AGE ESTIMATION USING PULP/TOOTH RATIO FROM SINGLE ROOTED PREMOLARS WITH DIGITAL INTRAORAL PERIAPICAL RADIOGRAPH AND LONGITUDINAL HEMISECTION OF TOOTH: A COMPARATIVE STUDY IN DRAVIDIAN POPULATION.

Dissertation submitted to

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In partial fulfillment for the Degree of

MASTER OF DENTAL SURGERY

BRANCH VI

ORAL PATHOLOGY & MICROBIOLOGY

2015 – 2018

CERTIFICATE BY THE GUIDE

This is to certify that the dissertation titled **"AGE ESTIMATION USING PULP/TOOTH RATIO FROM SINGLE ROOTED PREMOLARS WITH DIGITAL INTRAORAL PERIAPICAL RADIOGRAPH AND LONGITUDINAL HEMISECTION OF TOOTH: A COMPARATIVE STUDY IN DRAVIDIAN POPULATION"** is a bonafide work done by **DR. T.KEERTHI PRIYADHARSHINI,** Postgraduate student, during the course of the study for the degree of **MASTER OF DENTAL SURGERY** in the speciality of **DEPARTMENT OF ORAL PATHOLOGY AND MICROBIOLOGY,** Vivekanandha Dental College for Women, Tiruchengode, during the period of 2015-2018.

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF GRAPHS

LIST OF ABBREVIATIONS

P/ T	Pulp/Tooth.
CEJ	Cemento Enamel Junction.
SEE	Standard Error of Estimate
r	Correlation Coefficient
R^2	Coefficient of determination
P/R	Pulp Root length
P/T	Pulp Tooth length
T/R	Tooth Root length
RVG	Radiovisiography
IOPA	Intra Oral Periapical Radiograph
CBCT	Cone Beam Computed Tomography
PCTHR	Pulp Chamber Crown Coot Trunk height Ratios
TCI	Tooth Coronal Index

INTRODUCTION

The moral and professional responsibility of a dental surgeon to society is not only to perform in examination, investigation, diagnosis and treatment of diseases in oral and maxillofacial region, but also to assist in other community services and legal disputes. A dental surgeon can be an authoritative person in presenting evidence related to medico-legal identification of a person in interrogation. Forensic odontology mainly involves the collection, management, interpretation, evaluation, and presentation of dental evidence for criminal or civil legal proceedings. It is an interdisciplinary field between forensic medicine and dentistry.[1]

The word “Forensic” is derived from the Latin word forensis, which means ‘before the forum’. According to Jones, the forum was a public square where trials and debates took place and consequently served as a court of law. “Odontology” refers to the study of teeth. Federation Dentaire Internationale (FDI) defines Forensic odontology as “The branch of dentistry which, in the interest of justice, deals with the proper handling and examination of dental evidence, and with proper evaluation and presentation of dental findings”.[2]

Forensic odontology is the most unexplored and intriguing branch of forensic sciences. The main purpose of forensic dentistry is to recognize deceased individuals, for whom other clues of biometric identification (e.g., fingerprints, face, etc.) may not be accessible. The data collected from morphology of skull, jaws, odontometric analysis, palatal rugae pattern, DNA analysis of oral and paraoral tissues etc. may play a role in identification of gender and age of individual.[3]

Personal identification is required when the bodies of victims of violent crimes, fires, motor vehicle accidents and work place accidents, is mutilated to such an extent that identification by a family member is neither reliable nor desirable. Persons who have been deceased for some time prior to discovery and those found in water also present unpleasant and difficult in visual identifications.[4]

Physical features like ethnic characteristics which includes both inherited and acquired characteristics like surgical scars, previous fracture, dental restorations are prone to change overtime and is not reliable. Dental characteristics are shown to withstand time and extreme physical conditions offers a reliable method of personal identification.

The use of dentition for age estimation appears to dated back from the beginning of the nineteenth century. In 1889, Laccasagne was the first to utilize changes in the teeth of adults to estimate age. Later, Bodecker, in 1925, pointed out that few morphological changes in teeth could be related to increasing age.[5]

Though bones are hard, the enamel of the teeth are the hardest structures in the body and the fourth hardest structure in the universe by its homogenous content of calcium apatite crystals. The tooth resist heat, fine chemicals, toxins and microbial attack, hence damage to tooth is not instantaneous.[6]

Knowing your age is a basic human right and having it recorded gives identity to the individual. (UNICEF,1989). If the age can be accurately estimated it will significantly narrow the field of possible identities that will have to be compared to the remains in order to establish a positive identification. Hence the importance of age estimation for personal identification is noted. Age plays an important role in establishing the identity of the person. Age estimation of an individual is a procedure adopted by anthropologists, archaeologists and forensic scientists. Chronological age is noted from the registration of birth date and it is referred throughout an individual's life.[7]

In case of living individual such as refugees and adopted children who have no acceptable identification documents, confirmation of chronological age is required in order to avail the civil rights and social benefits. Ante mortem age estimation can be done by processing radiographs of long bones and teeth. Post-mortem age estimation involves analyzing the remains of bones and teeth directly and also by using radiographs.[8]

Age related changes in dentition are divided into three catergories, they are formative, degenerative and histological. Formative changes are subdivided into four stages that includes the beginning of mineralization, the completion of the crown, the eruption of the crown into the oral cavity and completion of the root. Degenerative changes includes change in color, attrition and periodontal attachment level. They provide obvious results or changes which help in visualization, visually collecting data and age estimation. Histological methods needs preparation of teeth structures for detailed microscopic examination, they are secondary dentin deposition, cementum apposition and dentin translucency.[8]

Age estimation in children and adolescents usually depends on the time of emergence of the tooth in the oral cavity and the tooth calcification, for adults it is volume assessment of teeth first using Pulp-to-tooth ratio method by Kvaal and Coronal pulp cavity index and then second method is Development of third molar. After the eruption of third molar it is not possible to measure.[9] In adults, however, age estimation based on these methods is much less accurate. Many studies have proved that dental age relates more closely to chronological age than skeletal, somatic or sexual maturity indicators.[10]

Teeth shows many regressive changes with advancing age and various studies have been done to estimate the age of an individual using these methods. One such factor is Secondary dentine deposition that have been regarded as a valuable age factor with advancing age, it is deposited along the wall of the dental pulp chamber leading to a reduction in the size of the pulp cavity. Estimation of age using secondary dentine is done qualitatively on ground sections of teeth by employing Gustafson's (0–3) scoring system and quantitatively in the form of micrometric measurements suggested by Kedici et al.[11]

Up to now many studies have been available in literature on age estimation using radiographs including both periapical and orthopantomography. Secondary dentin deposition have been studied extensively using various parameters in radiographic method. Dentin deposition was also studied by ground sectioning of the teeth which may sometimes lead to the breakage of dentin particles during the procedure. There are however a number of inherent drawback to the use of these techniques. But there is only single study available in the literature using hemisectioning method. As there is always a need for a accurate age estimation technique in forensic odontology, this study was done to compare the radiological and hemisectioning method.

AIM OF THE STUDY

To estimate and compare the age using digital intraoral periapical radiographs and longitudinal hemi section of tooth.

OBJECTIVES OF THE STUDY

1. To estimate the age by measuring the P/T area ratio and P/T width ratio at CEJ from digital intra-oral radiograph.
2. To estimate the age by measuring the P/T area ratio and P/T width ratio at CEJ from longitudinal hemisection section.
3. To compare the estimated age with chronological age in both the methods.

REVIEW OF LITERATURE

Review of literature is discussed under the following headings:

1. Kvaal's method
2. Camerier method
3. Kvaal's and camerier method
4. Histological method
5. Cone beam computed tomography method
6. Age estimation using combination of methods

KVAAL'S METHOD

Kvaal's et al., 1995 found a nondestructive method which could be used to estimate the chronological age of an adult from measurements of the size of the pulp on full mouth dental radiographs. The radiographs of six types of teeth from each jaw were measured: maxillary central, lateral incisors and second premolars, and mandibular lateral incisors, canines and first premolars were taken. To compensate for differences in magnification and angulation on the radiographs, the following ratios were calculated: P/R length, P/T length, T/R length and P/R width at three different levels. He observed that the coefficient of determination (R^2) for the estimation was strongest when the ratios of all the six teeth were included (R^2 = 0.76) and weakest when measurements from the mandibular canines alone were include (R^2= 0.56). He also concluded that the width ratio for all teeth, except the maxillary central incisors, is found to have a stronger correlation with age than the length ratio.[12]

Kollveit et al., 1998 found that the manual measurements of morphological parameters in dental radiographs showed a better correlation with chronological age than did the computer-assisted measurements. Lengths and widths of tooth and pulp were measured both manually and with computer assistance on periapical radiographs from six teeth in 40 patient. They concluded that a software program with automatic tracing ability could minimize bias in film density and observer which in the future could produce an objective approach for age estimation based on dental morphology as viewed in radiographs.[13]

Bosman et al., 2004 gave the idea that there is no significant difference on applying the regression formula from kvaal's original technique on standard long-cone periapical radiographs on data obtained from OPGs. Especially, in those conditions where either all six teeth or all three mandibular teeth participated in the age calculation no significant difference was found between the real age of the individual and the calculated age based on the orthopantomograph. He also detailed that the SEE values from original technique and OPG were relatively comparable.[14]

Paewinsky et al., 2005 suggested that the P/T width at CEJ correlated best with age in all six teeth except for the mandibular first premolars where the best correlation was found at level B (mid root level). The width ratios of the pulp cavity showed significant correlation to the chronological age and the coefficient of determination (R^2) was highest in the upper lateral incisors (R^2=0.913) when an exponential or a logistic regression model, was constructed. At the same distance with a linear regression model the coefficient of determination (R^2) reached 0.839. The coefficients of determination varied depending on the regression model used and the best correlations were obtained from the exponential and the logistic function. The highest combined linear correlation coefficient was also observed in the maxillary lateral incisors and the standard deviation reached 6.4 years. Finally, if the width ratios from all teeth were combined, a linear correlation coefficient r = -0.95 with a standard deviation of 5.6 years could be determined.[15]

Meinl et al., 2006 reported that there is underestimation of age with Kvaal's formula and overestimation of age with Paewinsky formula when he substituted the values from OPGs of 44 Austrian individuals aged between 13 and 24 years in their equations. From the results of this study, it can be concluded that the regression equations reported in Paewinsky and Kvaal cannot be applied to a young sample (13.03–24.61 years). Kvaal's formula showed mean underestimation of 31.44 years when applied for single teeth, 38.21 years if done for three maxillary teeth. The use of the formula for three mandibular teeth led to a mean underestimation of 47.10 years, with all six teeth from both jaws the calculation resulted in a mean underestimation of 46.04 years. The use of these formulas led to age estimations that are far away from the real chronological age.[16]

Landa et al., 2008 showed that the method reported by Kvaal et al., cannot be applied to direct digital OPGs as the values analyzed on digital images were so distant from the real ages. He used OPGs of 100 patients aged between 14 and 60 years from a private radiology department in Bilbao. They found difficulty in identifying the reference points in the image when viewed directly on the monitor. The reproducibility of the kvaal's method in OPG showed very low correlation between the parameters measured and real age. He reported that this method must be discouraged as being a reliable one to estimate age on a direct digital OPG samples.[17]

Sharma et al., 2010 aimed at evaluating the feasibility of the kvaal's technique in Indian population using digital long-cone intraoral periapical radiographs from 50 subjects in the age group of 15–60 years. They used 6 teeth as mentioned by

Kvaal's. They concluded that the coefficient of determination (R^2) was the strongest (0.198) for the mandibular first premolar and lowest when lower 3 teeth were used together indicating that age can be estimated better with lower premolars. No significant difference was observed between the estimated age and the actual age for all (P>0.05) except in mandibular lateral incisor and maxillary lateral incisor, where a significant difference was observed.[18]

