Review Article

JRAD Journal of Research and Advancement in Dentistry

J Res Adv Dent 2020;10:3s:61-69.

Application and Importance of Radiological Methods in Human Age Assessment: A Review

Chhaya Patel[1*] Kanan Dave[2] Dhaval Dave[3] Nirav Patel[4] Nilesh Raval[5]

[1]Reader, Department of Pedodontics, Karnavati School of Dentistry, Gandhinagar, Gujarat, India.
[2]MDS, Faculty of Dentistry, University of Toronto, Canada.
[3]Private Consultant, Niagara Falls, Ontario, Canada.
[4]Reader, Department of Oral and Maxillofacial Surgery, Goenka Institute of Dental Science, Gandhinagar, Gujarat, India.
[1]Professor and Head, Department of Oral Medicine and Radiology, Karnavati School of Dentistry, Gandhinagar, Gujarat, India.

ABSTRACT

Aim: Dental ageing systems are useful for forensic, research and clinical purposes. The present review article is aimed at describing the radiological methods utilised for human age identification.

Methods: The application and importance of radiological methods in human age assessment were discussed through the literature survey.

Results: Dental tissue is often preserved indefinitely after death. Implementation of radiography is based on the assessment of the extent of calcification of teeth and in turn, the degree of formation of the crown and root structures, along with the sequence and the stages of eruption. Several radiological techniques can be used to assist in both individual and general identification, including determination of gender, ethnic group and age. The radiographic method is a simpler and cheaper method of age identification compared with histological and biochemical methods. Radiographic and tomographic images have become an essential aid for human identification in forensic dentistry, particularly with the refinement of techniques.

Conclusion: Based on the appropriate knowledge of the available methods, forensic dentists can choose the most appropriate since the validity of age estimation crucially depends on the method used and its proper application. The multifactorial approach will lead to optimum age assessment.

Keywords: Age estimation, Dental Radiology, Dental age, Chronological age, Forensic odontology, Human identification.

INTRODUCTION

Age, or the time that a person has lived since birth, is an important cultural, religious and social phenomenon. [1]Radiology plays an indispensable role in human age determination. Radiological images are utilised in the process of age estimation, which is one of the essential tools in identification in forensic science. Growth is recognised as an indicator of health. The process of growth and development has been of considerable interest to physicians, anthropologists and dentists who have required guidance on normal development in order to correctly identify abnormalities.[2] Saunders, was the first to publish information regarding dental implications in age assessment by presenting a pamphlet entitled "Teeth A Test of Age" to the English parliament in 1837. [1]

The application of radiology in forensic sciences & odontology was introduced in 1896. Since 1982, dental radiography, a non-destructive and simple

Received: May. 15, 2020**: Accepted**: July. 3, 2020
***Correspondence Dr. Chhaya Patel.**
Department of Oral and Maxillofacial Surgery, Goenka Institute of Dental Science, Gandhinagar, Gujarat, India.
Email: dr.chhayachildcare@gmail.com

pISSN 2278-0076
eISSN 2321-9270

technique used daily in dental practice, has been employed in methods of age estimation.[2] Developing teeth are used most reliably in age estimation as teeth are the most indestructible part of the body and exhibit the least turnover of natural structure. They, therefore, remain relatively unchanged for many thousands of years.[3] Dental development has been shown to correlate with chronological age and be less affected by malnutrition.

The methods based on the stages of tooth formation as appreciated on radiographs seems to be more appropriate in the assessment of age than those based on skeletal development as the dental development, and calcification is controlled more by genes than by environmental factors. [4,5] Teeth are less susceptible to nutritional, hormonal and pathological changes.

Various radiographic images that can be used in age identification are intraoral periapical radiographs, lateral oblique radiographs, cephalometric radiographs, panoramic radiographs, digital imaging and advanced imaging technologies.[3] The analysis of the digitised images of the available radiographs for the volume measurements has provided new perspectives in the field of age estimation.

The current article presents a simple and comprehensive picture with regard to the human age estimation using various radiological methods.

