Age estimation in Indian adults by the coronal pulp cavity index

Introduction

In forensic medicine and dentistry, person identification is an important aspect. Key identification tools for the forensic odontology are the bones and teeth of the craniofacial complex. They effectively distinguish one person from others and one population from another and are used to determine the race, age, and sex of a person. Age estimation is of great importance for the identification of unknown bodies or skeletal remains of accidents and crimes as well as in disaster victims. The anthropological methods to estimate gender, age, height, and ethnicity give information of the individual that will guide police authorities when investigating cases of missing persons reported to the authorities. Teeth are the hardest part of the body and could be preserved for a long time after death without gross changes. Age estimation from teeth can be done by morphological, biochemical, and radiographical methods. The most widely used method was first used by Gustafson and modified by Johanson. The assessment of

Abstract

Background: Age estimation from tooth coronal index (TCI) using intraoral periapical radiographs by paralleling technique based on a reduction in the size of the dental pulp cavity with advancing age as a result of secondary dentin deposition. Aim and Objectives: The aim of this study is to estimate age for Indian adults using radiographs of mandibular first molar and second premolar teeth using coronal pulp cavity index. Materials and Methods: The study material consists of 400 intraoral periapical radiographs of mandibular second premolar and mandibular first molar from enrolled participants of either gender in the age group of 20–60 years. Statistical Analysis: Data analysis was done using SPSS (Statistical Package for Social Sciences), and Pearson's correlation coefficient (r) was used to find the correlation between age (years) and TCI. Results: TCI was computed for each tooth and regressed on the real age of the sample. The correlation coefficient “r” was −0.865 (for premolar combined sample) and −0.850 (for molar combined sample). The obtained equations were tested on test sample of fifty teeth and age was determined. The absolute mean error between actual and predicted age for premolars was 6.72 months and for molars, it was 9 months. Conclusion: Age estimation using TCI is a precise, noninvasive, less time-consuming, and an inexpensive method.

Key words: Age estimation, forensic anthropology, forensic dentistry
dentinal translucency and cementum annulations are some other methods. These methods required extraction of teeth and hence are not appropriate for living individuals. Thus, for living individuals, noninvasive radiological methods are developed.

Since 1925, Bodecker identified the apposition of secondary dentine as related to chronological age. The size of the pulp decreases with age due to the deposition of the secondary dentin. In 1985, Ikeda et al. developed tooth coronal index (TCI) for age estimation by taking radiographs on extracted teeth. In 1993, Drusini had studied age estimation by TCI by taking radiographs on living person.

Many studies have been done in Western population to derive a regressive formula for that population. However, the reproducibility of these parameters is uncertain as the values may be different for individuals from different ethnical groups. The present study aims to assess the accuracy of age estimation from TCI of mandibular second premolar and first molar using intraoral periapical radiograph taken by paralleling technique of known age and gender individuals and to develop regression equations that can be used in the Indian adult population.

**Materials and Methods**

The study protocol was approved by the Institutional Ethics Committee. To calculate the sample size based on the sample required to estimate a proportion with approximate 95% confidence level, the following formula was used.

\[ n_r = \frac{4pq}{d^2} \]

Where \( n_r \) = required sample size, \( p \) = proportion of the population having the characteristic, \( q = 1-p \) and \( d \) = the degree of precision.

If the value of \( p \) is unknown, use \( P = 0.5 \) which assumes maximum heterogeneity (i.e., a 50/50 split). The degree of precision (\( d \)) is the margin of error that is acceptable. As this is a preliminary study, you are prepared to accept a margin of error of ± 5% so \( d = 0.05 \). Thus, the sample size was calculated using formula

\[ n_r = \frac{4pq}{d^2} = \frac{4 \times 0.5 \times (1 - 0.5)}{0.05 \times 0.05} = 400 \]

Thus, 400 participants reporting to the Department of Oral Medicine and Radiology were recruited in the study with written consent obtained from them. The patients enrolled in the study belonged to the age group of 20–60 years. Patients with fully erupted sound mandibular second premolar, first molar and good occlusion were considered for the study.