Mala et al., 2012 studied the application of Kvaal's technique in digital Panoramic radiograph using 6 teeth, 3 maxillary and 3 mandibular teeth. He found out that upper second premolar tooth acts as a good predictor of age, when taking "M" (mean of all ratio's) and "W-L" (the difference between the mean of 2 width ratios and the mean of 2 length ratios) as the first and second predictors respectively. They also observed that the coefficient of determination R^2 was higher (0.076) in upper three teeth taken together compared to lower three teeth (0.049). In upper teeth "M" was found to be a significant predictor whereas in lower teeth, "W-L" was found to be the significant predictor.[19]

Talreja et al., 2012 analyzed the sample of 100 digital radiographs in Indian population and aimed at evaluating the versatility of Kvaal's technique. They reported that Kvaal's age estimation formulae produced vast age estimation errors in the Indian sample. They stated that a number of factors may be contributing to the large errors, including sample composition of the original study, differences in methodology, observer differences and most probably the variation in the rate of secondary dentinal deposition in the Indian sample owed to environmental and genetic effects. The India-specific age estimation equations reduced the error rates (in terms of SEE), with the bisecting angle technique yielding slightly smaller errors than the paralleling method. They also observed that the errors were still relatively large and higher than those obtained in European samples. Therefore, the variables used herein did not account for much of the variation, probably because the rate of secondary dentine deposition in Indians is not regular as age progresses. These reasons may preclude the routine use of this method in the estimation of Indian adult type.[20]

Erbudak et al., 2012 tested Kvaal's et al., technique of age estimation methods on Turkish individuals. The correlation between chronological and estimated ages was examined and the feasibility of length and width measurements of pulp cavity was evaluated for age estimation. Age was calculated using the linear regression models presented by Kvaal et al., and Paewinsky et al. He concluded that there was high differences on observing the values between chronological and estimated ages. Measurement ratios showed no significant or weak correlation with age. The linear regression models were derived using variables that were significantly correlated with age. The determination coefficients of the models varied from 0.035 to 0.345. In conclusion, a difference of more than 12 years in the chronological and estimated ages derived using regression models in literature was found on panoramic radiographs of Turkish individuals. The length and width of the pulp cavity, measured according to the method of Kvaal et al., using panoramic radiographs, were insufficient to precisely estimate the age of Turkish individuals.[21]

Agarwal et al., 2012 proved maxillary central incisor to be a significant indicator for measuring chronological age. The study was done in 50 subjects between 20-70 years of age using IOPA's and measurements made were for lengths of tooth, pulp, root and width of root and pulp at three different points. Linear regression equations was derived for all variables and then found and then age was calculated. He found that P/T width at A (CEJ) and B (Midpoint between CEJ and midroot) showed minimal SD with age. Maximum difference was seen for root length variable (-1.035 ± 1.86 years), no statistically significant difference was found between the estimated age and the actual chronological age the *P* value was >0.05, indicating significantly positive result.[22]

Limdiwala et al., 2013 determined that kvaal's criteria showed the accurate and precise measurements of age with the difference of 8.3 years which is within the acceptable limit. They included 150 radiographs with 100 in group A, without any pathology were selected based on kvaal's selection criteria and 50 in group B those radiographs were not according to the criteria (Non-ideal radiographs with caries, dental fillings, crowns and periapical pathology). Same set of teeth and parameters were applied to all the 150 OPG as originally designed by Kvaal's. Kvaal's criteria of selecting the radiographs showed a better correlation with age than the radiographs selecting without the criteria.[23]

Patil et al., 2014 intended at evaluating the accuracy of age estimation formula of Kvaal's and coauthors developed for Norwegian population in Indian samples. Digitalized IOPA of maxillary central incisors from 100 samples between the age group of 20 and 50 years were chosen for the study. Modified Kvaal's formula, Age = 33.5 -18.6 (M) -3.49 (W - L) was developed and applied to sample Indian population. Standard error of estimated age by modified Kvaal's formula (±6.5 years) was less when compared to standard error of estimated age of Kvaal and coauthors formula in Norwegian population (±9.5 years). Formula which was derived from Norwegian population (Caucasian) is not applicable to other population. Population specific formulae have to be derived to get accurate results.[24]

Rajpal et al., 2016 reported that Kvaal's method is a reliable method to estimate age in both younger and older populations. With a few modifications of Kvaal's method, we could estimate age with a SEE of ± 6.4-7.8 years in a sample of the Indian population. He concluded that the ratios X1, X2, and X3, width measurements are good indicators of age, while X4 length measurements is not correlated with age estimation in above population. He conveyed that the X1 showed the strongest correlation compared to the width ratios as depicted in the study conducted by Kvaal's et al.[25]

Mittal et al., 2016 aimed at testing the validity of regression equations as given by Kvaal et al., in OPG of Indian samples beyond 25 years of age. He indicated that the width ratios were better correlated than length ratios and "M" (mean value of all ratios) and "W ~ L" (difference between "W" and "L") were the best predictors for age estimation. Age could be estimated with greater accuracy by taking three mandibular teeth together followed by mandibular first premolar and maxillary second premolar. The least accuracy was shown by the mandibular lateral incisor taken individually. He also concluded that the applicability of Kvaal's equation was invalid in the study population. The results of the study give inference for the feasibility of this technique by calculation of regression equations on digital panoramic radiographs. However, it negates the applicability of same regression equations as given by Kvaal et al., on the study population. The results of the study give an inference for the feasibility of this technique by calculation of regression equations on digital panoramic radiographs. However, it negates the applicability of same regression equations as given by Kvaal et al., on the study population.[26]

CAMERIER METHOD

Camerier et al., 2004 studied OPGs collected from the sample of 312 Italian white Caucasian patients (135 men, 177 women) aged between 14 and 24 years. He aimed at assessing adult age based on the relationship between age and measurement of the P/T area ratio on second molar teeth and also to improve the precision and reliability of age estimations. They also considered the gender and the maturation stages of third molar teeth. These results were exploited to establish a threshold value to assign an individual to juvenile or adult age. A cut-off value of RA = 0.088 was applied if Tm = 0 and RA = 0.097 if Tm = 1. The sensitivity of this test was 91% and its specificity was 94.5%. The proportion of individuals with correct classifications was 92%.[27]

Camerier et al., 2006 showed that P/T ratio of upper canine teeth can also be used in determining age at death in skeletal remains for the first time. Age estimation was very precise in eight mummies aged less than 72 years. He concluded that this method can be used to provide age estimation of old subjects who died over 50 years, with great reliability.[28]

Camerier et al., 2007 conducted an in vitro study on 57 male and 43 female skeletons of Caucasian origin, aged between 20 and 79 years where a total of 200 X-rays were analyzed to test the accuracy of age evaluation by combined analysis of labio-lingual and mesial peri-apical X-rays of lower and upper canines. The results obtained with single canines were similar to those obtained with labio-lingual X-rays. Instead, age-at-death estimates obtained with the P/T area ratio on both canines and both labio-lingual and mesial projections were significantly better than those evaluated by measuring the P/T area ratio on upper and lower canines only by labio-lingual X-rays. If only one canine is available, the small difference between the estimates according to labio-lingual X-rays, and both types of X-rays mean that only the labio-lingual projection is required. This model showed a high degree of accuracy with the mean prediction error of just 2.8 years.[29]

Camerier et al., 2007 assembled a total of 200 peri-apical X-rays of upper and lower canines from 57 male and 43 female skeletons of Caucasian origin, aged between 20 and 79 years. For each skeleton, dental maturity was evaluated by measuring the P/T area ratio on upper and lower canines. These two variables explained 92.5% of variations in estimated chronological age and the residual standard error was 4.06 years. Better results were obtained when using both the canines than those obtained using only one canine.[30]

Camerier et al., 2009 applied the P/T area ratio of upper and lower canines using peri-apical X-ray images as an age indicator in a Portuguese samples and compared it with Italian samples done in previous studies. Comparisons between the equation referring to the Portuguese sample and the equivalent linear equations proposed by Cameriere et al., for the Italian sample did not reveal significant differences between the linear models, suggesting that a common regression model could be applied for both samples.[31]

Singaraju et al., 2009 assessed the chronological age based on the relationship between age and measurement of the P/T area ratio on right maxillary canine, using 200 orthopantomographs between the age group of 18 and 72 years . Sample was distributed into three different age groups 18-30, 31 – 50, 51- 70 years. The observed correlation coefficients ‘r’ were 0.89, 0.97, and 0.96. Student’s t test showed that there was no difference between estimated age and chronological age.

Also estimated age and chronological age showed that the two variables are linearly related to each other with correlation coefficient 0.99. He confirmed the fact that width of pulp is a better indicator of the age and also found that the gender had no significant influence on age.[8]

Babshet et al., 2010 conducted a study to test one of camerier formulas on an Indian sample and ascertain whether the original formula predicted age accurately or if population-specific equation improved age assessment. Intraoral periapical digital radiographs of mandibular canines were obtained from 143 individuals (aged 20–70 years). The Indian formula derived (age = 64.413 (195.265 PTR), mandibular canines gave sub-optimal prediction in Indians and inferior results compared to the camerier's formula . Although the Indian formula showed no recognisable improvement in age assessment, it is recommended that the population-specific equation be used since this produces more 'stable' age estimates as it takes into account the low correlation between secondary dentine deposition and age in Indians. An approach to enhance age prediction may be to use multiple teeth and future studies could include additional teeth, e.g. mandibular lateral incisor and premolars, and develop multiple regression models.[32]

Luca et al., 2010 applied Cameriere's method on a large sample of historical subjects from several cemeteries in Spain and Italy. Age estimations of canines were compared with the mean ranges of age obtained from other commonly applied anthropological methods such as tooth wear changes in the pubic symphysis or the metamorphosis of the auricular surface of the ilium. Tests on these Middle Aged cemeteries produced satisfactory results indicating that Cameriere's method is a reliable tool in determining age at death in skeletal remains of archaeological context.[33]

Zaher et al., 2010 used 144 periapical radiographs of maxillary (central & lateral) incisors (both sexes) aged 12 to 60 in Egyptians population. He concluded that P/T area ratios of incisors are reliable for estimation of age among Egyptians in forensic work. Results showed a correlation r ¼ 0.23 & P ¼ 0.006 for maxillary central incisors and r ¼ 0.2 & P ¼ 0.05 for maxillary lateral incisors.[34]

Babshet et al., 2011 evaluated the P/T area ratio of three mandibular teeth and revealed that the lateral incisor had the highest correlation to age when used alone followed by the first premolar and canine. The use of these teeth in various combinations did not result in recognizably higher correlation. They also stated that there were little practical differences in the accuracy of age estimates irrespective of whether single or multiple teeth were used, with S.E.E.s ranging between 12.1 and 13.1 years. He explained that these high errors are in contrast to previous studies and may be explained on account of the low-to moderate age correlation of PTR in our Indian sample, as well as evaluation of a living subjects in the present study.[35]

Jeevan et al., 2011 confirms that upper canines seem to be the ideal candidates for age estimation using the AR method in both deceased and living subjects. The present study also demonstrated that this method gives a more stable age estimate in younger age's up to 45 years. They studied 456 canines in an Indian sample using radiovisiography technique. Linear regression equations were derived for upper canine, lower canine and both using the AR to estimate chronological age. Upper canine equations gave the precise results with mean error ranging from 4.28 to 6.39 years.[36]

Camerier et al., 2011 examined the relationship between age and age-related changes in the P/T area ratio in monoradicular teeth with the exception of canines by orthopantomography. A total of 606 OPGs of Spanish white Caucasian patients (289 women and 317 men) aged between 18 and 75 years from Bilbao and Granada (Spain) were analysed. Regression analysis of age of monoradicular teeth indicated that the lower premolars were closely correlated with age. An ANCOVA did not show significant differences between men and women. Multiple regression analysis, with age as dependent variable and P/T area ratio as predictor, yielded several formulae. R^2 ranged from 0.69 to 0.75 for a single lower premolar tooth and from 0.79 to 0.86 for multiple lower premolar teeth. Depending on the available number of premolar teeth, the mean of the absolute values of residual standard error, at 95% confidence interval, ranged between 4.34 and 6.02 years, showing that the P/T area ratio is a useful variable for assessing age with reasonable accuracy.[37]