Review of literature:

Maturity Markers:[1,2]-

The maturity markers available for age estimation in children and adolescents include:

- Morphological Age.
- Skeletal Age:
  - Ossification of the hand-wrist
  - Ossification of the sternoclavicular joints
- Secondary sexual characteristics
- Psychological development.
- Dental Age (DA):
  - Tooth eruption
  - Tooth mineralisation assessed from dental radiographs

Chronologic Age

CA was calculated by subtracting the date of the birth from the date of the panoramic radiograph after having converted both to a decimal age[4].

Morphological Age

Height was used to assessing the growth and maturity of an individual and was historically used for age estimation (Horner 1834). [6] An individual‟s height is mainly determined by their gender, parents‟ height, and ethnicity[4].

Skeletal Age

Skeletal age is the degree of maturation of bones. Skeletal age gained prominence owing to the ease of use of radiographs of the hand and wrist, following the development of the Greulich and Pyle Atlas (Greulich & Pyle 1959).[7]

Secondary sexual characteristics

During puberty, the secondary sexual characteristics appear. These changes are caused by hormonal effects, mainly testosterone and oestrogen, which produce characteristic changes such as body hair, deepening of the voice in boys and onset of menarche in girls.[3,4] Once sexual maturity has been completed, and this is of limited use as it is not possible to say exactly when this has occurred, only that a person is fully mature. In addition, puberty maturation is unreliable as a means of estimating age, due to the wide age range, especially in relation to ethnicity.[6]

Psychological maturity

Psychological maturity or intellectual development is often assessed in children and young adults using Piaget's Stages of Cognitive Development. This is based on defined stages of development related to brain growth.[7]

Tooth eruption

For many decades tooth eruption was the only criterion available for estimating age. This is

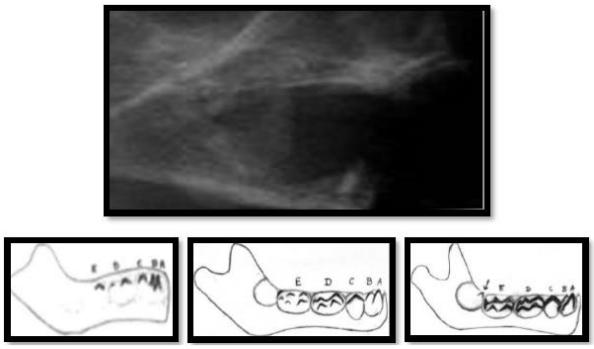

Fig 1: Diagrammatic representation of a radiograph of a mandible of a fetus at the thirtieth week of intrauterine life showing crown completion for anterior teeth, the fused cusps of the deciduous first molar, five cusps of the deciduous second molar and the crypt of a permanent first molar with no evidence of mineralisation.

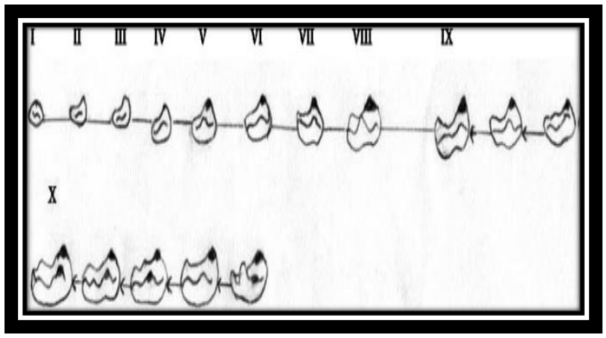

Fig 2: Developmental stages of lower deciduous first molar by Kraus and Jordan.

