

**DENTAL RADIOLOGY: AN ADJUNCTIVE AID IN AGE ESTIMATION**<sup>1</sup> Kusum Singal<sup>1</sup> Junior Research Fellow<sup>2</sup> Neelkamal<sup>2</sup> Assistant Professor<sup>1,2</sup> Department of Genetics, Maharshi Dayanand University, Rohtak, Haryana.

**ABSTRACT:** The concept of using radiographic methods for age estimation has kindled so much interest in the field of forensic dentistry in past few decades. Aim and Objectives: To evaluate the different dental radiographic methods for age estimation and their significance in the field of forensic dentistry. Methodology:- 64 articles were collected after an extensive literature review. Literature survey of these articles was done. Conclusion:-Radiographic methods play an indispensable role in age estimation specifically in living persons because of their non-invasive and non-destructive nature. This review paper focus on different radiographic methods and new developments available for radiological dental age estimation and their effective aid in identification and crime investigation.

**KEYWORDS:** Age estimation, Radiographic methods, Forensic Odontology, Identification, Dental Radiology

**INTRODUCTION**

In the field of forensic anthropology and forensic dentistry, identification of unknown becomes an important question to answer. Photographs, identity cards and some advance methods based on DNA, biometrics and dental patterns are some of the tools that can be used for identification<sup>[1]</sup>. But, all these methods of identification have certain limitations specially when bodies are badly decomposed, mutilated and charred or in cases where only small skeletal remains are left<sup>[2,3]</sup>. That's why others methods of identification should be considered.

Among the biological parameters of individualization of human remains, both sex and age are essential<sup>[4]</sup>. Age estimation plays a significant role in various criminal cases as well as to clarify civil liability and social issues and also in forensic medicine, pediatric endocrinology, clinical dentistry, and archaeology<sup>[5,6,7,8]</sup>. Forensic Age Estimation (FAE) is defined as "Expertise in forensic medicine which aims to define in the most accurate way the chronological age of person of an unknown age involved in judicial or legal proceedings"<sup>[9]</sup>. Although various methods for age estimation exists in literature but a universal system has not been achieved<sup>[10,11,12,13]</sup>.

Frequently used techniques for estimation of age are based on bone remodelling in pelvis, sternal ends ribs, developments stages of various ossification centres and long bones; degree of closure of cranial sutures; and physiological and degenerative changes in dental tissues<sup>[14]</sup>. Application of multiple age indicators at the same time will provide more accurate results. But when these methods are analyzed separately, dental age estimation

techniques offer more accurate results than other methods.<sup>[15,16,17,18]</sup>

**Importance of teeth as age indicator**

Development pattern of teeth is very predictable in nature because they are tightly constrained by genetics<sup>[19,20,21]</sup>. They are preserved for a longer period of time and thus used for more accurate age estimation. Teeth consist of enamel (outermost covering of crown), dentin and cementum (outermost covering of root) which makes it resistant to decomposition<sup>[22,23,24,25]</sup>.

**Significance of radiographic methods**

In recent years, various age estimation methods based on morphological, biochemical, radiological and histological characteristics of dentition have been utilized by experts for medicolegal purposes<sup>[26,27]</sup>. Morphological methods are subjective in nature and predict a wider range of age. Biochemical and histological methods are destructive methods as these methods require teeth to be extracted that cannot be possible for every case specially in living persons<sup>[28]</sup>. This makes usage of dental radiographs, a more practical and relevant approach for age estimation in living individuals as it is non-destructive in nature<sup>[29]</sup>.

**Types of dental Radiographs**

Various types of radiographs can be used for age assessment such as intraoral periapical radiographs commonly known as IOPA, lateral cephalometric

radiographs, panoramic radiographs, digital imaging technologies like Orthopantomogram (OPG), Radiovisiographs (RVG), Cone beam computed tomography (CBCT) [30]. There are many features which can be assessed i of age:- [30,31,32,33,34,35,36]

1. Appearance of Jaw bones pre-natally.
2. Tooth germs appearance.
3. Different mineralization stages in deciduous teeth.
4. Stages of crown completion.
5. Eruption of crown.
6. Root completion level.
7. Resorption rate in primary teeth.
8. Open Apex measurements in teeth.
9. Third molar development.
10. Assessment of Physiologic Changes in teeth as dentine and cementum deposition.
11. Tooth-to-pulp ratio.
12. Pulp Volume assessment.