Camerier et al., 2013 analysed apposition of secondary dentine deposition since 2004 and have published many papers on it. He studied upper and lower incisors to examine the application of P/T area ratio as an indicator of age. The samples of 116 individuals, 62 men and 54 women, aged between 18 and 74 years were studied. The results demonstrated that the variability in age explained by the P/T area ratio in incisors was affected by sex and also more accurate estimations were obtained by analysing upper lateral incisors. Lower laterals showed (R2 ¼ 0.513), a standard estimate error of 10.9 years while upper incisors showed 6.64 years. These results showed that, although incisors are less reliable than canines or lower premolars, they can be used to estimate age-at-death.[38]

Joseph et al., 2013 measured pulp to tooth area mandibular premolars using the radiovisuographic images (RVG's) from 120 subjects and derived the regression formula Age = 89.778-379.020 (AR) with a mean absolute error (MAE) of 5.38 years, specific for South Indian population and concluded that this method of age estimation provided a fairly accurate and reliable results.[39]

Camerier et al., 2014 proposed a segmentation algorithm for use with peri-apical x-ray images of canines, using Matlab code for the automatic evaluation of the ratio of tooth and pulp areas, to assess age using Cameriere's formula. He found out that these preliminary results are consistent with those obtained by a skilled operator, and yet demand considerably less time. The advantage of using this algorithm is that reproducibility of the result.[40]

Afify et al., 2014 evaluated the P/T area ratio of three mandibular teeth revealing that the 2nd premolar (r = -0.947) had the highest correlation to age when used alone, followed by the canine (r = -0.941).and 1st premolar (r =-0.914) The use of these teeth in combinations slightly increases the correlation. The standard errors of estimates (SEE) of the regression analyses for the individual tooth and teeth combinations were found to be ranged from ± 4.10 to 5.66 years. Standard errors of estimates and little difference in SEEs (± 4.10 to 5.66 years) between the various linear and multiple regression equations were suitable for forensic application among Egyptian population.[41]

Azevedo et al., 2014 developed a specific formula to estimate age in a Brazilian adult population and compared the original formula of Camerier to this Brazilian formula. He measured P/T area from canines and showed Brazilian formula was more accurate than using camerier formula. The highest mean errors were found in the periapical radiographs of the group aged 20-29 years and in the elderly groups (60-69 and 70-79 years). The best results were found in the groups aged 30-39, 40-49, and 50-59 years.[42]

Kumar et al., 2016 measured P/T ratio from second molars of 400 digitised IOPA and observed that there was high differences between estimated and chronological age of 12 years which was not in acceptable range. They also showed that gender have an effect on the morphological variable.[43]

Basoya et al., 2016 aimed to compare the accuracy of age prediction in three computer- aided softwares like Adobe Photoshop , Auto CAD and image J in periapical radiographs of maxillary central incisors taken using (RVG). There was no statistical significant difference in age calculated by Adobe Photoshop $p= 0.432$ and Auto CAD $p= 0.004$; though there was significant statistical difference in age calculated by Image J, $p<0.001$. It was concluded that P/T area ratios of maxillary central incisor are reliable for estimation of age and AutoCAD gave the most accurate results.[44]

KVAAL'S AND CAMERIER METHOD

Camerier et al., 2004 measured P/T area and Kvaal's measurements of length and width of P/T ratio in 100 maxillary right canine of Caucasian patients using digitized OPG of age between 18 to 72 years. He found out that P/T area correlated best with age ($R2 = 0.85$) followed by P/R width at mid-root level. Width is a better indicator of age than length was also reported. The variable p (P/R ratio) had very poor correlation with age and was therefore excluded from further statistical analysis. The full model explained 85.1 % of total variance, whereas the model, with the AR and c variables explained 84.9% (R2 = 0.849). The gender did not influence the regression model used to estimate chronological age. It can be concluded that the RIC technique can produce reliable and reproducible intra-observer measurements.[45]

Juneja et al., 2014 studied on Karnataka population using maxillary canines 200 OPG with age between 18-72 years. He measured variables p, r, a , b, c and AR in all the OPGs. All morphological variables were statistically analyzed and found that area AR (r = -0.974) and P/T width (b) yielded significantly to the fit. The ratios between length measurements correlated worst with age among them the variable 'r' (P value 0.140) in particular had poor correlation. They derived a regression formula Age = 87.305-480.455(AR) + 48.108 (b) with the 2 variables. This formula showed a SEE of 3.0186 years, 96% of total variance (R^2 = 0.960) with the median of the residuals (observed age minus predicted age) of 0.1614 years. There was no signifcant difference between chronological and estimated age for any of the age groups (P value > 0.05) thus signifying that the derived formula is appropriate for all the selected age groups.[46]

HISTOLOGICAL METHOD

Debta et al., 2010 stated that measuring amount of secondary dentin seems to be reliable and rapid method in forensic odontology. They evaluated the change in pulp width at the level of CEJ and its correlation to different age groups. Ground section of 100 extracted maxillary first premolars were done up to the midpulpal area in labiolingual plane. The correlation of different age group with reduction in ratio of score of pulp width (SPC) and score of tooth width (STC) at CEJ was found . All teeth were examined under stereomicroscope then SPC and STC were measured by

Leica Qwin software. Pearson correlation between SPC/STC ratio with different age group was found to be statistically significant.[47]

Bhaskar et al., 2013 aimed to measure the deposition of the secondary dentin deposition in dried ground sections of teeth and correlate this with the known age of the individual. They found that mean calculated age was slightly higher than actual age but this difference was not significant. They used 200 single and double rooted teeth. Cases for the study were divided into different age groups and maximum number of cases in the study belonged to age group of 25 to 30 years, next being 35 to 40 years.[48]

Metzger et al., 1980 has made a slight modification in the criteria for using ground sections for age estimation using Gustafson's method . Out of six parameters two of these changes, transparency of radicular dentin and secondary dentin, have the highest correlation with age. The evaluation of these parameters only from thin (0.25-mm) ground sections may lead to an artificially high "secondary dentin value." These artifacts may be caused by the attempt to include the whole pulp chamber and root canal in a 0.25-mm-thick ground section and by an accidental overgrinding of the apical area of the root, respectively. A modification of the data-collecting method is suggested to make possible the use of thick (1.0-mm) ground sections for the evaluation of most of the aging criteria, thereby eliminating the possible inaccuracies in the preparation and evaluation of the thin (0.25-mm) ground sections.[49]

Shrigiriwar et al., 2013 applied six parameters of Gustafson like attrition, periodontosis, secondary dentin deposition, root translucency, cementum apposition and root resorption in 80 cases, and then developed regression equations $y = 3.71x +$

16.03 from which age was estimated. The average age difference between known and estimated age in this study was found to be ± 4.43 years.[50]

Solheim 1992 estimated the amount of secondary dentin in a tooth according to various scoring systems, and the Pearson correlation coefficient with age has been found to be approximately 0.6. He used 1000 teeth, with exclusion of molars. The teeth were prepared according to the half tooth technique. In addition, the area of the coronal pulp and the widths of the root and pulp chamber were measured in a stereomicroscope at the CEJ and at three other defined points along the root. The Pearson correlation coefficient between age and secondary dentin varied in different types of teeth. Of the scoring systems, scores according to Johanson were most strongly correlated with age (r = 0.59 to 0.74). Correlation between age and the coronal pulp area varied from -0.47 to -0.72, and the range between age and ratio between pulp- and tooth width at the CEJ was from -0.46 to -0.77. Correlations between age and ratio between sum of pulp widths and the sum of tooth widths for all four such measurements ranged from -0.58 to -0.81. Multiple regression analyses showed that by combining several types of measurements, the correlation with age was increased. A tendency was also observed towards reduced speed of secondary dentin formation in the elderly and in women.[51]

Bajpai et al., 2016 applied Gustafson’s formula to 228 teeth. The results showed strong correlation (0.92; p<0.001) between chronological and estimated age by using both formulae. We found the mean error of ± 5.47 by using newly derived and formula and ± 6.35 by Gustafson's formula. As a result of our study it was found that newly derived formula provides better results in comparison with Gustafson's formula in Indian population. A positive correlation between age and total scores of physiological changes also revealed.[52]

Singh et al., 2014 aimed to evaluate the results and to check the reliability of modified Gustafson's method for determing age. Degree of attrition, root translucency, secondary dentin deposition, cementum apposition, and root resorption were measured. A linear regression formula was obtained using different statistical equations in a sample of 70 patients. The mean sage difference was this ±2.64 years and was statistically significant.[5]

CONE BEAM COMPUTED TOMOGRAPHY METHOD

Star et al., 2010 determined to evaluate a human dental age estimation method based on the ratio between the volume of the pulp and the volume of its corresponding tooth calculated on clinically taken cone beam computed tomography (CBCT) images from monoradicular teeth. On the 3D images of 111 clinically obtained CBCT images of 57 female and 54 male patients ranging in age between 10 and 65 years the pulp–tooth volume ratio of 64 incisors, 32 canines, and 15 premolars was calculated with Simplant Pro software. A linear regression model was fit with age as dependent variable and ratio as predictor, allowing for interactions of specific gender or tooth type. The obtained pulp–tooth volume ratios were the strongest related to age on incisors.[53]

Maret et al., 2011 have stated that using CBCT , quantitative volumetric measurement of various parts of each tooth can be useful to determine significant variables for dental age estimation in living subjects and multiple regression analysis requires the constitution of a larger sample sizes which may demonstrate that CBCT data can be helpful to study other aspects of dental morphology in greater depth, especially dental growth. He also included in this hypothesis that CBCT needs integration with a larger network system. Quantitative measurements include the volume of each component of all teeth, especially enamel, dentin, pulp cavity, crown and root, and ratios of these different parts. Quantitative measurements of the alveolar bone and surrounding cortical bone could also be included in the analysis as, in combination with other variables, these measurements could contribute interesting information that would help to estimate the age of a living subject. The accuracy of age estimation equations for each tooth would be assessed using the coefficient of determination (R2).[54]

Jagannathan et al., 2011 stated that computed tomography can be used to measure P/T ratio volumes and is a useful indicator of age. Volumetric reconstruction of scanned images of mandibular canines from 140 individuals (aged 10 - 70 years) was used and he tested his method in 48 samples and showed that mean absolute errors of 8.54 years in Indian samples.[55]

Porto et al., 2015 studied the the usefulness of some morphometric parameters of the teeth in 5 different age groups through images of Cone Beam CT. 118 upper central incisors clinically acquired of 60 women and 58 men aged between 22 and 70 years were selected. The pulp cavity volume and the pulp cavity/tooth volume ratio showed significant differences between age groups ($p < 0.001$). Linear regression analysis showed a coefficient of determination of 0.21 which suggests that there is a weak correlation between the pulp cavity/tooth volume ratio and age.[56]

Pinchi et al., 2015 used a total of 148 CBCTs for assessing the correlation of P/T ratio with age. The outcome of the study states that narrowing of the pulp is the reliable indicator of age of adults and CBCT is an easy and conservative approach that allows accurate calculation of tooth volumes. This method also shows the inter – examiner agreement of ICC 0.99 and stated that is is reproducible. Highest accuracy was seen between age group 30 to 59 years.[57]

Penaloza et al., 2016 aimed at applying Kvaal's et al., method on CBCT images from a malaysian population.. Sample consisted of 55 males and 46 females, with a median age of 31 years. Sagittal and coronal views of the teeth were obtained, Kvaal's P/T area ratio was calculated in both buccolingual and mesiodistal aspects for each tooth. The SEE of ± 10.58 years from a combination of measurements. Mesiodistal measurements of central incisor at CEJ showed SEE of ± 12.84 years. He concluded that the original technique of using radiographs was more accurate than using CBCT and also it is time consuming.[58]

Arpita Rai et al., 2016 estimated age based on P/T ratio of the maxillary canines and measured in three planes obtained from CBCT image data. He included sixty subjects aged 20–85 years in the study and assessed each tooth for mid-sagittal section ,mid-coronal section and three axial sections cementoenamel junction (CEJ), one-fourth root level from CEJ, and mid-root. He concluded that PTR in axial plane at CEJ had significant age correlation ($r = 0.32$; $P < 0.05$) and this is probably because of clearer demarcation of P/T outline at this level.[59]