Exclusion criteria for the study were person’s suffering from any systemic disease, carious teeth, restored teeth, endodontically treated teeth, cracked teeth, attrition or abrasion of the enamel, crown covered teeth and teeth with developmental anomalies.

The selected participants were then categorized into four groups, given in Table 1.

Each group included fifty male and fifty female participants for the study.

Intraoral periapical radiograph of mandibular second premolar and mandibular first molar was considered for this study for the following reasons:
1. The radiographic resolution of mandibular teeth is better than the maxillary ones
2. Mandibular third molar varies considerably in morphology in different individuals and presents anomalies of form and in position very frequently
3. Normally, mandibular second molar is smaller than mandibular first molar in all dimensions
4. Mandibular second premolar has a larger crown, coronal pulp chamber, and root than the first premolar
5. In adults, there may be an early loss of anterior teeth due to periodontal disease or partial loss of crown structure due to trauma.

Intraoral periapical radiographs were made by GNATUS Timex 70 (Ribeira Preto – São Paulo, Brasil) IOPA machine with operating range of 70 kVp, 7 mA, and 0.5 s

| Table 1: Number of participants in different age groups for premolar and molar radiograph |
|-----------------------------------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| Group | Age (years) | Gender | Number of participants | Group | Age (years) | Gender | Number of participants |
|-------|-------------|--------|-----------------------|-------|-------------|--------|-----------------------|
| A     | 20-29       | Male   | 25                    | A     | 20-29       | Male   | 25                    |
|       |             | Female | 25                    |       |             | Female | 25                    |
| B     | 30-39       | Male   | 25                    | B     | 30-39       | Male   | 25                    |
|       |             | Female | 25                    |       |             | Female | 25                    |
| C     | 40-49       | Male   | 25                    | C     | 40-49       | Male   | 25                    |
|       |             | Female | 25                    |       |             | Female | 25                    |
| D     | 50-60       | Male   | 25                    | D     | 50-60       | Male   | 25                    |
|       |             | Female | 25                    |       |             | Female | 25                    |
of exposure time. Intraoral periapical radiographs were made by paralleling technique using Rinn XCP film holder (Dentsply, UK) [Figure 1].

Processing was done manually following standard procedure by a visual method. Images which were elongated, foreshortened, or distorted were repeated. Radiographs were mounted on a viewer under ideal viewing conditions, and the following measurements were noted in millimeters using scale and divider by two investigators. After 15 days, a measurement done by the primary investigator was repeated.

1. Length of the tooth crown (crown length [CL]) [Figure 2]
2. Length of the coronal pulp cavity (CPCL) or coronal pulp cavity height (CPCH) [Figure 3].

Radiographic landmarks
Cervical line – this is the line joining the mesial and distal cementoenamel junction points on the radiograph and divides the tooth into crown and root.

Crown height or length CL – this is the maximum perpendicular distance from the cervical line to the tip of the highest cusp of tooth.

Pulp height – this is the distance from cervical line to the coronal tip of the pulp chamber.

Then, the TCI for each tooth was calculated as follows:

\[
TCI = \frac{CPCH \text{ or } CPCL}{CL} \times 100
\]

Where TCI – Tooth coronal index, CPCH or CPCL – Coronal pulp cavity height or length, CL – Crown length.

Statistical analysis
Data analysis was done using SPSS (Statistical Package for the Social Sciences) version 20.0 (IBM SPSS Statistics [IBM Corp. Released 2011, IBM SPSS Statistics for Windows, version 20.0. Armonk, NY, USA]). Test used for interobserver reliability for CPCH, CL, and TCI measurement was Pearson’s correlation coefficient.

Intraobserver reliability for TCI was tested by a paired t-test.

We have used Pearson’s correlation coefficient (r) to find the correlation between age (years) and TCI. P < 0.05 considered as statistically significant correlation between TCI and age. TCI was regressed on actual age for each group of teeth, for males and females, and for combined sample. Regression equation used to estimate the age (years) using TCI.

Finally, test sample of fifty teeth (25 premolars and 25 molars) which were not included in the regression analysis was randomly selected. Regression equations were used and age was estimated which was then verified with actual age of the patient.

