation coefficients of 0.717 ($p < 0.05$) and 0.595 ($p < 0.05$) were observed in teeth extracted for non periodontal reasons by method 1 and 2 respectively. In both methods, the value of correlation coefficient decreased in case of teeth extracted for periodontal reasons. Using methods 1 and 2, correlation coefficient of 0.217 ($p < 0.05$) and 0.228 ($p > 0.05$) respectively were shown by teeth extracted for periodontal reasons (Table 7). Actual and estimated ages were compared by t-test, it was found that ages differed significantly in method 2 only. Teeth extracted for non-periodontal reasons gave an absolute mean error of ±11.16 years and ±11.90 years for methods 1 and 2 respectively. Absolute mean errors of ±9.47 years and ±15.67 years were obtained for teeth extracted for periodontal reasons using methods 1 and 2 respectively. Absolute mean errors of teeth extracted for NPD and PD reasons were compared by t-test in their respective method. The results showed that in method 1, there was no significant difference between absolute mean error of teeth extracted for different reasons however, the value was found to be significant using method 2 (Table 7). On this basis, for method 2 separate regression equation was

Table 7 Correlation coefficient (r), actual age vs estimated age and absolute mean error of age in teeth extracted for non periodontal and periodontal reasons by methods 1 (Gustafson's) and 2 (Kedici's).

	Gustafson's method		Kedici's method	
	NPD	PD	NPD	PD
r (p)	0.694 (0.000*)	0.491 (0.000*)	0.595 (0.000*)	0.228 (0.506)
Actual age (years) mean ± SD	44.54 ± 18.48	54.56 ± 12.72	36.60 ± 12.99	59.91 ± 12.81
Estimated age (years) mean ± SD	46.38 ± 12.29	52.25 ± 8.87	46.17 ± 17.55	49.46 ± 6.02
t-Value, p-value (actual vs estimated age)	−0.866, 0.387	1.388, 0.166	−6.171, 0.000*	6.846,0.000*
Absolute mean error (Absolute difference b/w actual & Estimated age)	± 11.16	± 9.47	± 11.90	± 15.67
t-Value, p-value	1.697 (0.091)		−3.276 (0.001*)	

* $p < 0.05$.

Table 9 Correlation coefficient (r), actual age vs estimated age and absolute mean error of age in males and females by methods 1 (Gustafson's) and 2 (Kedici's).

	Gustafson's method		Kedici's method	
	M (N = 85)	F (N = 111)	M (N = 80)	F (N = 100)
r (p-value)	0.620 (0.000*)	0.682 (0.000*)	0.473 (0.002*)	0.470 (0.000*)
Actual age (years) mean ± SD	51.78 ± 15.85	46.86 ± 17.43	50.62 ± 16.25	45.44 ± 17.69
Estimated age (years) mean ± SD	51.03 ± 11.05	47.43 ± 11.24	46.82 ± 6.90	48.49 ± 7.06
t-Value, p-value (actual vs est. age)	0.549, 0.583	−0.289, 0.772	1.888, 0.060	−1.601, 0.110
Absolute mean error (absolute difference b/w actual and estimated age)	±9.93	±10.79	±13.35	±14.00
t-Value, p-value (absolute mean error)	−0.833, 0.40		−0.542, 0.587	

* $p < 0.05$.

devised for teeth extracted for non periodontal reasons which in turn was applied for the teeth extracted for periodontal reasons. For this group of data, value of 0.354 and 10.737 was obtained as a coefficient of determination and standard error of estimate respectively. Using this specific equation for method 2, teeth extracted for non-periodontal and periodontal reasons gave an absolute mean error of ±8.79 years and ±23.11 years respectively. A significant difference was obtained between absolute mean errors of age for teeth extracted for different reasons as evident from t-test (Table 8).