Penaloza et al., 2016 aimed to test the variability of the volume measurements using three different segmentation methods in pulp volume reconstruction with a sample of 21 dental CBCT,s from upper canine and first molars. The reported mean absolute error using automatic segmentation of the first molar's pulp chamber is 6.26 years . The cone shape geometric approach of P/T has a standard error of estimation of ± 11.45 years and manual segmentation of P/T, has a prediction interval of ± 12 years it is possible to observe that the use of CBCT and dental structures volume reconstruction, do not improve the final results for adult age estimation when compared to kvaal's method and camerier method in radiographs.[60]

Alsoleihat et al., 2017 concluded that MD pulp-to-tooth ratio taken at the neck of lower molar is not a reliable predictor of chronological age in adults, possibly due to the large variation in the timing of development. The coefficients of determination (R squared= 13.0 %) for the regression equation is very low and means that only 13 % of the variation image can be explained by the MD pulp-to-tooth ratio taken at the neck of the tooth.[61]

Biuki et al., 2017 evaluated the correlation between chronological age and pulp to tooth volume ratios in anterior teeth with the use of the CBCT technique and to determine a regression model to estimate human age. They found out that pulp to tooth volume ratios had a stronger correlation in males than females and also of all the anterior teeth they found out that maxillary central incisor and canines had a better correlation. The results of the present study showed that it is advisable to use the mean of all the ratios of anterior teeth in forensics to estimate age.[62]

AGE ESTIMATION USING PULP AREA

Ravindra et al., 2015 analysed total pulp area in maxillary central incisor involving 308 subjects of both genders with the age range of 9-68 years. He concluded that the right maxillary central males (32.50, 32.87 mm2) had more pulp area when compared with females (28.82, 30.05 mm). The mean pulp size on the right size (31.537 ± 10.173) is more than that of the left side (30.757 ± 9.685) and was found to be significant (t = -2.549, P = 0.011). Pearson correlation 'r' for males was -0.588 which was significant for apical, middle, coronal and total area with 'P' value of 0.01. Moreover same was seen with females (r = -0.452).[63]

Indira et al., 2015 showed that a gradual reduction in pulp size was observed with respect to the total pulp length and cervical pulp width with an increase in age and this showed a significant correlation with the chronological age. The correlation between total pulp length and age was r value was -0.241 at P = 0.016 and cervical pulp width with age was -0.392 at P < 0.0001. He analysed in Intraoral periapical radiographs taken using paralleling cone technique involving 100 subjects inclusive of both the genders aged between 16 and 50 years.[64]

AGE ESTIMATION USING COMBINATION OF METHODS

Ajmal et al., 2001 determined age using three methods namely, Johanson method, Kashyap and KoteswarRao method and Average stage of attrition method (ASA). They included 100 patients from the age range of 21-60 years. ASA method was found to be the best method. When range of errors was compared ASA method is found to be more reliable than kashyap method which showed incorrect results.[65]

Ubelaker et al., 2008 estimated adult age using three different methods such as Bang and Ramm, Lamendin and Prince and Ubelaker. They used 100 intact single rooted teeth and observed root translucency, root length and the extent of periodontosis. Of the three methods the prince and Ubelaker method offered most accurate results. A new regression equation, specifically for Peruvian samples has provided most accurate results.[66]

Dumpala et al., 2013 aimed to compare the age estimated using OPGs and hand wrist radiographs with the chronological age of the patients. Dental age was calculated using P/T area ratio of right mandibular canine in digital orthopantamographs (OPGs) in 30 patients and had a better correlation with chronological age when compared with the skeletal age using Bjork Grave and Brown method. Comparision between chronological and dental age indicates that there was no significant differance (0.65) and with skeletal age there was a significant difference (0.04).[67]

Khorate et al., 2013 estimated age based on tooth development. The panoramic radiographs of 500 healthy Goan, Indian children (250 boys and 250 girls) aged between 4 and 22.1 years were selected. Modified Demirjian's method (1973/2004).Acharya AB formula (2011), DrAjit D. Dinkar (1984) regression equation, Foti and coworkers (2003) formula (clinical and radiological) were applied for estimation of age. The result of our study has shown that DrAjit D. Dinkar method is more accurate followed by Acharya Indian-specific formula.[68]

Shrestha et al., 2014 Age estimation in this study was done by two established radiological methods like (Tooth Coronal index (TCI) and Kvaal's method) and two histological techniques (Kashyaps and Koteswara modifcation of Gustafson's method and secondary dentine method). TCI method was found to be the best radiologic and secondary dentin estimation was found to be the best histological techniques. Morphological parameters such as attrition, histological parameters such as secondary dentin, root transparency and cementum apposition were assessed from ground sections. In the Kvaals method only the pulp width at the CEJ parameter was found to be significant with a p value of (0.023).[69]

Bajpai et al., 2015 evaluated age using three different factors like Secondary dentin deposition, root translucency, and cementum apposition in a combination. He used 95 extracted teeth and grinded the teeth until the thickness of 1-mm, on this thickness root translucency was noted, teeth were further undergone grinding up to 0.25 mm thickness afterward they were viewed under microscope for secondary dentin deposition and cementum apposition. By using the combination of these three factors for age estimation they got a mean error of ±4.51.[70]

Shruthi et al., 2015 compared and evaluated the accuracy of age estimation using translucent dentin and cemental annulations. The overall mean difference between chronological age and estimated age using translucent dentin in 150 teeth was 5.6 with a standard deviation (SD) ± 4.2 years. The overall mean difference between chronological age and estimated age using cemental annulations in 150 teeth was 2 with a SD ± 5.6 years. It was found that cemental annulations (r = 0.97, S.E = 4) method was marginally better than translucent dentin (r = 0.98, S.E = 3.6) as the mean error obtained was comparatively less than that of the translucent dentin method.[71]

Supreet Jain et al., 2017 aimed to evaluate reliability and accuracy of dental age assessment through two different methods for adults i.e. tooth coronal index (TCI) and P/T ratio the pulp chamber crown root trunk height ratios (PCTHR) using digital panoramic radiographs. PCTHR showed slightly higher negative correlation and has been proved as a better tool for age estimation than TCI. Negative linear correlation was observed between the PCTRH and the chronological age of mandibular first molar (r = 0.921) and second molar (r = 0.901). Correlation of TCI with age was found to be higher for mandibular first molar.[72]

MATERIALS AND METHODS

SAMPLE SOURCE

Specimens for the study were collected from Department of Oral and Maxillofacial Surgery, Vivekananda Dental College for Women, Tiruchengode.

INCLUSION CRITERIA

1. Age range 20 – 70 years
2. Mandibular premolars with fully formed roots.
3. Teeth without any trauma.

EXCLUSION CRITERIA

1. Tooth with any pathology, such as caries or periodontitis or periapical lesions, which would alter the surface area of the tooth.
2. Teeth with developmental dental anomalies.
3. Teeth with any prosthetic fittings or restoration.
4. Teeth with extreme root curvature at mid root level.
5. Fractured teeth

METHODOLOGY

The total sample of 120 mandibular premolars was collected and were divided into 5 groups. First group included teeth samples from the patients in the age group of twenty to thirty years, thirty one to forty as second group, forty one to fifty as third group, fifty one to sixty as fourth group, sixty one to seventy as fifth group respectively.

Two methods namely radiographic and hemisectioning, were used to estimate age using two parameter namely P/T area ratio and P/T width ratio at CEJ.

Radiographic method

Digital Intra Oral Periapical radiographs of extracted mandibular premolars were taken using paralleling radiographic technique. The base of the plastic ring was fixed on the wooden block to stabilize the holder (rinn XCP) vertically. The sensor was stabilised using a piece of wax. Teeth were placed labiolingually such that the distal surface lies on the radiographic sensor. Digital intraoral periapical radiographs (AMS X- Ray machine) were acquired using Sirona RVG machine with the exposure of 65 KVp and 8 mA for 0.2 s. Sirona software was used to record the images. The images were stored as high resolution JPEG images in the desktop monitor named with the same sample numbers. These images were then stored separately for further analysis.

Hemisectioning method

After recording the radiographic images, midline of the teeth were marked using a marker. A line was drawn from the cusp tip to the root tip on the labial and lingual surface to mark the midline. Then the distal surface of the teeth was stuck to the wooden block using cyanoacrylate. The samples were grounded till the point marked using the cast trimmer. Then fine grinding was done using the wheel stone attached to the lathe. The photos of all the samples were taken using the stereomicroscope under 6.5x magnification. Reflected light was used to record the surface details.

Measurement procedure

Radiographic and hemisectioned teeth images were imported to image analysis pro premier software version 9.1. Point to point tool was used to draw a line to measure the width of the tooth and pulp at the level of CEJ. To measure the area twenty points were marked on the periphery of tooth surface and ten points on the outline of the pulp although few points were added in some cases for accurate measurements using the polygonal tool. Both two parameters were measured for each sample and data was transferred to Microsoft office 2010 Excel spread sheet (Microsoft Corp., Redmond, WA, USA) and Ratio's were calculated. The results obtained were submitted for statistical study. Intra observer reliability was checked by cohen's Kappa statistics in randomly selected 30 samples from after a period of 30 days. The Kappa Co-efficient value for intra examiner variability was 0.84 and this confirms the degree of conformity in judgements made at two point of time is reliable.

STATISTICAL ANALYSIS

The data was collected and entered in MS office excel spread sheet and subjected to statistical analysis. Statistical analysis was performed using statistical package for social science (SPSS) software version16, 2010 program. To test for normality of the data distribution Kolmogorov-Smirnov test and Shapiro-Wilk test was performed.

Both descriptive and inferential statistics was performed.

Descriptive statistics

Frequency, Mean, standard deviation, confidence interval and ratio was performed for all the parameters.

Inferential statistics

1. Cohen's kappa statistics (κ) was used to check for the intra observer reliability.
2. Pearson correlation coefficients were used to find out the correlation.
3. Linear regression analysis was performed among the measured parameters to generate regression equation. A stepwise linear regression procedure was followed to take in to consideration of only the significant parameters that can influence the age.

   Linear regression models were developed by using the equation

   Y = a + bX

   Y = Dependent variable – Chronological age.

   X = Independent variable – P/T area ratio and P/T ratio at CEJ.

   b = The slope of the line.

   a = Is the y intercept.
4. Students T test was performed to compare the estimated age and chronological age.
5. Cohen’s kappa statistics was done to find out the reliability between chronological age and estimated age in each method.

RESULTS

The aim of the present study was to estimate and compare the age using digital intraoral periapical radiographs and longitudinal hemisection of tooth. This study included 120 mandibular premolars with equal distribution of 24 samples in all age groups ranging from 20 to 70 years and the mean age was found to be 45.07 years. The mean age and standard deviation for each group is shown in table 1.

Table 1: Age distribution of the study samples.

S.No	Age groups	Number of samples	Mean ± standard deviation
1	20-30	24	24.0 ± 3.01
2	31-40	24	33.95±2.35
3	41-50	24	46.16± 2.65
4	51-60	24	56.66±2.92
5	61 -70	24	64.79±2.07

Table 2: Pearson correlation ratio between chronological age and predictor variables.

Methods	Variables	Correlation coefficient
Radiological Method	P/T area ratio	-0.78
	P/T width ratio at CEJ	-0.80
Hemisectioning Method	P/T area ratio	-0.76
	P/T width ratio at CEJ	-0.77

Pearson correlation coefficient was used to find out the correlation. On comparing the correlation coefficient between the variables, the P/T width ratio at CEJ have shown higher correlation than P/T area ratio in both the methods. On comparing the correlation coefficient between the methods. Radiological method have shown higher correlation than hemisectioning method.

After finding the correlation coefficients for each predictor variable, stepwise linear regression analysis was done to derive the equation for each predictor variable separately and combining both the variables in each method.

Table 3: Stepwise regression analysis for radiological method using P/T area ratio as independent variable.