Results
Interobserver reliability for CPCH, CL, and TCI measurement was 0.997, 0.996, and 0.996 accordingly. Test used was Pearson’s correlation coefficient.
Intraobserver reliability of measurement for TCI was 99.96%. Paired t-test was used.

Maximum TCI, minimum TCI, their means, medians, and standard deviations for males, females, and the combined sample for premolar and molar are shown [Tables 2-7].

The graph shows scatter plots and the regression lines of age (Y) and the TCI (X) values for premolars (combined sample) [Figure 4].

Correlation coefficient (r): \(-0.865\) \(P < 0.001\)

The graph shows scatter plot with the regression lines of age (Y) and the TCI (X) values for molars (combined sample) [Figure 5].

Correlation coefficient (r): \(-0.850\) \(P < 0.001\)

Using correlation test \(P < 0.05\), therefore, there was a significant negative correlation between age (years) versus TCI.

![Graph showing correlation between age and TCI for premolars](image1)

![Graph showing correlation between age and TCI for molars](image2)

**Table 2: Descriptive statistics for tooth coronal index for premolar with age group for gender male**

| Age group | n  | Mean  | Median | SD  | 95% CI for mean | Minimum | Maximum |
|------------|----|-------|--------|-----|-----------------|---------|---------|
| 20-29      | 25 | 59.53 | 57.14  | 3.85| 57.94           | 61.12   | 50.00   |
| 30-39      | 25 | 42.27 | 42.86  | 2.76| 41.13           | 43.41   | 35.71   |
| 40-49      | 25 | 35.11 | 35.71  | 2.91| 33.91           | 36.31   | 26.67   |
| 50-59      | 25 | 30.66 | 28.57  | 3.78| 29.10           | 32.23   | 21.43   |
| Total      | 100| 41.89 | 41.67  | 11.53| 39.61           | 44.18   | 21.43   |

SD: Standard deviation, CI: Confidence interval

**Table 3: Descriptive statistics for tooth coronal index for premolar with age group for gender female**

| Age group | n  | Mean  | Median | SD  | 95% CI for mean | Minimum | Maximum |
|------------|----|-------|--------|-----|-----------------|---------|---------|
| 20-29      | 25 | 61.66 | 57.14  | 6.65| 58.92           | 64.40   | 50.00   |
| 30-39      | 25 | 39.88 | 42.86  | 3.20| 38.56           | 41.20   | 33.33   |
| 40-49      | 25 | 34.60 | 35.71  | 3.70| 33.07           | 36.12   | 31.25   |
| 50-59      | 25 | 28.60 | 28.57  | 3.27| 27.25           | 29.95   | 22.22   |
| Total      | 100| 41.18 | 35.70  | 13.28| 38.55           | 43.82   | 22.22   |

SD: Standard deviation, CI: Confidence interval

**Table 4: Descriptive statistics for tooth coronal index for premolar with age group for gender male and female (combined sample)**

| Age group | n  | Mean  | Median | SD  | 95% CI for mean | Minimum | Maximum |
|------------|----|-------|--------|-----|-----------------|---------|---------|
| 20-29      | 25 | 57.89 | 56.25  | 4.43| 56.63           | 59.15   | 50.00   |
| 30-39      | 25 | 41.39 | 40.00  | 2.99| 40.54           | 42.24   | 35.71   |
| 40-49      | 25 | 34.72 | 31.25  | 2.88| 33.90           | 35.53   | 26.67   |
| 50-59      | 25 | 30.58 | 28.57  | 3.17| 29.68           | 31.48   | 21.43   |
| Total      | 100| 41.14 | 37.50  | 10.98| 39.61           | 42.67   | 21.43   |

SD: Standard deviation, CI: Confidence interval
Regression analysis on the sample produced the following linear regression equation

**Premolars:**
1. For combined sample, \( Y = 78.63 - 0.9666 \times X \)
2. For male sample, \( Y = 79.61 - 0.9681 \times X \)
3. For female sample, \( Y = 78.15 - 0.9779 \times X \)

Where, \( Y = \) Predicted age and \( X = \) TCI.