When data were analyzed on the basis of sex of an individual, significant correlation coefficients (method 1 (M = 0.620 ($p < 0.05$); F = 0.682 ($p < 0.05$)), (method 2 (M = 0.473 ($p < 0.05$); F = 0.470 ($p < 0.05$)) were shown by males and females in both techniques. Using t-test, no significant differences were seen between actual and estimated ages as well as in absolute mean errors of males (method 1 (±9.93); method 2 (±13.35)) and females (method 1 (±10.79); method 2 (±14.00)) in both methods (1 and 2) (Table 9).

Table 10 Frequency of the cases under acceptable and unacceptable range of errors by methods 1 (Gustafson's) and 2 (Kedici's).

Method used	Acceptable (⩽±10 years) (%)	Unacceptable (>±10 years) (%)
Gustafson's method	51.52	48.46
Kedici's method	33.88	66.11

The magnitude of errors was grouped according to the range acceptable in forensic identifications i.e. ⩽±10 years. It was appreciated that 51.52% cases were considered as acceptable in method 1 (qualitative) while on applying method 2 (quantitative) only 33.88% cases showed the error within this range (Table 10).

Table 8 Regression equation, Coefficient of determination, standard error of estimates absolute mean error of age for teeth extracted for non periodontal reasons by method 2 (Kedici's).

Kedici's method				
Regression equation for non periodontal diseased teeth	R^2	SEE	Absolute mean error of age (absolute difference b/w actual and estimated age)	
$Y = 24.2931 + 3.824 * CTT + 0.5212 * PH - 8.992 * PW + 3.7943 * HPD - 0.1106 * LLPW$	0.354	10.737	NPD (N = 94) ±8.79	PD (N = 86) ±23.11
t-Value, p-value			−10.556, 0.000*	

In the above regression equation, Y is the estimated age.
* $p < 0.05$.

5. Discussion

Dentine is a vital tissue and lays down throughout the life of the an individual. Secondary dentine deposition is a regular process if not influenced by caries or some periodontal factors.[36] Burke and Sammarawickrama[37] stated that pulp dentinal complex responds to various physiological and pathological (caries, restorative treatment etc.) stimuli. This action of pulp results in the reduction of size of pulp cavity due to formation of secondary dentine – an important feature of aging.[19] Thus, it can be utilized for age estimation. The relationship between tooth dimensions and age is an important feature in forensic odontology.[38] Bermudez and Nicolas[39] stated that tooth dimensions differ with environment, dietary habits and evolution whereas; Townsend et al.[40] believe that genetics plays an important role in the morphology of tooth. It has been widely accepted that age can be assessed on the basis of physiological changes in tooth. Physiological changes like attrition, root dentine translucency, and root resorption can be studied microscopically and macroscopically in a constant light source while age changes like formation of secondary dentine, cementum apposition or thickness can be examined on thin ground sections under light microscope. Gustafson's[21] work was the first published data on age estimation from histological teeth sections. In his study, secondary dentine was included as one of the physiological variable for formulating the regression equation for age estimation. On radiographs, a standard method of analyzing secondary dentine was proposed by Kvaal et al.[23] He measured maximum tooth length, pulp length, root length and pulp and root width at three different points (CEJ, midroot length and midpoint between CEJ and midroot) for evaluating the amount of secondary dentine formation.

In the present study, secondary dentine was measured on ground sections of teeth as an exclusive parameter for age estimation by following the techniques of Gustafson[21] (qualitative) and Kedici[22] (quantitative). Using Gustafson's method, the present study revealed a correlation coefficient of 0.664 between amount of secondary dentine and known age which was comparable to 0.76 observed by Shrigiriwar and Jadhav[6] and was superior to the value observed by Mandojana et al.[16] (>0.5). However, Gupta et al.[36] used thickness of secondary dentine as a measure of age estimation among North Indians. They found a correlation coefficient of 0.96 between known age and thickness of secondary dentine. When Ajmal et al.[41] used methods of Johanson[14] and Kashyap and Rao[42] to study secondary dentine, standard deviation of ±8.9 and ±7.7 years respectively was found; which was superior to the present study (±10.42) years.