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig	95% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	84.127	2.949		28.531	.000	78.287	89.966
P/T area ratio	-262.513	18.955	-0.787	-3.849	.000	-300.050	-224.977

A simple linear regression was calculated to predict chronological age based on P/T area ratio. A significant regression equation was found (F(1, 118) = 191.796, p ,< 0.00), with an R2 of 0.619. The regression equation is

Age = 84.12 -262.513 (P/T area ratio)

Graph 1: Plots of observed age against the predicted age using the regression model for P/T area ratio.

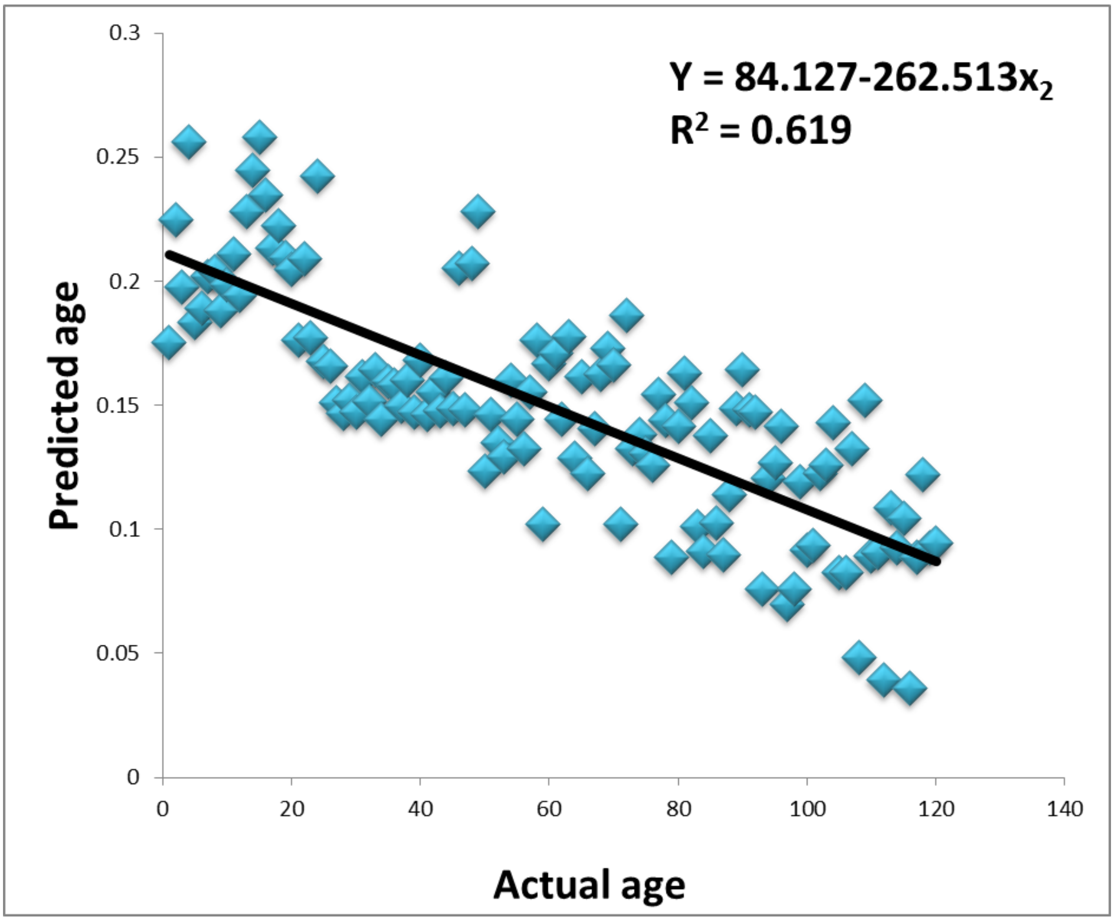

Table 4: Stepwise regression analysis for radiological method using P/T width ratio at CEJ as independent variable.

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig	95% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	95.001	3.543		26.814	.000	87.985	102.017
P/T area ratio	-165.817	11.432	-.800	-14.504	.000	-188.456	-143.178

A simple linear regression was calculated to predict chronological age based on P/T area ratio. A significant regression equation was found (f (1, 118) = 191.796, p <0.00, with an R^2 of 0.641.The regression equation is

Age = 95.01-165.81(P/T width ratio at CEJ)

Graph 2: Plots of observed age against the predicted age using the regression model for P/T width ratio at CEJ.

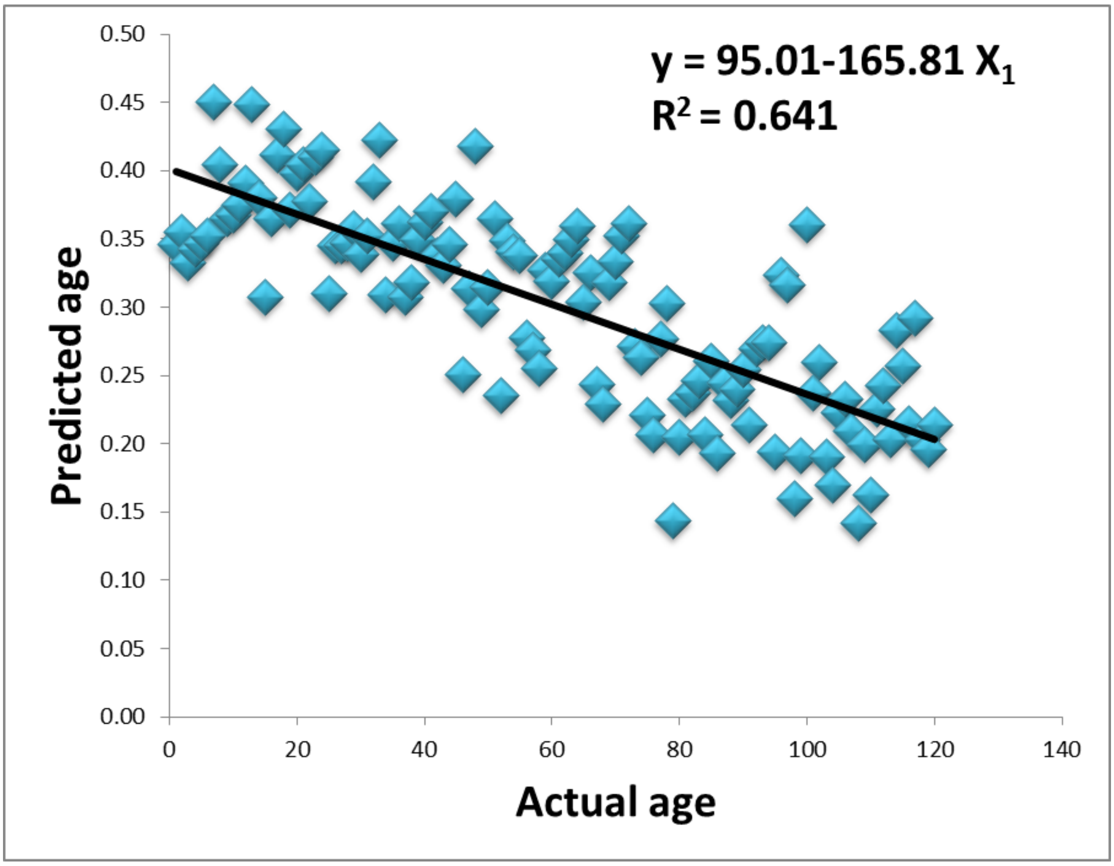

Table 5: Stepwise regression analysis for radiological method using both variables.

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig	95% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	99.207	2.935		33.804	.000	93.394	105.019
P/T area ratio	-154.015	19.7251	-.462	-7.808	.000	-193.079	-114.951
P/T width ratio at CEJ	-103.668	2.248	-.500	-8.464	.000	-127.924	-79.412

A simple linear regression was calculated to predict chronological age based on P/T area ratio and P/T width ratio. A significant regression equation was found (f (1, 118) = 191.796, (p 0.00 <), with an R^2 0.764. The regression equation is

AGE = 99.20 - 154.015 (P/T area ratio) -103.668 (P/T width ratio at CEJ)

Table 6: Stepwise regression analysis for hemisectioning method using P/T area ratio as independent variable.

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig	95% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	77.862	2.728		28.541	.000	72.459	83.264
P/T area ratio	-227.747	17.916	-.760	-12.712	.000	-263.226	-192.269

A simple linear regression was calculated to predict chronological age based on P/T area ratio. A significant regression equation was found (f (1, 118) = 161.593, ($p < 0.00$), with an R^2 of 0.578. The regression equation is

Age = 77.86-227.74 (P/T area ratio)

Graph 3: Plots of observed age against the predicted age using the regression model for P/T area ratio.

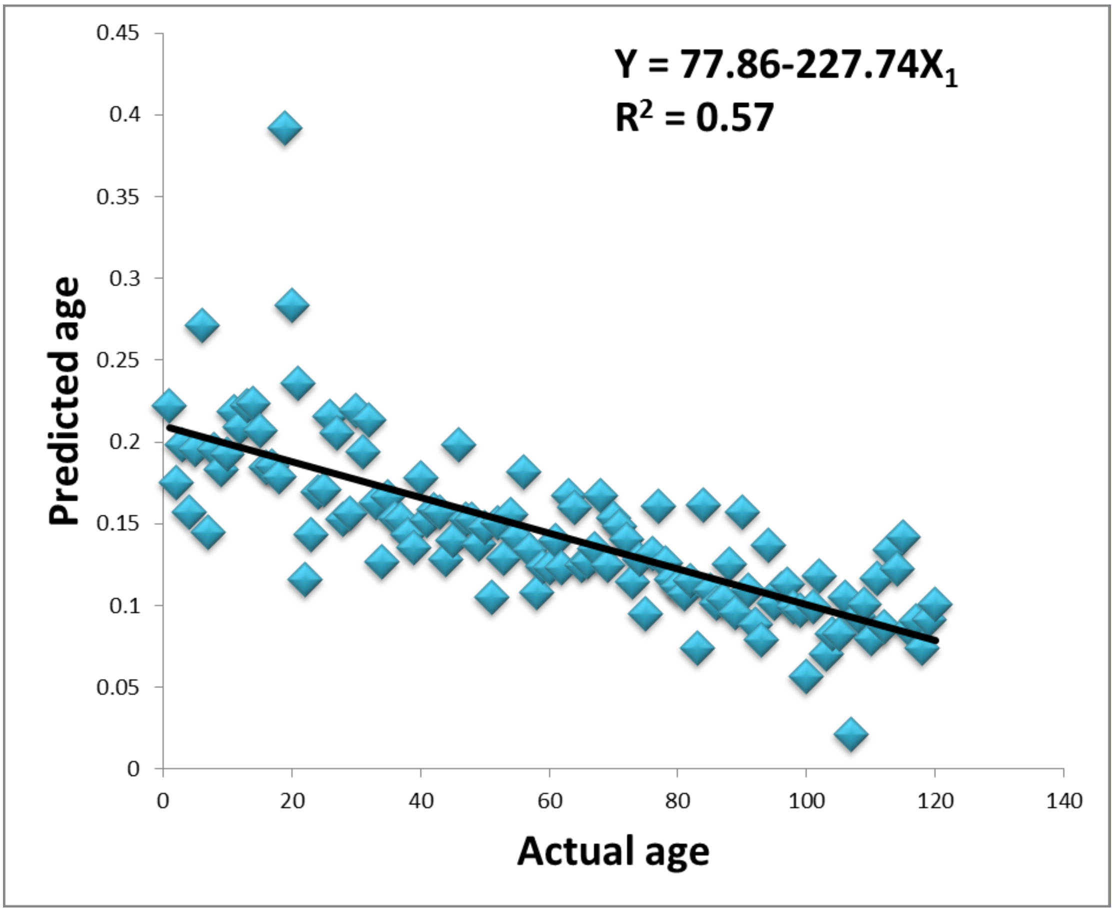

Table 7: Stepwise regression analysis for hemisectioning method using P/T width ratio at CEJ as independent variable.