For estimation of age, broadly three phases are used. First phase is age assessment in neonates before birth (prenatal), at the time of birth (neonatal) and after birth (post natal). Second phase is age assessment in children and adolescents (up to age of 17 years). Third phase is age assessment in adults (after age of 18 years) [31].-

#### First Phase

**Age assessment in neonates:** As the tooth germs starts developing in the sixteenth week of intrauterine life, they appear on radiographs as radiolucent areas. After twenty-sixth week, anterior teeth of foetus showed advanced mineralization. [37, 38]. Karus and Jordan categorized the mineralization degree of primary teeth into 10 stages [37, 38].

#### Second Phase

**Age assessment in Children and Adolescents:** Methods used in children and adolescents are based on radiographic analysis of various development stages of teeth and eruption in the oral [39]. Mineralization process of permanent teeth is divided into various stages by different researchers for the purpose of age estimation such as Schour and Masseler published some development charts [39]. Moorees, Fanning and Hunt classified the tooth development into fourteen stages [40]. Demirjian, Goldstein and Tanner described tooth development into eight stages [41,42,43,44]. Chaillet and Demerjian have derived a modification in original method and divided the calcification of teeth into ten stage (0-9) [45]. Nolla conducted another study to overcome the limitations of previous studies and divided the mineralization levels of teeth into ten stages. This method can be applied even in absence of third molar [46].

#### Third Phase:

**Age assessment in Adults:** Radiographic age estimation becomes complicated in adults as all permanent teeth got erupted in the oral cavity [47]. Development of third molar and changes in tooth-pulp area/volume are important parameters that can be used for age assessment in adults. Developmental stages of third molar described as age indicator of an individual in various studies. [47,48,49,50]. Van Heerden and Harris described the development of the mesial root of the third molar in five stages using dental Radiographs [48,49,50]. Changes in tooth-pulp area/volume is also proved a significant tool for age estimation. Ikada and his associates studied the correlation between the chronological age and coronal tooth pulp index. Formula given as,

$$TCI = \frac{CPCH \times 100}{CL}$$

Where, CPCH is coronal pulp cavity height and CL is coronal length in mm [51,52]

Kvaal calculated some measurements on intraoral radiographs of six mandibular and maxillary teeth as pulp, tooth, root lengths and their ratios at three different level [53]. In a study conducted by Robert Cameriere, age estimation was done using pulp tooth area ratios in 100 individuals aged between 18 to 72 years in right maxillary canines using orthopantomographs (OPG) [54,55,56,57,58]. Further studies were done by Jeevan, Zaher, Babshet and Acharya using this method. All these studies showed significant results and proved that change in tooth- pulp area can be used for determining the age of individual [59,60,61].

#### Advanced Radiographic Techniques [62]

Cone beam computed tomography (CBCT) is a non-invasive developing technique based on pulp/tooth volume assessment used for age estimation and gender determination. It is designed to reduce dose of radiation and to provide high resolution. Singaraju also has done study on age estimation using pulp/tooth area ratio in right maxillary canines and monoradicular teeth [63,64].

#### CONCLUSION

As lot of research had been done in area of age estimation, numerous radiographic methods are available in literature for assessing dental age. But there is no study till now describing which digitized parameters are best suited for age determination in different age groups. More than one method of age estimation should be used to get a more effective and reproducible age range. To achieve more accurate age estimation, there is need for a corroborative population specific study with larger samples

of varying age groups. Development of this population specific age estimation tool may be significant to forensic odontologists and anthropologists in various civil and crime cases.