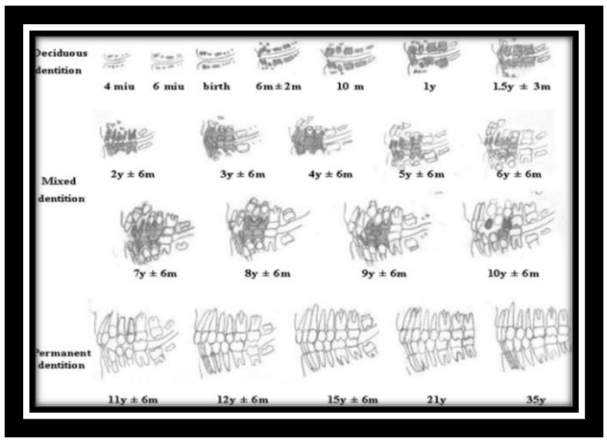

Fig 3: Dental development chart by Schour and Masseler

unreliable as there is a wide age range for the eruption of primary teeth (Hagg & Taranger 1986) [8] and permanent teeth (Nystrom et al. 2001).[9] Other factors such as the space available, ankylosis and early or delayed extraction of primary teeth alter the normal eruption of the permanent successors. The advantage of using tooth eruption or tooth emergence, as an indicator of age is that the procedure is quick and non-invasive.[7,9]

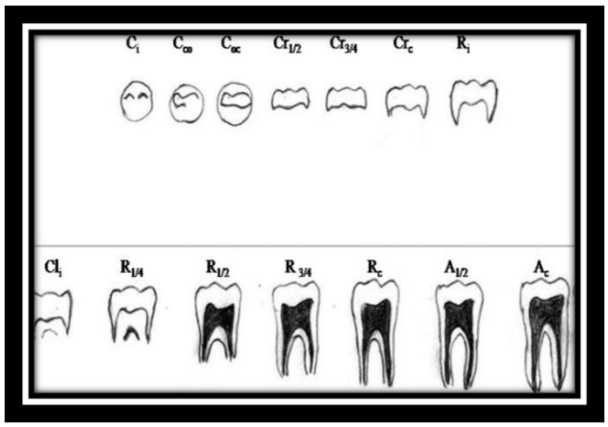

Fig 4: 14 stages of tooth formation of multi-rooted tooth (Moorees et al).

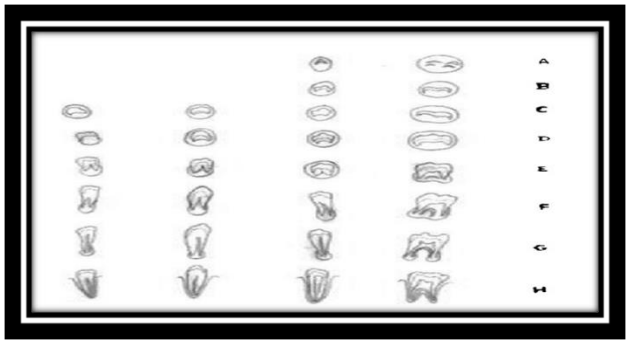

Fig 5: Eight stages (A to H) of mineralisation of tooth (Demirjian system).

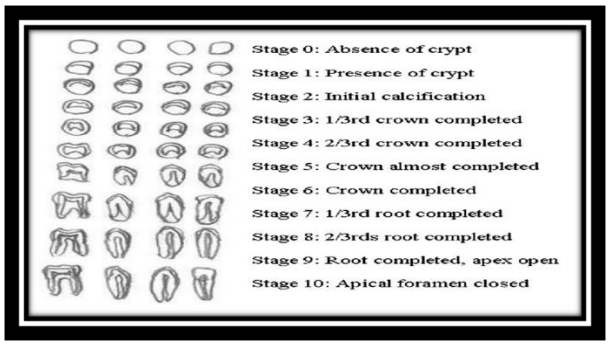

Fig 6: Ten stages of tooth formation with description (Nolla's method)

Tooth mineralisation

The most widely used methods of attainment of the developmental stages of tooth growth as a means of

estimating age, are based on assessment of the calcifying tooth which is divided into developmental stages discernible on dental radiographs.[9]