Kedici et al.[22] measured eighteen (18) age related physiological changes in tooth on thick ground sections under scanning electron microscope (SEM). However, the present study selected five (5) of these parameters i.e. Cervical total thickness, pulp height from cervical line, pulp width at cervical line, and height of predentine over pulp tissue and Labiolingual pulp width at 5 mm over root apex as a measure of amount of secondary dentine formation. These variables were chosen because these correspond to the reduction in the size of pulp chamber due to the formation of secondary dentine. These measurements were subjected to multiple regression analysis to estimate the age of an individual. It was found that pulp width at cervical line and height of predentine over pulp tissue significantly contributed to age estimation. With age, there should be a decrease in the size of pulp chamber due to the formation of secondary dentine within the cavity. The present study showed that cervical pulp width decreases with increasing age ($r = -0.337$) which was in accordance with previous studies.[19,21,43,44] Solheim[19] found that width decreases by 2 mm over a mean age range of 28–74 years. Absolute mean error of the pooled data was found to be a ±13.71 years which was comparable to the studies of Babshet et al.[32] and Talreja et al.[44] In method 1, non-significant differences in absolute mean errors among different age groups suggested that the method was found to be equally reliable in all the age groups studied however, method 2 predicted the best results in age group III i.e. 46–60 years, followed by age group II > IV > I (Tables 5 and 6). In both methods, significant correlation coefficients ($p < 0.05$) were observed in males and females but statistically no significant differences were noted in absolute mean error of age between two sexes (Table 9). This suggested that there was no need to separate data on the basis of gender. However, Kedici et al.[22] presented two sex specific regression equations for age estimation and found standard error of prediction of 1.27 for females and 1.37 for males. The data were also analyzed according to the reason of extraction. It was evident from the results obtained from both the methods that Pearson's correlation coefficient was higher in teeth extracted for non periodontal reasons which decreased in teeth extracted for periodontal reasons. Statistically significant differences were noted in the absolute mean error of age on the basis of reason of extraction in method 2 only. This result clearly indicated that age estimation from secondary dentine is highly influenced by the periodontal status of the tooth using Kedici's method which was in concordance with that of Gupta et al.[36] In such cases, methods like root dentine translucency, cementum annulation count may be given preferences. Contrary to this, periodontitis seemed to have no effect on age estimation using Gustafson's method (Table 7).

Precision and accuracy is a significant aspect especially in forensic science where evidence is presented as part of expert witness testimony. In forensic cases, an error of ±10 years of age is considered as an acceptable range.[41,45] On comparison of absolute mean error of age in pooled data, technique 1 claimed an error within acceptable range i.e. approximately ⩽ ± 10.42 years. However, the results were surprising for the present population where Gustafson's[21] technique was found to be a better indicator for age estimation than the quantitative method suggested by Kedici.[22] Moreover, the qualitative method was found to be fast and easy to apply but the quantitative method was found to be complicated in terms of its application. It is recommended here that the use of measuring software might improve the accuracy of quantitative method.

6. Conclusion

The present study was conducted on 196 single rooted teeth to estimate age from secondary dentine by qualitative (Gustafson's) and quantitative (Kedici's) methods among North Western adult Indians. Age was estimated by formulating regression equations. Results were analyzed on the basis of absolute mean error of age calculated for different sets of data. On the basis of pooled data, it can be concluded that

Gustafson's method was found to be superior to Kedici's method of age estimation among North Western adult Indian population. In method 1, no significant differences were obtained in absolute mean error of age between different age groups however; each group differed significantly from each other when method 2 was applied. Periodontal status of the tooth affects the accuracy of the age estimation process using Kedici's method however; periodontitis seemed to have no effect on age estimation process when Gustafson's method was applied. Sex differences were not observed for age related changes in the secondary dentine by any of the methods. Thus, there is no need to separate data on the basis of gender. There is a need to validate the results of quantitative method using measuring software. The regression equations formulated from secondary dentine in the present study can be used to estimate age among North Western adult Indians. Moreover, qualitative method is more reliable than quantitative method of age estimation using secondary dentine.

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Informed consent

Before data collection, permission of institutional ethics committee was taken and also, written informed consent was obtained from the subjects.

Conflict of interest

None declared.

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