**Conflict of interest:** None

**Source of Funding:** None

#### References

- Acharya AB, Sivapathasundharam B. Forensic Odontology. In: Rajendran R, Sivapathasundharam B, editors. Shafer's text book of oral pathology. 6th ed. Noida, Elsevier publ; 2009. p. 871.
- Stefen C. Enamel structure of arctoid carnivora: Amphicyonidae, Ursidae, Procyonidae and Mustelidae. *J Mammal* 2001;82:450-2.
- Holland MM, Cave CA, Holland CA, Bille TW. Development of a quality, high throughput DNA analysis procedure for skeletal samples to assist with the identification of victims from the World Trade Center attacks. *Croat Med J* 2003;44:264-72.
- Komar DA. forensic anthropology: Contemporary theory and practice, oxford university press, new York, 2008.
- Lewis JM and Senn DR. Dental age estimation utilizing third molar development: A review of principles, methods, and population studies used in the United States. *Forensic Sci. Int.* 2010; 201(1-3):79-83.
- Ferenandes M, Pereira D, Braganca P, de Lima SH, Francesquini Junior L et al. Estimation by Measurements of Developing Teeth: Accuracy of Cameriere's Method on a Brazilian Sample. *J Forensic Sci.* 2011;56:1616 – 9.
- Schmeling A, Geserick G, Reisinger W, Olze A. Age estimation. *Forensic Sci Int.* 2007; 165:178–181.
- Rai B and Anand SC. Age estimation in children from dental radiograph: A regression equation. *Int J Biol Anthropol* 2008; 1:1–5.
- Ritz-Timme S, Cattaneo C, Collins MJ, Waite ER, Schütz HW, Kaatsch HJ, Borrman HI. Age estimation: the state of the art in relation to the specific demands of forensic practise. *Int J Legal Med.* 2000;113(3):129-36
- Willems G. A review of the most common used dental age estimation techniques. *J. Forensic Odontostomatol.* 2001; 1:1-9.
- Cattaneo C, De Angelis D, Ruspa M, Gibelli D, Cameriere R, et al. How old am I? Age estimation in living adults: a case report. *J Forensic Odontostomatol.* 2008; 26: 39-43.
- Baccino E, Schmitt A. Determination of adult age at death in the forensic context. In: Schmitt A, Cunha E, Pinheiro J, editors. *Forensic anthropology and medicine.* New York: Humana Press : 2006; 259-280.
- Warhekar AM, Wanjari PV, Phulambrikar T. Correlation of radiographic and chronological age in human by using demirjian's method: a radiographic study. *J Indian Academy Oral Med Radiol* 2011;23:1-4.
- Martrille L, Ubelaker DH, Cattaneo C, Seguret F, Tremblay M, Baccino E. Comparison of Four Skeletal Methods for the Estimation of Age at Death on White and Black Adults. *J of Forensic Sci.* 2007; 52(2):302-07.