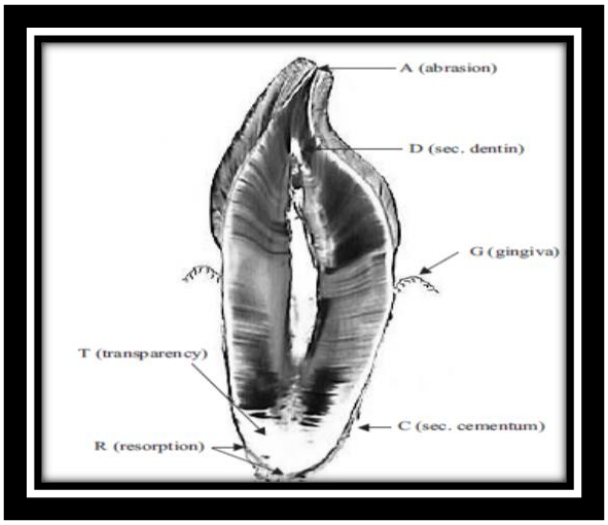

Fig 7: Five stages of lower third molar root development (Harris and Nortje` method)

Methods of dental age assessment

Pre-natal, neonatal and post-natal age estimation

Radiographically, the mineralisation of deciduous incisors starts at the sixteenth week of intrauterine life.[8] Before the mineralisation of tooth germs starts, the tooth germs may be visible as radiolucent areas on the radiograph; the subsequent radiographs of the mandible will depict the deciduous teeth in various stages of mineralisation as per the pre-natal age of the fetus.[10] A radiograph of the mandible of the fetus taken at the twenty-sixth week of intrauterine life shows advanced mineralisation in anterior teeth. The mineralised outline for the two cusps of the deciduous first molar, the one cusp outline for the deciduous second molar and the crypt of permanent first molar is seen.[11]

A radiograph of the mandible of the fetus taken at the thirtieth week of intrauterine life shows three-fifth crown completion for anterior teeth. The deciduous first molar cusps show fusion. The deciduous second molar with five cusps is seen, while there is no evidence of mineralisation in the permanent first molar [Figure-1].[11] While the radiograph of the newly born fetus shows completely fused cusps for the deciduous first and second molar, for the deciduous second molar there is no continuity across the occlusal surface. Within the crypt of the permanent first molar, there is evidence of a tip of one of the mesial cusps.[11]

Stages by Kraus and Jordan:

Kraus and Jordan [12] studied the early mineralisation in various deciduous

teeth as well as in the permanent first molar. The development is described in ten stages, denoted by Roman numerical from I to X; the IXth stage includes three stages, and the Xth stage includes five stages. [Figure-2]

Age estimation in children and adolescents

Methods applied for age determination in children and adolescents:

- Schour and Masseler method;
- Moorees, Fanning and Hunt method;
- Demirjian, Goldstein and Tanner method;
- Nolla's method (Figure 11); and
- Age estimation using open apices

Schour and Masseler method:

In 1941, Schour and Masseler [13] studied the development of deciduous and permanent teeth, describing 21 chronological steps from 4 months to 21 years of age and published the numerical development charts for them.[Figure-3]

Moorees, Fanning and Hunt method:

In this method, the dental development was studied in the 14 stages of mineralisation for developing single and multirooted permanent teeth and the mean age for the corresponding stage was determined.[Figure-4] Moorees et al. [14] used panoramic radiographs or lateral oblique radiographs for their study. The earliest age in the survey was six months, and the data also includes the development of the third mandibular molar. Notably, female development was ahead of the male, and the root formation stages showed variation compared with crown formation stages.[12]

Demerjian

In 1973 Demirjian et al[15] studied, 1446 boys and 1482 girls of French-Canadian origin and gave a new method of age estimation based on the

radiological appearance of the seven teeth on the left side of the mandible. [Figure-5] Each stage of the seven teeth was allocated a score, and the sum of the scores gave an evaluation of the subject's dental maturity, measured on a scale from 0 to 100. The dental maturity score of each subject was then converted to DA by using standard tables and/or percentile curves which were given for each gender, separately. [15]