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig	95% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	92.071	3.612		25.493	.000	84.919	99.223
P/T area ratio	-156.594	11.689	-.777	-13.396	.000	-179.742	-133.446

A simple linear regression was calculated to predict chronological age based on P/T area ratio. A significant regression equation was found (f (1, 118) = 179.461, (p <0.00), with an R^2 of 0.603. The regression equation is

Age = 92.07-156.55 (P/T width ratio at CEJ)

Graph 4: Plots of observed age against the predicted age using the regression model for P/T width ratio at CEJ

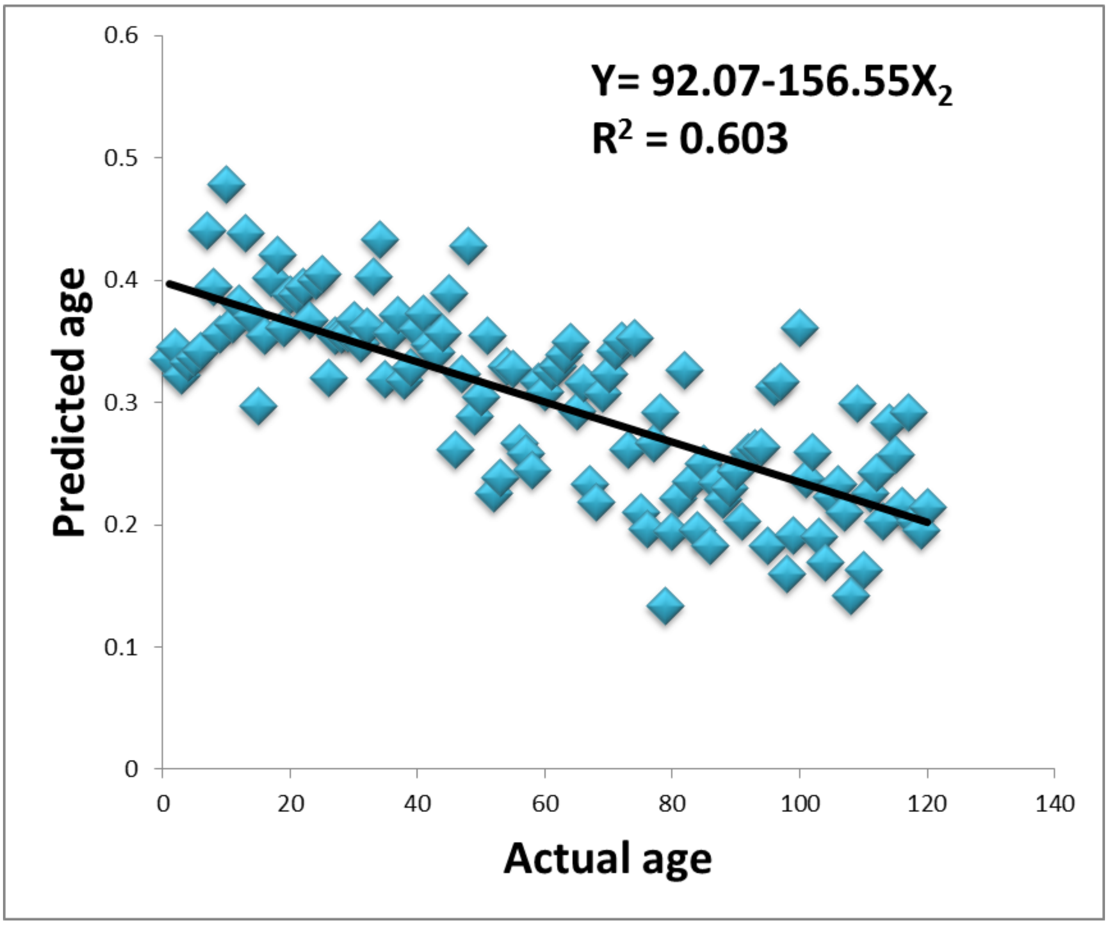

Table 8: Stepwise regression analysis for hemisectioning method using both variables

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig	95% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	96.005	2.913		32.956	.000	90.236	101.774
P/T area ratio	-103.210	11.347	-.512	-9.096	.000	-9.096	-107.062
P/T width ratio at CEJ	-139.551	16.860	-.466	-0.466	.000	-8.277	-79.852

A stepwise linear regression was calculated to predict chronological age based on P/T area ratio and P/T width ratio at CEJ. A significant regression equation was found (f (2,117) = 176.29. (p <0.00), with an R^2 of 0.751. The regression equation is

Age = 96.005 - 103.210 (P/T area ratio) – 139.551 (P/T width ratio at CEJ)

Table 9: Regression analysis equation with coefficient of determination (R^2) and standard error of estimate (SEE in years).

Methods	Regression equation	R^2	SEE (years)
RADIOLOGICAL METHOD			
P/T area ratio	Age = 84.12-262.51(P/T area ratio)	0.619	9.35
P/T ratio at CEJ	Age = 95.01-165.81 (P/T width ratio at CEJ)	0.641	9.08
BOTH	Age = 99.20-154.015 (P/T area ratio) - 103.668(P/T width ratio at CEJ)	0.764	7.40
HISTOLOGICAL METHOD			
P/T area ratio	Age = 77.86-227.74 (P/T area ratio)	0.578	9.84
P/T ratio at CEJ	Age= 92.07-156.55 (P/T width ratio at CEJ)	0.603	9.54
BOTH	Age = 96.005-140.490 (P/T area ratio) - 102.34 (P/T width ratio CEJ)	0.751	7.59

Coefficient of determination (R^2) was found to be strongest for radiological method compared to histological method. Standard error of estimate (SEE) is higher for radiological method than histological method.

The estimated age was calculated using the derived equations of those respective variables in each method. To find out the statistically significant difference between the estimated age using the variables in the same group and across the groups students T test was performed and shown in table 10 and table 11.

Table 10: Comparision done between two variables in each methods using unpaired students T test

Methods	Mean ± S.D	T value	P value
RADIOLOGICAL METHOD			
P/T area ratio	45.041±11.87	.000	1.000
P/T width ratio at CEJ	45.041±12.08		
HEMISECTIONING METHOD			
P/T area ratio	45.117±11.46	.000	1.000
P/T width ratio at CEJ	45.117±11.71		

Students T test showed that there was no statistically significant difference between the estimated age by the two variables in each method.

Table 11: Comparision done between the two methods for each variable using unpaired

Predictors	Methods	Mean ± S.D	T value	P value
P/T area ratio	**RADIOLOGICAL**	45.041±11.87	-0.050	0.960
	HEMISECTIONING	45.117±11.46		
P/T width ratio at CEJ	**RADIOLOGICAL**	45.041±12.08	-0.049	0.961
	HEMISECTIONING	45.117±11.71		

Students T test showed that there was no statistically significant difference between the estimated age in P/T area ratio (P = 0.960) among the two methods. Similarly there was no statistically significant difference between the estimated age in P/T width ratio at CEJ (0.961) among the two methods.

Table 12: Estimation of age across different age groups in radiological method.

Groups	P/T area ratio	P/T width ratio at CEJ	Both variables
Group I	28.96 ± 6.4	31.80 ± 6.0	27.33 ± 5.05
Group II	33.66 ± 4.2	37.60 ± 6.0	38.84 ± 4.50
Group III	46.16 ± 7.4	42.94 ± 6.8	43.33 ± 5.7
Group IV	56.66 ± 6.5	42.56 ± 6.5	41.89 ± 6.42
Group V	64.70 ± 7.8	57.81 ± 8.5	61.21 ± 6.5

The estimated age in group II using P/T area had minimum SD of ± 4.2 whereas group I and group II had an equal SD of ± 6.0 in P/T width ratio at CEJ. On combining both the variables group II showed a SD of ± 4.5.

Table 13: Estimation of age across different age groups in hemisectioning method.

Groups	P/t area ratio	P/T width ratio at CEJ	Both
Group I	31.33 ± 12.55	33.30 ± 6.53	28.89 ± 8.2
Group II	40.06 ± 6.28	36.12 ± 5.90	36.11 ± 4.5
Group III	46.10 ± 4.3	45.15 ± 6.69	45.75 ± 4.9
Group IV	48.88 ± 5.2	44.18 ± 7.84	46.83 ± 6.2
Group V	56.38 ± 5.7	56.29 ± 8.35	59.37 ± 6.8

The estimated age in group III using P/T area had minimum SD of ± 4.3 whereas group II had an equal SD of ± 5.9 in P/T width ratio at CEJ. On combining both the variables group II showed a SD of ± 4.5.

Table 14 : Cohen's kappa coefficient value

Methods	Coefficient value
Radiological	0.928
Hemisectioning	0.929

The reliability of the radiological and hemisectioning in estimating the age was performed using cohen's kappa statistics. The value obtained by radiological method was 0.928 and by hemisectioning method was 0.928 and thus the reliability of both the methods are almost similar from the obtained values.

DISCUSSION

Age estimation plays an important role in Forensic Dentistry for identification of dead individuals and to clarify criminal and civil liability issues concerned with live persons.[73] Establishing a biological profile for the victim is the responsibility of the forensic practitioner which acts as the vital evidence for identifying the unknown individuals.[4]

In this study, the proposed morphometric method for measuring pulp tooth ratio was done using radiological method and hemisectioning method. The results were expressed for both the variables (P/Tarea ratio and P/T width ratio at CEJ) individually for both the methods, aiming at comparing the accuracy of prediction by the developed regression models for these methods. We intended to arrive at a correlation between the secondary dentin deposition and age estimation in forensic dentistry when teeth were the only source available to identify the age of the unknown person.

The studies by Philippas and Applebaum, reported that pattern and rate of secondary dentin deposition were able to relate to the chronological age of the person.[74] The secondary dentin deposition changes with age progression has been demonstrated by Gustafson’s, followed by Johanson, Maple and Metzger.[75] Some authors on the contrary argued that secondary dentin changes have not proven useful as a indicator to estimate age of the individual.

Kvaal and Solheim proposed a new method for measuring the secondary dentin deposition by combining morphometric analysis and radiological methods. They have reported that the secondary dentine deposition were able to demonstrate a correlation with chronological age and could be used for age estimation. They used linear measurements like both vertical and horizontal dimensions for measuring the pulp and teeth proportions in intraoral periapical radiographs.[76] These were also tested in panoramic radiographs and RVG by many authors.[14,16,17,23,26] All the studies so far mentioned that width measurements have a superior correlation with chronological age than length measurements. Similar findings were also stated by few other authors. [8,18,19,24] Later Camerier et al., in 2004 also indirectly measured the secondary dentin deposition but unlike Kvaal, calculated the surface area of pulp and tooth by tracing the outline of the same and hence found that this also showed nice correlation with chronological age.[15-18]

Since the aim of the present study was to find an accurate method for the age estimation, the best parameters which has been proved to be accurate predictors in the previous studies has been selected in this study. In order to have a standardized methodology as in accordance with various studies, the present study was designed considering the participants above 20 years. Since gender has been proven, not a contributing or biasing factor in the determination of secondary dentin deposition, it has not been considered in this study.[27]

Paralleling technique was used as it reduces the technical and angulation errors and also have better reproducibility.[20,64] The radiographic image capturing was done using RVG which has got advantages over conventional radiographs like enhanced boundary distinction which helps in precise marking of the boundaries of pulp and tooth space. The higher image quality of this technique will probably narrow the age estimation error and helps in improving the prediction. Mandibular premolars were considered in the study as few authors have mentioned it to be a reliable teeth for age estimation.[18,35,37,39] This teeth was easily available as premolars were mostly opted for orthodontic extraction.

The two parameters selected for this study are P/T area ratio and P/T width ratio at CEJ. Numerous authors have proven these parameters to be the better predictor than others hence this was considered in this present study[15,59,69] Correlation of these two parameters with age was found to be significant. Hence these two parameters were included in regression model derivation. As stated by various author, the quality of secondary dentin deposition is influenced by factors like race, ethnicity, diet and lifestyle. Hence there is always a need for population specific equations.[12,14,16,17] We intended to derive a separate equation for both the method which could help in appropriate comparision with outcome of prediction model.

The main finding of this study is that there is not much difference in prediction with these two methods. We attempted to compare a new hemisectioning method which offers a direct visualizations for observing the pulp tooth volume width that of the older method like radiological method. We have found out that hemisectioning method offers the same outcome as that of radiological method, and it is not superior than the older methods found in the literature.

