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Age-related root dentin translucency in mandibular second premolars: A cross-sectional study

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Abstract:
Age estimation is an important part of forensic identification in adults, where dental developmental markers are no longer useful. Hence, this cross-sectional study assessed root dentin translucency in 100 extracted mandibular second premolars from a Pune population to determine its usefulness as an age marker across different age groups. Translucency length increased progressively with age, from a mean of 0.3 ± 0.5 mm in the 11–20 year group to 8.8 ± 1.6 mm in the 61–70 year group and showed a strong positive correlation with chronological age ($r = 0.890$, $p = 0.001$). The regression equation Age = 22.29 + 4.670 translucency length explained 79.21% of the age variation, while individuals above 30 years showed a much more consistent translucency pattern than younger adults ($p < 0.001$). Thus, we show root dentin translucency as a practical and reliable digital age estimator in adults, especially after the third decade of life.

Keywords: Forensic odontology, age estimation, root dentin translucency, mandibular second premolar, digital analysis

Background:
Chronological age determination is a basic aspect of human identification in forensic science, especially where documentary evidence is absent, ambiguous, or controversial. The value of teeth in this regard is that they are one of the most resistant tissues in the human body, do not change after death, and biologic changes related to aging have been better preserved by teeth than most other tissues **[1, 2]**. Regressive dentinal changes are some of the dental techniques that have been used to estimate age in adults. Age estimation was first formalised by Gustafson with six dental parameters, such as root translucency, and has since been found by other researchers that translucency can be the most convenient single variable since it is relatively easy to detect and measure **[3, 4]**. Root dentin translucency is due to sclerosis and deposition of minerals in the dentinal tubules. With increasing age, translucency spreads coronally out of the root apex and its length can be measured and compared with chronological age. This principle was demonstrated in a large sample by Bang and Ramm and regression formulae were suggested which later became the focus of forensic odontology studies **[5]**. Subsequent research validated the usefulness of this parameter but also pointed to critical methodological and population-related shortcomings. Solheim claimed that translucency length was closely related to age whereas Kvaal and Solheim found that predictive performance could depend on the type of tooth and the combination of measurements taken **[6, 7]**. Drusini *et al.* and colleagues discovered that premolars tend to give good predictive success, and subsequent computer-based techniques enhanced objectivity and reproducibility of translucency measurement **[8]**. Experience with Indian populations has shown that regression equations obtained in one population may not be directly applicable in another. Acharya and Vimi showed that Bang and Ramm equations could not be fully applicable to Indians, and Singhal *et al.* and others found that the dimensions of transparency were strongly associated with age but still needed to be interpreted with care and population-specificity **[9, 10]**. Still more recent digital research has again affirmed translucency as a convenient and objective measure, especially with scanned sectioned teeth measured using standard image-processing software **[11–14]**. Therefore, it is of interest to assess the age-related trend of root dentin translucency in extracted mandibular second premolars of a population in Pune and to identify the age range within which the parameter under consideration becomes regularly useful.

Materials and Methods:
This cross-sectional observational study was founded on a thesis-based set of extracted teeth found in Pune. The sample size was 100 permanent mandibular second premolars, which were gathered in the Department of Oral and Maxillofacial Surgery at M.A. Rangoonwala College of Dental Sciences and Hospital, Pune, and in the private dental clinics in Pune city. Only comparatively healthy, erupted, single-rooted, mandibular second premolar teeth extracted due to valid clinical reasons like periodontal disease, malocclusion, orthodontic therapy, or denture prosthesis planning were considered. Teeth with significant attrition, abrasion, erosion or dental caries were excluded. The information about the age of the patient, his/her sex, and the number of teeth was noted at the moment of extraction. The teeth were extracted and rinsed with running water, debrided of soft tissue debris and fixed in 10% neutral formalin. Each specimen was marked with a central longitudinal line, and then the tooth was embedded in autopolymerising acrylic resin to support it during sectioning. Buccolingual sections of the same teeth, about 250 µm thick, were made using a hard-tissue microtome through the center of the tooth. A flat-bed scanner was used to scan the sections at 600 dpi, and the digital images were saved to be analyzed. The Adobe Photoshop version 7 was used to measure root dentin translucency as per the Bang and Ramm method **[2]**. The clear dentin of the root was

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determined in a coronal direction at the apical end of the root to the point where clear dentin was joined by the opaque dentin. All data were tabulated in Microsoft Excel and statistically analyzed with SPSS version 10.0. Descriptive statistics were means and standard deviations of age and length of translucency in each decade. The relationship between chronological age and length of translucency was measured using Pearson correlation coefficient. A simple linear regression was employed to obtain an equation of age estimation. To interpret, decade-wise distributions were analyzed and early-age groups were compared with later age groups to establish the stage where translucency was reliably manifested. A p value of below 0.05 was deemed to be statistically significant.