Nolla

Each left permanent mandibular tooth was assessed and assigned a stage of between 1 (no sign of calcification) and 10 (apical end completed). [Figure-6] If the tooth was between stages an appropriate fraction (0.2, 0.5 or 0.7) was added as recommended by Nolla. The sum of scores was compared to the average sum for males or females, and DA calculated.[16]

Age estimation using open apices:

They were using panoramic radiographs of the patients, which were digitised for the analysis. The seven left permanent mandibular teeth were valued. [13,15]The number of teeth with root development completed with apical ends completely closed was calculated. For the teeth with incomplete root development, that is with open apices, the distance between inner sides of the open apex was measured. For the teeth with two roots, the sum of the distances between inner sides of two open apices was evaluated. The dental maturity was calculated as the sum of normalised open apices and the numbers of teeth with root development complete.[14]

Age estimation in adults

1. Volume assessment of teeth:

- pulp-to-tooth ratio method by Kvaal
- coronal pulp cavity index.

2. Development of the third molar:

- Harris and Nortje method
- Van Heerden system.

Volume assessment of teeth:

The age estimation in adults can be achieved by radiological determination of the reduction in size of the pulp cavity resulting from a secondary dentine deposition, which is proportional to

the age of the individual.[17]

Method by Kvaal et al:

In this method, pulp-to tooth ratio was calculated for six mandibular and maxillary teeth, such as maxillary central and lateral incisors; maxillary second premolars; mandibular

lateral incisor; mandibular canine; and the first premolar. The age is derived by using these pulpto-tooth ratios in the formula for age determination is given by Kvaal et al. .[18]

The coronal pulp cavity index:

The correlation between the reduction of the coronal pulp cavity and the chronological age was examined in a sample of 846 intact teeth from 433 individuals of known age and sex using panoramic X-ray photographs.[17] For each radiograph, only mandibular premolars and molars were considered, as the mandibular teeth are more visible than the maxillary ones. The side where the pulp chamber was more visible was chosen. Panoramic radiography was used to measure the length (mm) of the tooth crown (CL, coronal length) and the length (mm) of the coronal pulp cavity (CPCH, coronal pulp cavity height or length) (Figure 14). The tooth-coronal index (TCI) was computed for each tooth and regressed on the real age of sample.[17]

Development of third molar:

The radiographic age estimation becomes problematic after 17 years of age as eruption of permanent dentition completes by that age with the eruption of the third molar. Later, the development of the third molar may be taken as a guide to determine the age of the individual.[19]

Third molar development by Harris and Nortje method:

Harris and Nortje [20] have given five stages [Figure-7] of third molar root development. The males and females were surveyed separately and no significant differences were found between them.

Third molar development by Van Heerden system:

Van Heerden assessed the development of the mesial root of the third molar to determine the age. He described the development of the mesial root in five stages using panoramic radiographs. The males and females were surveyed separately, and no significant differences were found between them. [21]

Table 1: Number of tooth developmental stages by different authors.

Authors	Year	Sample size	Number of stages
Schour and Massler	1941	-	22
Gleiser and Hunt	1955	50	17
Garn et al.	1959	255	3
Hotz et al.	1959	298	11
Nolla	1960	50	10
Moorees et al.	1963	345	14
Nanda and Chawla	1966	720	12
Haavikko (modification of Gleiser and Hunt)	1970	1162	12
Johanson	1971	155	7
Liliequist and Lundberg	1971	287	8
Demirjian et al.	1973	2928	8
Gustafson and Koch	1974	41	4
Rosen (modification of Schour and Massler)	1981	760	19-22
Nortje	1983	500	8
Gat	1984	196	6
Kullman	1992	677	7
Mesotten et al. (modification of Gleiser and Hunt)	2002	1175	10
Sarnat	2003	693	7

DISCUSSION

Comprehensive knowledge of growth and development is fundamental in gaining an understanding of morphological variation in children. An assessment of the state of an individual's dental development can be important in the evaluation of his or her overall maturity and can be used to compare growth and health between individuals and populations. In addition, the state of dental development can be used to ascertain the age of an unidentified child.