When the pulp tooth area ratio parameter was considered, it showed no difference between the two methods. P/T width ratio at CEJ also showed a similar result between the methods. When both the parameters were compared with in the same method, it showed no significant difference in estimating age.

Coefficient of determination R^2 in regression model explains about the proportion of the variance in the dependent variable (age) that is predictable from the independent variable. Standard error of estimate states about the accuracy of the prediction made with the regression equation. Smaller the error better is the accuracy of prediction.The results obtained by the radiographic method in the present study showed a R^2 0.76% variance and SEE of 7.4 years.

According to the few radiological studies, Camerier et al., the regression equation with variables like P/T area ratio has shown 84.9% variance and SEE of 5.35 years whereas Saxena has shown 99.7% variance with SEE of 0.60 years with selected variables. Juneja et al.,[46] combined two parameters like area and width, have got a S.E.E of 3.01 wheareas Joseph et al.,[39] using mandibular premolars and had area as only parameter reached upto 5.38 years of error in prediction. Babshet et al.,[35] on comparing the three mandibular teeth had found lateral incisor to be best predictor and equation with all three teeth showed a error range of 12.1 to 13.1 years. On comparing the studies in literature for radiological method, we have been met those range of errors showed.

When only one variable was included in the study the error was more but when two variables were included the error estimate came down. Previous studies had shown comparable results which had demonstrated that when the number of parameters and teeth were increased there was a surge inaccuracy of prediction.[35] This was also proved in our study.

Estimation of the P/T area ratio from the direct hemisection gave an error of 7.59 years and R^2 value of 0.751. Gustafson[75] who have first studied various parameters in age estimation using the histological ground section has given an error of 12.78 years and a R^2 value of 0.963. The higher accuracy of the present study may be due to the better preservation of tooth structure with hemisectioning than the ground sectioning of the tooth.

Debta et al.,[47] has obtained a correlation of 0.99 on estimating the secondary dentin at the level of CEJ in hemisectioned maxillary first premolars, whereas we had only 0.76 with mandibular premolars. This decrease in correlation may be because of difference in the teeth used for the study.

Few other parameters used in histological methods like cementum annulations and dentin translucency[70] have shown a error range of somewhat higher than the present study. As this method shows superior results we could consider using this method over the difficult procedure of grinding the teeth.

The latest technology of using CBCT for constructing pulp/tooth volume has shown a results of similar range of this study but has a lot of technical difficulties and is not cost effective. The presence of artefacts increases the SEE even in the CBCT, resulting in lesser accuracy in calculating the pulp tooth ratio. The apical third of the pulpal area was better observed in intra oral periapical radiographs than the CBCT. These difficulties in CBCT validates the use of radiographic method for rapid measurements. CBCT study by Jaganathan et al., showing an error estimate 8.58 years was comparable with the present study which showed an error estimate of 7.40 years.[54,58]

The limitations of the present study are, though the teeth with abnormal curvature beyond middle third of the root were excluded, curvatures of the apical third couldn't be avoided which would have culminated in reduced accuracy in pulp chamber measurement in the apical third, where there can be loss of structure during sectioning. The chronological age recorded from the case sheet rather than calculating it from the date of birth could have resulted in similarity of the methods. The structure loss during hemisectioning of tooth might have been another reason for showing no difference in age prediction. Since the color change in posterior teeth is not evident as in anterior teeth, the inclusion of non vital posterior teethcould give discrepancy in accuracy as the process of secondary dentin deposition is stopped. This hemisectioning method employs extracted teeth as it could not be used for living individuals.

Presently, there is no evidence that the process of secondary dentin formation occurs in a linear manner, or that every age group needs the same time span to present itself with a defined amount of secondary dentin. It is greatly influenced by the masticatory forces encountered by the specific teeth. The bite force magnitude, size of masticatory muscles and craniofacial morphology also greatly contribute to the variation in each person. Population differences may be attributable to differences in tooth dimensions which are indirect measurement of secondary dentin, even if the amount of secondary dentin deposition is identical.

Although linear regression is widely used in forensics to provide the estimate of the measurement, for instance the age at death or the living stature, it should be kept in mind that human growth is not a linear process. Keeping in mind about the biological variation and uncertainity associated with it there is always a need for better method for age estimation.

Currently we have more accurate age estimation methods like aspartic acid racemization in dentin or tooth enamel and radiocarbon dating of tooth enamel. Both have shown to give high precision in age estimation like ±3 to ± 1-2 years respectively. The improvement of this method could be done by combining other parameters of adult age estimation and inclusion of other teeth for deriving the regression equation.

SUMMARY

Age estimation is an important arena in forensic odontology. The present study was carried out to estimate and compare the age using digital intraoral periapical radiographs and longitudinal hemisection of the tooth. A sample of 120 extracted mandibular premolars were collected and analysed by radiological method, followed by hemisectioning method. Secondary dentin deposition was indirectly estimated using P/T area ratioand P/T width ratio at CEJ which decreases as age progress. Linear regression analysis was used for deriving the equation to estimate the age for each method. The reliability of both the methods was found to be statistically similar. However it was more reliable in the age group of 31- 40 years in both the methods. P/T area ratio was found to be better predictor in age group of 31- 40 years in radiographic method and 41-50 years in hemisectioning method. Hemisectioning method was found to least accurate in predicting age for age group of 20-30 years. Addition of more predictors like dentin translucency, might considerably improve the precision in age estimation.

CONCLUSION

The forensic judiciary has strict requirements for exact age estimation. Both radiographic and hemisectioning method have not shown any statistically significant differences in this present study. Since there are only limited methods available for adult age estimation using extracted teeth, a combination of various methods are required for accurate age estimation. Increasing the number of parameters which would involve clinical parameter like attrition, radiological parameter like secondary dentin deposition and histological parameters like cementum annulations, dentin transluceny along with contribution of additional number of teeth can be a beneficiary aid in standardizing the precision of age estimation procedure in near future.

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Annexure I – Radiological Method

S.No	AGE	A1	A2	A3	A4	A2/A1	A4/A3
1	21	290848	54955	363.77	128	0.1889	0.3519
2	34	145789	21456	273.81	95.72	0.1472	0.3496
3	42	136196	31039	239.84	71.58	0.2279	0.2985
4	43	125618	16963	234.80	55.34	0.1350	0.2357
5	35	114561	18451	351.81	121.81	0.1611	0.3462
6	55	146294	13012	237.00	34.1	0.0889	0.1439
7	50	115431	19193	222.33	74.1	0.1663	0.3333
8	33	110234	17456	341.23	123.13	0.1584	0.3608
9	35	345161	50924	349.81	115.75	0.1475	0.3309
10	69	143029	13488	229.29	49.04	0.0943	0.2139
11	65	159668	14441	268.38	60.51	0.0904	0.2255
12	31	102584	17188	220.30	68.19	0.1676	0.3095
13	46	115007	20251	247.39	63.11	0.1761	0.2551
14	21	293894	65974	365.49	129.81	0.2245	0.3552
15	54	119814	18506	243.23	67.38	0.1545	0.2770
16	61	101871	7108	237.23	75.09	0.0698	0.3165
17	50	139790	26008	225.57	81.39	0.1861	0.3608
18	26	275681	58789	345.11	142.12	0.2133	0.4118
19	64	130450	10749	255.22	56.9	0.0824	0.2229
20	60	127839	19009	229.47	55.1	0.1487	0.2401
21	52	294050	40689	360.23	94.89	0.1384	0.2634
22	62	129007	11809	224.86	81.09	0.0915	0.3606
23	46	158922	26488	262.47	83.61	0.1667	0.3186
24	21	147043	29997	258.50	104.6	0.2040	0.4046
25	34	115421	18451	364.23	115.86	0.1599	0.3181
26	43	145118	23205	251.60	85.57	0.1599	0.3401
27	26	176083	41307	264.67	96.63	*0.2346*	0.3651
28	38	347538	71313	361.44	90.71	0.2052	0.2510
29	55	260921	42472	334.59	77.8	0.1628	0.2325
30	60	156525	25749	265.62	67.48	0.1645	0.2541
31	40	155316	32145	261.07	109.05	0.2070	0.4177
32	26	264521	58785	330.12	142.11	0.2222	0.4305
33	38	135668	20101	239.04	74.87	0.1482	0.3132
34	47	105009	13530	207.92	74.65	0.1288	0.3590
35	35	315876	49075	364.26	122.97	0.1554	0.3376
36	55	124021	17542	251.54	51.58	0.1414	0.2051
37	20	382036	67042	403.54	139.56	0.1755	0.3458
38	50	132450	13494	223.66	78.72	0.1019	0.3520
39	56	128184	17674	218.11	56.72	0.1379	0.2600
40	44	123745	17845	271.12	91.56	0.1442	0.3377
41	63	131053	16488	235.85	44.87	0.1258	0.1902

S.No	AGE	A1	A2	A3	A4	A2/A1	A4/A3
42	32	324957	47804	376.93	127.62	0.1471	0.3386
43	60	163235	12361	247.33	67.66	0.0757	0.2736
44	59	289729	26039	382.50	93.47	0.0899	0.2444
45	33	324945	51912	356.85	123.59	0.1598	0.3463
46	46	140467	14362	243.45	79.61	0.1022	0.3270
47	21	326034	59811	359.13	124.6	0.1835	0.3469
48	34	112579	16451	345.23	127.65	0.1461	0.3698
49	45	300439	46605	333.44	89.57	0.1551	0.2686
50	60	90238	13368	189.53	40.49	0.1481	0.2136
51	64	130456	10785	244.22	56.9	0.0827	0.2330
52	32	142317	22951	185.24	65.23	*0.1613*	0.3521
53	47	296501	42805	377.46	128.28	0.1444	0.3398
54	45	144521	19145	261.45	72.45	0.1325	0.2771
55	27	264511	54123	231.23	92.12	0.2046	0.3984
56	42	128768	18846	238.85	87.18	0.1464	0.3650
57	21	264561	53456	245.16	110.45	0.2021	0.4505
58	62	122570	9296	228.54	36.55	0.0758	0.1599
59	54	272428	39133	328.72	99.53	0.1436	0.3028
60	47	124609	22131	240.43	83.95	0.1776	0.3492
61	21	121399	31103	233.15	79.82	0.2562	0.3424
62	47	133014	22733	247.81	83.11	0.1709	0.3354
63	23	256423	54124	334.25	125.12	0.2111	0.3743
64	69	131220	12123	248.05	48.46	0.0924	0.1954
65	60	172391	25358	240.47	64.87	0.1471	0.2698
66	51	130171	17243	214.66	58.31	0.1325	0.2716
67	31	141231	21451	224.56	80.23	*0.1519*	0.3573
68	55	286976	43312	365.69	86.57	0.1509	0.2367
69	56	112963	11557	228.06	44.04	0.1023	0.1931
70	64	313785	41505	340.75	71.4	0.1323	0.2095
71	35	134581	19995	384.86	145.96	0.1486	0.3793
72	55	124789	11387	227.30	46.9	0.0913	0.2063
73	65	147620	13194	251.47	40.91	0.0894	0.1627
74	49	143143	23247	284.18	65.08	0.1624	0.2290
75	65	124180	4897	231.48	56.1	0.0394	0.2424
76	30	282932	68527	342.94	142.35	*0.2422*	0.4151
77	28	284512	59451	358.11	135.23	0.2090	0.3776
78	65	147606	22436	263.61	52.54	0.1520	0.1993
79	48	151783	24508	243.18	73.73	0.1615	0.3032
80	60	125405	17739	236.82	76.51	0.1415	0.3231
81	65	124741	13561	227.85	46.17	0.1087	0.2026
82	66	150535	15719	348.23	89.37	0.1044	0.2566
83	31	135411	19845	235.23	81.52	0.1466	0.3466