Results:

As shown in (**Table 1)**, translucency length increased progressively with age. The lowest mean translucency values were recorded in the 11–20 year and 21–30 year groups (0.3 ± 0.5 mm and 0.8 ± 0.7 mm, respectively), while the highest mean translucency was observed in the 61–70 year group (8.8 ± 1.6 mm). This decade-wise increase clearly demonstrates the age-related progression of dentinal sclerosis. **Table 2** demonstrates a strong positive and statistically significant correlation between chronological age and translucency length ($r = 0.890$, $p = 0.001$). Linear regression analysis produced the equation Age = 22.29 + 4.670 × translucency length, with an R^2 value of 79.21%, indicating that translucency length alone explained nearly four-fifths of the observed variation in age. **Table 3** emphasizes the biologic limitation of translucency as an age marker in younger individuals. In the combined 11–30 year age group, mean translucency was only 0.6 mm, indicating minimal and irregular expression. In contrast, subjects older than 30 years showed a mean translucency length of 6.4 mm, and the difference between the two groups was highly significant ($p < 0.001$). This suggests that translucency becomes consistently useful only after the third decade of life. Overall, the results show that root dentin translucency is not simply present as an isolated change but increases in a structured decade-wise pattern. The increase becomes particularly pronounced after 30 years of age and remains closely related to chronological age in later decades.

Table 1: Decade-wise distribution of actual age, translucency length, and estimated age

Age group (years)	n	Actual age, mean ± SD	Translucency length (mm), mean ± SD	Estimated age by Pune formula, mean ± SD
11–20	8	15.4 ± 3.2	0.3 ± 0.5	23.5 ± 2.2
21–30	8	26.4 ± 2.8	0.8 ± 0.7	25.9 ± 3.1
31–40	17	38.5 ± 2.3	4.7 ± 1.2	44.3 ± 5.5
41–50	20	47.2 ± 2.9	5.3 ± 1.5	46.9 ± 6.8
51–60	25	57.7 ± 1.9	6.3 ± 0.9	51.7 ± 4.5
61–70	22	64.3 ± 3.1	8.8 ± 1.6	63.6 ± 7.4

Table 2: Correlation and regression analysis between chronological age and translucency length

Parameter	Value
Pearson correlation (r)	0.890
p value	0.001
Regression equation	Age = 22.29 + 4.670 × translucency length
Coefficient of determination (R^2)	79.21%
Interpretation	Strong positive age-translucency relationship

Table 3: Comparison of early and later age groups for translucency expression

Comparison	Actual age (years)	Mean translucency length (mm)	Interpretation
11–30 years (n = 16)	20.9	0.6	Minimal/irregular translucency
31–70 years (n = 84)	52.9	6.4	Consistent progressive translucency
Mean difference	32.0	5.8	Marked increase after 30 years
p value	<0.001	<0.001	Highly significant

Discussion:

The current research revealed that root dentin translucency of mandibular second premolars is positively correlated with chronological age, which is why it can be used as an age estimator in adults. This observation is in line with the classic works of Gustafson and Bang and Ramm who both determined that age-related alterations in dentin could be converted into practical forensic evidence **[3, 5]**. Among the most significant findings in the current sample was the significant rise in translucency beyond the age of 30 years. This helps to substantiate the biologic fact that dentinal sclerosis is a slow process and that translucency can be absent, weak, or irregular in younger adults. The extremely low mean translucency scores in the 1120 year and 2130 year groups are a sign that deficiency in translucency should not be regarded too accurately in the younger age group, but rather as an overall sign of younger adulthood. The same caution has been observed with respect to the early age groups of adults in previous forensic dental studies (Garizoain *et al.,* 2023) **[15]**. The selection of mandibular second premolars seems to be suitable in this case. Drusini *et al.* and Solheim discovered that the premolars often demonstrate good predictive ability, and Kvaal and Solheim also discovered that premolars often provide better age-related correlations than other types of teeth **[6–8]**. Their single-root morphology and comparatively simple anatomy make them easy to section and minimise uncertainty when measuring. The present findings also support the increasing role of digital measurement in forensic odontology. The use of traditional manual methods with calipers has a historical significance, but digital analysis provides a clearer visualization of the border between opaque and

translucent dentin, permanent storage of images, and improved standardization. The digital technique of age estimation, developed by Acharya and Vimi subsequently by Singhal, showed that standard software can be successfully applied in forensic age estimation **[9, 10]**. The current research employed a comparable digital workflow, which probably enhanced the consistency of measurements and enhanced the practical usefulness of the findings. The other implication of significance is a locally observed pattern of biology in the Pune sample. The slope and predictive value of the equations that are based on translucency have been demonstrated to be not always constant across populations by previous studies of other geographic and ethnic populations **[7, 9]**. The trend over the decade recorded in this direction justifies the opinion that regional databases and local interpretations are to be created rather than thinking that the regression equations that have been published before are universal. In forensic terms, the conclusion that translucency is especially informative after age 30 is the most relevant. This parameter may reduce the probable age range in adults over 30 years of age, and when used together with regression analysis, can give fairly accurate age estimates. Translucency, however, in younger adults, must be viewed with caution and preferably complemented with other developmental, radiographic or histologic criteria. This study has certain limitations. The sample was restricted to one city and extracted teeth were used instead of a broader community-based population. Moreover, teeth with clear attrition and caries were not included which enhanced internal consistency but could decrease direct generalizability to all forensic case scenarios. However, the internal pattern was statistically significant, clear and biologically plausible.

Conclusion:

Root dentin translucency of mandibular second premolars improved with age in this Pune sample and was significantly correlated with chronological age. The marker was least expressed at age below 30 years, which means that it was not very reliable in younger people, though it was more consistent and informative during the later decades. Online determination of translucency length thus seems a viable and regionally applicable complement to adult forensic age determination especially in individuals above the age of 30 years.

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