To determine age, compare information obtained from the skeleton, that is the teeth, and then translates this morphology into an approximate chronological age. Dental age is, therefore, a predictor of actual age. Analysis of subadult dentition for ageing purposes seems to be fairly robust, especially since it has been determined that the formation of the teeth is reasonably resistant to environmental influences. Tooth formation is generally viewed as a progressive, continuous, and cumulative processes.

Various methods or surveys have been devised for evaluation of tooth mineralisation; the preferred ones are discussed here. Age estimation is relatively difficult in pre-natal and neonatal phases compared with the post-natal phase. Though a histological examination of tooth germs will be able to decide the age earlier in the prenatal phase, it will be an invasive and time-consuming procedure.4 From the pre-natal dental development of the fetus until the eruption of the first tooth into the oral cavity post-natally, the radiological examination of the jaw bones for the developing tooth germs will be the mainstay for the age assessment.

Various age estimation methods or dental development surveys are available, although they are different from each other. They provide us with two types of information: the sequence of developmental events and the timing at which these events occur.

The Schour and Masseler method have some drawbacks as these charts do not have separate surveys for males and females, and the mean age

range of 2–5 years is put at 6 months and is thus too narrow.[13] Later, Ublekar[22] modified these charts to widen these ranges. Regardless of these drawbacks, these charts are being used more commonly in age determination.

Although the method by Moorees et al[14] has separate surveys for males and females, the method by Demirjian et al[15] is the most highly recommended and developed of all dental age surveys. However, interobserver variation was found and is confined to ¡ one of the eight stages. Besides, the ratings in the survey are based on mandibular teeth only; hence the mandibular teeth need to be present for the survey to be applicable. Also, it does not include the third molar in the classification. Demirjian [15]determined that dental development has a close association with chronological age.

The advantage of Nolla's method is that it can be applied to an individual with or without the third molar.[16] For boys, there was no significant difference in values when both the methods were compared; this was in contradiction to girls where a significant difference in values was found. Overall, the mean dental ages were underestimated in both the methods and a significant difference was found between the estimated dental age and the chronological age.[23]

Age estimation in adults would be challenging as the development of dentition completes by this age, and there is no clue which could be reliable to assess the age. The two criteria that can be utilised for age determination in adults are an assessment of the volume of the pulp cavity and of third molar development. The reduction in the size of the pulp cavity resulting from deposition of secondary dentine with ageing as assessed by radiography can be taken as a guide to estimate the age of the individual.

Various authors have compared dental age with chronological age and skeletal age. Scheuer and Black identified three phases that comprise skeletal development including (1) formation of the centres of ossification, (2) the growth of the centres of ossification, and (3) the time during which fusion of the centre with a separate centre of ossification occurs. Recently, volume matching of teeth imaged by cone-beam CT41 and the X-ray microfocus CT21 can be used to obtain pulp vs tooth volume ratio. Conventional Xrays provide two-dimensional information at low resolution while this technique allows the three-dimensional structure of the root canal of the extracted tooth. It works with the same scanning principle as in medical CT; however, the spatial resolution is an order of magnitude higher.[24]

In all the methods used for age determination, the evaluation of radiographs for stages of tooth calcification is the most reliable as tooth calcification can be observed from radiographs for a period of several years [25,] and it is not altered by local factors such as lack of space or over retention of deciduous teeth. It also allows the assessment of the period when no clinical tooth emergence takes place.[3] Additionally, age estimation would be relatively accurate since the number of teeth passing through various stages of calcification is available.

CONCLUSION

Radiology has become an essential tool in the processes of human age identification. There cannot be rigid guidelines regarding age estimation. Hence the degree of dental certainty or probability of the findings may be specified. Use of multiple age estimation methods, multiple teeth and experienced investigators aid towards the optimal age estimation.[26]

CONFLICTS OF INTEREST

The authors declare they have no potential conflict of interests regarding this article.

REFERENCES

1. Saunders E. 'The Teeth A Test of Age' considered with the reference to the factory children, addressed to the members of both Houses of Parliament. London: Renshaw, 1837, pp 47-56.