S.No	AGE	A1	A2	A3	A4	A2/A1	A4/A3
84	50	115658	20003	215.11	68.36	0.1729	0.3178
85	34	147131	24748	343.65	124.57	0.1682	0.3625
86	60	224630	25585	308.42	71.34	0.1139	0.2313
87	63	153762	14361	261.49	62.06	0.0934	0.2373
88	62	148671	17721	233.39	44.59	0.1192	0.1911
89	63	151703	18576	261.65	67.84	0.1224	0.2593
90	60	160677	20342	246.39	47.75	0.1266	0.1938
91	67	116309	14177	227.99	46.32	0.1219	0.2032
92	67	144065	12779	237.52	69.36	0.0887	0.2920
93	22	317650	59822	376.93	137.66	0.1883	0.3652
94	25	110938	28623	220.23	67.66	0.2580	0.3072
95	23	290062	56290	363.06	141.77	0.1941	0.3905
96	22	284514	56442	289.45	106.45	0.1984	0.3678
97	21	291004	57445	378.13	125.78	0.1974	0.3326
98	23	234561	53456	324.12	145.23	0.2279	0.4481
99	31	103451	15642	232.45	80.25	0.1512	0.3452
100	42	268153	33153	347.66	109.29	0.1236	0.3144
101	48	159504	22404	259.79	63.16	0.1405	0.2431
102	43	154721	19945	261.50	91.21	0.1289	0.3488
103	32	121453	18413	215.34	84.45	0.1516	0.3922
104	34	146269	21902	230.76	70.93	0.1497	0.3074
105	27	274512	57451	265.12	98.46	0.2093	0.3714
106	30	354856	62932	377.27	154.47	0.1773	0.4094
107	32	104456	17145	213.23	90.12	0.1641	0.4226
108	33	134546	19451	253.56	78.24	0.1446	0.3086
109	27	187170	32937	262.97	106.23	0.1760	0.4040
110	24	284480	69585	377.10	143.28	*0.2446*	0.3800
111	31	107894	17899	230.24	79.34	0.1659	0.3446
112	48	352545	43154	365.68	119.03	0.1224	0.3255
113	54	287539	37502	335.30	74.03	0.1304	0.2208
114	55	95527	9667	181.54	44.62	0.1012	0.2458
115	54	115971	14615	226.44	46.79	0.1260	0.2066
116	60	135244	16332	219.69	60.25	0.1208	0.2743
117	64	111480	15929	223.84	37.89	0.1429	0.1693
118	65	122477	5923	238.71	33.8	0.0484	0.1416
119	66	322580	29785	359.61	101.72	0.0923	0.2829
120	67	315414	11403	338.64	72.74	0.0362	0.2148

Annexure I – Hemisectioning Method

S.No	AGE	A1	A2	A3	A4	A2/A1	A4/A3
1	21	1239239	194387	763.32	253.62	0.1569	0.3323
2	34	1536421	273254	356.84	128.35	0.1779	0.3597
3	42	1242214	170392	677.35	195.25	0.1372	0.2883
4	43	1221885	184299	746.30	168.28	0.1508	0.2255
5	38	1327012	185626	731.95	284.99	0.1399	0.3894
6	55	994224	114433	680.38	221.83	0.1151	0.3260
7	50	1016044	150650	687.77	235.05	0.1483	0.3418
8	34	1117374	171121	617.71	220.17	0.1531	0.3564
9	35	1443621	184563	387.45	138.06	0.1278	0.3563
10	70	1301749	119082	648.30	126.65	0.0915	0.1954
11	65	942793	95155	617.70	184.89	0.1009	0.2993
12	31	1543542	235214	743.12	264.06	0.1524	0.3553
13	46	1411349	173733	811.74	250.31	0.1231	0.3084
14	21	1473415	213414	786.41	346.35	0.1448	0.4404
15	54	1261109	159093	732.23	213.87	0.1262	0.2921
16	61	1052288	119224	702.68	222.42	0.1133	0.3165
17	50	1115588	156476	646.25	226.59	0.1403	0.3506
18	26	1652341	295621	678.64	285.29	0.1789	0.4204
19	64	1186571	124203	747.21	174.09	0.1047	0.2330
20	60	1541619	121317	731.95	192.40	0.0787	0.2629
21	52	1192999	152584	739.98	261.00	0.1279	0.3527
22	62	1352614	76482	734.96	265.04	0.0565	0.3606
23	46	1200978	148361	747.59	236.85	0.1235	0.3168
24	21	1387265	274538	743.34	239.76	0.1979	0.3225
25	34	2545216	364523	942.34	299.19	0.1432	0.3175
26	43	1896542	295412	643.46	212.28	0.1558	0.3299
27	26	1520500	280686	765.82	271.86	0.1846	0.3550
28	39	1311994	200173	794.24	256.79	0.1526	0.3233
29	55	1043168	168031	656.64	128.46	0.1611	0.1956
30	60	1201780	150711	688.80	151.96	0.1254	0.2206
31	40	1395144	212935	768.61	328.81	0.1526	0.4278
32	26	1432765	265431	654.12	262.77	0.1853	0.4017
33	38	1303976	258665	775.02	202.34	0.1984	0.2611
34	47	878952	122770	627.41	204.02	0.1397	0.3252
35	35	2532149	398432	346.74	118.24	0.1573	0.3410
36	55	1166858	125257	752.76	166.98	0.1073	0.2218
37	20	1617748	359047	832.12	279.38	0.2219	0.3357
38	50	928909	142422	631.76	204.12	0.1533	0.3231
39	56	890433	90166	652.17	118.96	0.1013	0.1824

S.No	AGE	A1	A2	A3	A4	A2/A1	A4/A3
40	44	5235532	744512	874.32	286.35	0.1422	0.3275
41	63	1015286	100444	645.29	153.15	0.0989	0.2373
42	33	1532181	249135	874.46	351.77	0.1626	0.4023
43	60	1362759	120506	800.26	207.32	0.0884	0.2591
44	59	1171578	121426	759.98	177.58	0.1036	0.2337
45	33	1672143	211362	734.64	317.91	0.1264	0.4327
46	46	1298256	139946	752.05	184.18	0.1078	0.2449
47	21	1274715	248853	746.30	251.39	0.1952	0.3368
48	35	1207992	183847	733.12	273.15	0.1522	0.3726
49	45	1259989	228754	682.14	182.07	0.1816	0.2669
50	60	787260	123753	641.99	156.23	0.1572	0.2434
51	64	11589621	243195	894.64	187.46	0.0210	0.2095
52	32	1843251	393298	773.84	280.31	0.2134	0.3622
53	47	1029533	172394	693.82	235.18	0.1674	0.3390
54	45	2456329	328742	687.42	177.64	0.1338	0.2584
55	27	1564807	613602	799.51	288.85	0.3921	0.3613
56	42	1157104	121307	545.48	193.53	0.1048	0.3548
57	21	1528427	414604	825.48	282.12	0.2713	0.3418
58	62	1218094	118639	649.62	124.11	0.0974	0.1911
59	54	1016657	163072	649.95	173.10	0.1604	0.2663
60	47	1165973	143570	755.23	248.96	0.1231	0.3296
61	21	1129031	197994	712.23	245.77	0.1754	0.3451
62	47	1200044	192255	781.65	272.66	0.1602	0.3488
63	23	1116612	244291	723.74	263.61	0.2188	0.3642
64	70	1251045	126339	786.82	168.28	0.1010	0.2139
65	60	1317653	125658	743.13	170.49	0.0954	0.2294
66	51	1070397	122280	604.11	157.64	0.1142	0.2609
67	31	1828562	311703	609.29	246.76	0.1705	0.4050
68	55	1174502	86705	753.18	177.06	0.0738	0.2351
69	56	1043421	113966	594.77	148.30	0.1092	0.2493
70	64	1234107	102359	685.15	152.75	0.0829	0.2229
71	35	1423126	225631	543.16	188.85	0.1585	0.3477
72	55	1100589	122978	674.61	131.12	0.1117	0.1944
73	65	1101917	87937	766.46	124.69	0.0798	0.1627
74	49	1282964	214850	813.77	178.06	0.1675	0.2188
75	65	1079881	144727	635.45	128.76	0.1340	0.2026
76	30	1375268	196624	799.22	293.73	0.1430	0.3675
77	28	1147590	132714	763.67	300.78	0.1156	0.3939
78	65	1232441	114758	758.43	107.39	0.0931	0.1416
79	48	1366006	172953	757.58	238.87	0.1266	0.3153

S.No	AGE	A1	A2	A3	A4	A2/A1	A4/A3
80	60	1160139	126691	743.56	150.89	0.1092	0.2029
81	65	1040194	120948	674.98	152.18	0.1163	0.2255
82	66	1442244	205044	733.35	188.21	0.1422	0.2566
83	31	1645313	257433	894.83	319.15	0.1565	0.3567
84	50	1197481	149101	670.83	206.34	0.1245	0.3076
85	34	2185423	295412	854.37	280.40	0.1352	0.3282
86	60	1069807	118050	720.74	225.14	0.1103	0.3124
87	63	1374528	162450	832.20	215.77	0.1182	0.2593
88	62	241712	24033	704.73	112.71	0.0994	0.1599
89	63	1349091	95218	803.68	152.90	0.0706	0.1902
90	60	922499	126045	602.50	158.79	0.1366	0.2636
91	67	1288052	109895	729.58	156.71	0.0853	0.2148
92	67	1052615	77657	688.80	139.94	0.0738	0.2032
93	22	2534465	488356	784.31	374.64	0.1927	0.4777
94	25	952411	197046	630.03	187.20	0.2069	0.2971
95	23	1763843	391546	735.13	321.97	0.2220	0.4380
96	22	1183074	216741	753.61	267.62	0.1832	0.3551
97	21	1873545	366345	842.31	332.32	0.1955	0.3945
98	23	1634514	341276	645.13	245.40	0.2088	0.3804
99	31	1542431	317421	743.61	263.76	0.2058	0.3547
100	42	1034441	152384	703.08	213.85	0.1473	0.3042
101	48	1293557	160823	701.86	205.64	0.1243	0.2930
102	43	1122709	144473	696.22	166.12	0.1287	0.2386
103	32	1561234	342171	654.34	240.39	0.2192	0.3674
104	34	1543681	235421	684.54	253.92	0.1525	0.3709
105	27	1563451	443451	765.52	297.25	0.2836	0.3883
106	30	1150980	194648	737.66	294.58	0.1691	0.3993
107	32	1453411	281481	624.37	217.70	0.1937	0.3487
108	33	1615242	269212	354.94	113.11	0.1667	0.3187
109	27	1462341	345231	752.13	292.05	0.2361	0.3883
110	24	1216363	271618	796.40	294.55	0.2233	0.3699
111	31	1636254	352151	356.41	113.92	0.2152	0.3196
112	48	1361967	183737	779.88	181.65	0.1349	0.2329
113	54	992419	94335	709.15	148.98	0.0951	0.2101
114	55	1023915	118476	714.92	95.21	0.1157	0.1332
115	54	1116013	146952	638.27	125.06	0.1317	0.1959
116	60	1204298	122228	700.39	128.24	0.1015	0.1831
117	64	899216	74445	658.49	111.46	0.0828	0.1693
118	65	1268219	110241	807.51	195.70	0.0869	0.2424
119	66	1355343	165799	728.19	205.98	0.1223	0.2829
120	67	1246894	112455	746.39	217.96	0.0902	0.2920

A 1- Tooth area.

A2 - Pulp area.

A3 - Tooth width at CEJ.

A4 - Pulp width at CEJ.

A2/A1 - P/T area ratio.

A4/ A3 - P/T width at CEJ.

No:VDCW/IEC/08/2015

Date: 14.12.2015

TO WHOMSOEVER IT MAY CONCERN

Principal Investigator:Dr.T.KeerthiPriyadharshini

Title: Age Estimation Using Pulp Tooth Ratio from Single rooted premolars with digital Intraoral Periapical Radiographs and longitudinal hemisection of tooth – A comparative study in Dravidian population.

Institutional ethics committee thank you for your submission for approval of above proposal ,It has been taken for discussion in the meeting held on 04 .12.15.The committee approves the project and it has no objection on the study being carried out in Vivekanandha Dental College For Women.

You are requested to submit the final report on completion of project.Any case of adverse reaction should be informed to the institutional ethics committee and action will be taken thereafter.

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