- Baccino E, Ubelaker DH, Hayek LA, Zerilli A. Evaluation of seven methods of estimating age at death from mature human skeletal remains. *J Forensic Sci.* 1999; 44(5):931–6.
- Rogers and Spencer L. *Personal Identification from Human Remains.* Springfield: Thomas Books. 1987.
- Rogers and Spencer L. *The Personal Identification of Living Individuals.* Springfield: Thomas Books. 1986.
- Rogers and Spencer L. *The Testimony of Teeth: Forensic Aspects of Human Dentition.* Springfield: Thomas Books. 1988.
- Willems G. A review of the most commonly used dental age estimation techniques. *J Forensic Odontostomatol.* 2001;19:9–17.
- Amandeep S, Gorea RK, Singla U. Age Estimation from Physiological Changes of Teeth. *J Indian Forensic Sci.* 2004;26:0971-3.
- Maber M, Liversidge HM, Hector MP. Accuracy of age estimation of radiographic methods using development teeth. *Forensic Sci. Int.* 2006;159(1):68–73.
- Yang FR, Jacobs GW. Dental age estimation through volume matching of teeth imaged by cone-beam CT. *Forensic Sci. Int.* 2006;159:S78–S83.
- Someda H, Saka H, Matsunaga, S, Ide Y, Nakahara K, et al. Age Estimation Based on Three-Dimensional Measurement of Mandibular Central Incisors in Japanese. *Forensic Sci Int.* 2009;185:110–14.
- Joseph CC, Reddy BHS, Cherian NM, Kannan SK, George G, et al. Intraoral Dental Radiography for Adult Age Estimation: A Reliable Technique. *J Indian Academy Oral Medi Radiol.* 2013;25:287–90.
- Limdiwala PG, Shah JS. Age estimation by using dental radiographs. *J Forensic Dent Sci* 2013;5:118-22.
- Takasaki T, Tsuji A, Ikeda N, Ohishi M. Age Estimation in Dental Pulp DNA Based on Human Telomere Shortening. *Int J Legal Med.* 2003;117:232-34.
- Shrestha J. Comparative Evaluation of Two Established Age Estimation Techniques (Two Histological and Radiological) by Image Analysis Software Using Single Tooth. *Forensic Res.* 2014;5:1-6.
- Meinl A. The Application of Dental Age Estimation Methods: Comparative Validity and Problems in Practical Implementation. Doctoral Dissertation. Department of Anthropology, University of Vienna, 2008.
- Babshet M, Acharya AB, Naikmasur VG. Age estimation in Indians from pulp/tooth area ratio of mandibular canines. *Forensic Sci Int.* 2010;197:125.
- Dayal PK. *Textbook of Forensic Odontology.* 1st ed. Paras Medical Publishers 1998:1-267.
- Karjodkar FR. Role of dental radiology in forensic odontology. *Text book of dental and maxillofacial radiology.* 2nd ed. Jaypee Brothers Medical Publishers (P) Ltd 2009:929–63.
- Nuzzolese E, Lusito S, Solarino B, Di Vella G. Radiographic dental implants recognition for geographic evaluation in human identification. *J Forensic Odontostomatol* 2008; 27(1):8-11.