2. Matsikidis G, Schultz P. Alterbestimmung nach dem Gebbis mit Hilfe des Zahnfilms. Zahnarztl Mitt 1982; 72: 2524–2528.

3. Ciapparelli L. The chronology of dental development and age assessment. In: Clark DH, (ed). Practical forensic odontology. Oxford:

Wright Butterworth-Heinemann Ltd, 1992, pp 22–42.

4. Babar MG, Iqbal S, Jan A. Essential guidelines for forensic dentistry. Pakistan Oral Dent J 2008; 27: 79–84.

5. Ardakani F, Bashardoust N, Sheikhha M. The accuracy of dental panoramic radiography as an indicator of chronological age in Iranian individuals. J Forensic Odontostomatol 2007; 25: 30–35.

6. Drusini A, Calliari I, Volpe A. Root dentin transparency: age determination of human teeth using computerised densitometric analysis. Am J Phys Anthropol 1991;85:25- 30.

7. Paewinsky E, Pfeiffer H, Brinkmann B. Quantification of secondary dentine formation from orthopantomograms—a contribution to forensic age estimation methods in adults. Int J Legal Med 2005;119:27-30.

8. Hagg U and Taranger J (1986). Timing of tooth emergence. A prospective longitudinal study of Swedish urban children from birth to 18 years. Swedish Dental Journal; 10: 195-206.

9. Drusini AG. The coronal pulp cavity index: A forensic tool for age determination in human adults. Cuad Med Forensic 2008; 53– 54: 235–249.

10. Masthan KMK. Age and sex. Textbook of forensic odontology. New Delhi: Jaypee Brothers Medical Publishers (P) Ltd, 2009, pp 59–65.

11. Whittakar DK, McDonald DG. Age determination from teeth. A color atlas of forensic dentistry. England: Wolfe Medical Publications Ltd, 1989, pp 58–66.

12. Solheim T, Sundnes PK. Dental age estimation of Norwegian adults: a comparison of different methods, Forensic Sci Int 1980;16:7-17.

13. Schour I and Massler M (1941). The development of the human dentition. Journal of the American Dental Association; 28: 1153-60.

14. Moorrees CFA, Fanning EA and Hunt EE (1963). Age variation of formation stages for ten permanent teeth. Journal of Dental Research; 42: 1490-1502.

15. Demirjian A and Goldstein H (1976). New systems for dental maturity based on the seven and four teeth. Annals of Human Biology; 3(5): 411-21.

16. Acharya AB, Vimi S. Effectiveness of Bang and Ramm's formulae in age assessment of Indians from dentin translucency length. Int J Leg Med 2009;123:483-488.

17. Kvaal S, Kollveit K, Thomsen I and Solheim T (1995). Age estimation of adults from dental radiographs. Forensic Science International; 74: 175-85.

18. Nuzzolese E, Di Vella G. Forensic dental investigations and age assessment of asylum seekers. Int Dent J 2008; 58: 122–126.

19. Nortjé CJ (1983). The permanent third molar. It's value in age determination. Journal of Forensic Odonto-Stomatology; 1: 27-31

20. Bang G, Ramm E. Determination of age in humans from root dentine transparency. Acta Odontol Scand 1970;28:3-35

21. Cameriere R, Ferrante L, Cingoloni M. Age estimation in children by measurement of open apices in teeth. Int J Legal Med 2006; 120: 49–52.

22. Vandevoort FM, Bergamans L, Cleyenbreugel JV, Bielen DJ, Lambrechts P, Wevers M. Age calculation using X-ray microfocus computed tomographical scanning of teeth: A pilot study. J Forensic Sci 2004; 49: 787–790.

23. Kurita LM, Menezes AV, Casanova MS, Haiter-Neto F. Dental maturity as an indicator of chronological age: Radiographic assessment of dental age in a Brazilian population. J Appl Oral Sci 2007; 15: 95–104.

24. Solheim T. Dental color as an indicator of age. Gerodontics. 1988;4:114-8.