Regression analysis on the sample produced the following linear regression equation

**Molars:**
1. For combined sample, \( Y = 71.68 - 0.812 \times X \)
2. For male sample, \( Y = 69.72 - 0.7425 \times X \)
3. For female sample, \( Y = 78.15 - 0.9779 \times X \)

Where, \( Y = \) Predicted age and \( X = \) TCI.

The regression equations were tested on a randomly selected sample of fifty teeth (25 premolars and 25 molars). Calculated age using derived formula was verified with the actual age of the patient [Tables 8 and 9].

**Discussion**

Ikeda *et al.*[^10] took X-ray of 116 extracted human teeth (53 incisors and 63 molars) and made their quadruple size prints. On the prints, he measured the lengths of coronal pulp cavity and crown and calculated the TCI.

Drusini[^11,13] studied the correlation between reduction in coronal pulp cavity and chronological age in a sample of 846 intact teeth from 433 individuals of known age and gender. Panoramic radiography was used to measure the height (mm) of the crown. The TCI after Ikeda *et al.* was computed for each tooth and regressed on real age.

Numerous accurate age estimation equations have been derived for the Western population using measurements of secondary dentin deposition, which when applied for Indian population produced errors unacceptable in forensic age estimation. The quality of secondary dentin deposition is also influenced by factors such as race, ethnicity, diet, and lifestyle. Authors have highlighted the need for population-specific formulas due to differences in ethnicity to achieve precise and accurate results.[^14-16] The present study was carried out to enhance the accuracy of age estimation by deriving age estimating formulas specific for Indian adult population.

Most of the studies are done using orthopantomograph. However, in the present study, intraoral periapical radiograph by paralleling technique of mandibular second

[^10]: Ikeda *et al.*[^10]
[^11]: Drusini[^11,13]
[^14]: Ikeda *et al.*[^10]
[^15]: Drusini[^11,13]
[^16]: Ikeda *et al.*[^10]
Table 8: Age estimation (years) on a randomly selected test sample of 25 premolars

| Code number | Gender | TCI (years) | Actual age (years) | Predicted age using the combined formula (years) A | Residual A | Predicted age using the gender formula (years) B | Residual B |
|-------------|--------|-------------|--------------------|-----------------------------------------------|-----------|-----------------------------------------------|-----------|
| P-1         | Male   | 57.14       | 22                 | 23.43                                          | -1.43     | 24.29                                          | -2.29     |
| P-2         | Female | 56.25       | 23                 | 24.29                                          | -1.29     | 23.14                                          | -0.14     |
| P-3         | Male   | 42.86       | 37                 | 37.20                                          | 0.20      | 38.19                                          | -1.19     |
| P-4         | Male   | 28.57       | 54                 | 51.01                                          | 2.99      | 51.95                                          | 2.05      |
| P-5         | Female | 33.33       | 45                 | 46.41                                          | -1.11     | 45.55                                          | -0.55     |
| P-6         | Male   | 35.71       | 46                 | 44.11                                          | 1.89      | 45.03                                          | 0.97      |
| P-7         | Male   | 42.86       | 38                 | 37                                             | 1         | 36.69                                          | 1.31      |
| P-8         | Male   | 57.14       | 25                 | 23.39                                          | 1.61      | 24.29                                          | 0.71      |
| P-9         | Female | 42.86       | 34                 | 37.20                                          | -3.2      | 36.23                                          | -2.23     |
| P-10        | Female | 57.14       | 22                 | 23.43                                          | -1.43     | 22.27                                          | -0.27     |
| P-11        | Male   | 42.86       | 37                 | 37.20                                          | -0.2      | 38.19                                          | -1.19     |
| P-12        | Male   | 35.71       | 45                 | 44.11                                          | 0.89      | 45.03                                          | -0.03     |
| P-13        | Female | 33.33       | 52                 | 46.41                                          | 5.59      | 50.21                                          | 1.79      |
| P-14        | Male   | 42.86       | 38                 | 37.20                                          | 0.8       | 38.19                                          | -0.19     |
| P-15        | Female | 35.71       | 46                 | 44.11                                          | 1.89      | 43.229                                         | 2.78      |
| P-16        | Female | 28.57       | 53                 | 51                                             | 2         | 51.95                                          | 1.05      |
| P-17        | Male   | 57.14       | 24                 | 23.43                                          | 0.57      | 24.29                                          | -0.29     |
| P-18        | Female | 42.86       | 36                 | 37.20                                          | -1.2      | 36.23                                          | -0.23     |
| P-19        | Female | 35.71       | 43                 | 44.11                                          | -1.11     | 43.229                                         | -0.22     |
| P-20        | Male   | 35.71       | 42                 | 38.35                                          | 3.65      | 45.03                                          | -3.03     |
| P-21        | Male   | 41.67       | 39                 | 38                                             | 1         | 39.26                                          | -0.26     |
| P-22        | Female | 35.71       | 40                 | 44                                             | -4        | 43.229                                         | -3.22     |
| P-23        | Female | 42.86       | 35                 | 37.20                                          | -2.2      | 36.23                                          | -1.23     |
| P-24        | Male   | 57.14       | 22                 | 23.43                                          | -1.43     | 24.29                                          | -2.29     |
| P-25        | Male   | 43.75       | 36                 | 36.34                                          | -0.34     | 37.25                                          | -1.25     |

TCI: Tooth coronal index

premolar and mandibular first molar was used. Resolution of intraoral periapical radiograph is higher compared to orthopantomograph. Furthermore, for standardization, paralleling technique was used which shows more accurate images without any distortion of shape and size.

In this study, the length of the coronal pulp cavity shows a significant correlation with individual chronological age. There is a negative correlation of TCI with age. This is similar to study done by Drusini,[11] Żądzińska et al.,[17] in Italy; Igbigbi and Nyirenda[18] in Malawi and Karkhanis et al.[19] in Western Australia, and recently a study done by Talabani et al.[20] in Iraq.

Moreover, the current work revealed that the mean TCI of premolars is larger than those of molars. This difference is considered to be due to the fact that the mandibular molars have more morphological diversity than premolars. These findings are consistent with that of Igbigbi and Nyirenda[18] in Malawi who mentioned that gender has a significant influence on age estimation using TCI, and hence, there is a need for gender-specific formulae in the sampled population. They explained this difference by the influence of estrogen on the formation of secondary dentin. Hietala et al.[21] reported the existence of an estrogen receptor in odontoblast of human pulp tissues. In addition, Yokose et al.[22] reported that estrogen deficiency promotes the substrate synthesis of odontoblast. These reports suggest

The present study results reveal that there is no gender difference in TCI. This is in agreement with studies done in Italy by Drusini[11] and Żądzińska et al.,[17] in India by Shrestha,[23] in Egypt by Khattab et al.,[24] and in Western Australia by Karkhanis et al.[19] They stated that gender of individual appears to have no significant influence on age estimation so that gender-specific formulae are not necessary for age estimation in specimens of unknown gender.

On the other hand, this result is on the contrary to that of Agematsu et al.[24] in Japan, Igbigbi and Nyirenda[18] in Malawi, who mentioned that gender has a significant influence on age estimation using TCI, and hence, there is a need for gender-specific formulae in the sampled population. They explained this difference by the influence of estrogen on the formation of secondary dentin. Hietala et al.[21] and Jukic et al.[25] reported the existence of an estrogen receptor in odontoblast of human pulp tissues. In addition, Yokose et al.[22] reported that estrogen deficiency promotes the substrate synthesis of odontoblast. These reports suggest...
that estrogen exerts a strong influence on the formation of secondary dentin.

**Conclusion**

From the present research work, it can be concluded that regressive equations derived from TCI are applicable for age estimation in 20–60 years of age groups in Indian population. Mandibular second premolar and first molar TCI can be used for age estimation in male, female, or combined sample of the Indian population. Age estimation by intraoral periapical radiographs taken by paralleling technique is a simple, cost-effective, easily available, accurate method for calculating TCI for age estimation for forensic dentistry and anthropology.

Thus, age estimation by TCI is precise, noninvasive, less time-consuming, and an inexpensive method that can be easily used in adult population of developing country like India. However, for the use of regression equation, there is a need for further studies founded on a larger sample size and use of other teeth.

**Declaration of patient consent**

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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**Conflicts of interest**

There are no conflicts of interest.

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