33. Kvaal S.I., Kolltveit K.M., Thomsen I.O., and Solheim, T. Age estimation of adults from dental radiographs. *Forensic Science International* 1995; 74: 175-185.
34. Shamim T, Ipe Varghese V, Shameena PM, Sudha S. Age Estimation: A Dental Approach. *JPAFMAT*, 2006; 67:116-121.
35. Grandmaison GL, Banasr A, Durigon M. Age estimation using radiographic analysis of laryngeal cartilage. *Am J Forensic Med Pathol* 2003; 24:96-9.
36. Pretty IA and Addy LD. Associated post-mortem dental findings as an aid to personal identification. *Sci Justice* 2002; 42:65-74.
37. Masthan KMK. Age and sex. *Textbook of forensic odontology*. 1st ed. New Delhi: Jaypee Brothers Medical Publishers (P) Ltd 2009:59-97.
38. Whittakar DK and McDonald DG. Age determination from teeth. *A color atlas of forensic dentistry*. England, Wolfe Medical Publications Ltd 1989;58-66.
39. Rajendran R and Sivapathasundharam B: *Shafer'S Textbook of Oral Pathology : Forensic odontology : Fifth edition: Elsevier 2006 : 1199-1224*
40. Schour I and Massler M. Development of human dentition. *J Am Dent Assoc* 1941; 20:379-427.
41. Moorees CFA et al .Determination of age from formation stages of permanent teeth: *J Dent Res* 1968; 52:264-73.
42. Demirjian A., Goldstein H., Tanner J.M. A new system of dental age assessment. *Hum Biol* 1973;45:211-27.253
43. Mimkin K and Kleinman PK. Imaging of child abuse. *Pediatr Clin North Am* 1997; 44:615-35.
44. Balwant Rai and S.C. Anand *Tooth Developments: An Accuracy of Age Estimation of Radiographic Methods*. *World J. Med. Sci.*, 1 (2): 130-132, 2006.
45. Chaillet N, Demirjian A. Dental maturity in South France: A comparison between Demirjian's method and polynomial functions. *J Forensic Sci*. 2004;49:1059-66.
46. Nolla CM. Development of the permanent teeth. *J Dent child* 1960; 27:254-66.
47. Rajendran R and Sivapathasundharam B: *Shafer'S Textbook of Oral Pathology : Forensic odontology : Fifth edition: Elsevier 2006 : 1199-1224*.
48. Harris MPJ and Nortje CJ. The mesial root of the third mandibular molar. *J Forensic Odontostomatol* 1984; 2:39-43.
49. Vandervoort FM, Bergmans L, Van Cleynenbreugel J, Bielen DJ, Lambrechts P, Wevers M, Peirs A, Willems G. Age calculation using X-ray microfocus computed tomographical scanning of teeth: a pilot study. *J Forensic Sci*. 2004 Jul; 49(4):787-790.
50. Panchbhai AS. *Dental radiographic indicators, a key to age estimation. Dentomaxillofacial Radiology*. 2011; 40:199-212.
51. Ikeda N, Umetsu K, Kashimura S, Suzuki T, Oumi M. Estimation of Age from Teeth with Their Soft X-Ray Findings. *JPN J For Med*. 1985;39:244-50.
52. Drusini AG. The coronal pulp cavity index: A forensic tool for age determination in human adults. *Cuad Med Forensic* 2008; 53:235-49.
53. Kvaal SI, Kolltveit KM, Thomsen IO, Solheim T. Age estimation of adults from dental radiographs. *Forensic Sci Int* 1995;74:175-85.
54. Cameriere R, Ferrante L, Math D, Cingolani M. Variations in pulp/tooth area ratio as an indicator of age: A preliminary study. *J Forensic Sci* 2004;49:317-19.
55. Cameriere R, Ferrante L, Cingolani M. Age estimation in children by measurement of open apices in teeth. *Int J Legal Med*. 2006; 120:49-52.
56. Cameriere R, Ferrante L. Age estimation in children by measurement of carpals and epiphyses of radius and ulna and open apices in teeth: A pilot study. *Forensic Sci Int*. 2008; 174:59-62.
57. Cameriere R, Brkic H, Ermenc B, Ferrante L, Ovsenik M, Cingolani M. The measurement of open apices of teeth to test chronological age of over 14 years in living subjects. *Forensic Sci Int*. 2008; 174:217-21 5.
58. Cameriere R, Ferrante L, Liversidge HM, Prieto JL, Brkic H. Accuracy of age estimation in children using radiograph of developing teeth. *Forensic Sci Int*. 2008; 176:173-7.
59. Jeevan MB, Alka DK, Punnya VA, Seema H. Age estimation by pulp/tooth area ratio in canines: Cameriere's method assessed in an Indian sample using RadioVisioGraphy. *Forensic Science Int*. 2010;204(1)209 :1-5.
60. Zaher JF, Fawzy IA, Habib SR, Ali MM. Age estimation from pulp/tooth area ratio in maxillary incisors among Egyptians using dental radiographic images. *J Forensic Leg Med* 2011;18:62-65.
61. Babshet M, Acharya AB, Naikmasur VG. Age estimation in Indians from pulp/tooth area ratio of mandibular canines. *Forensic Sci Int* 2010;197:1-125.
62. Olze A, Bilang D, Schmidt S, WerneckekD, Geserick G, Schmeling A. Validation of common classification systems for assessing the mineralization of third molars. *Int J Legal Med* 2005; 119:1-8.
63. Yang F, Jacobs R, Willems G. Dental age estimation through volume matching of teeth imaged by cone-beam CT. *Forensic Sci Int* 2006;159:78-83.
64. Singaraju S, Sharada P. Age estimation using pulp/tooth area ratio: a digital image analysis. *J Forensic Dent Sci* 2009;1(1): 37-41.

## Corresponding Author

**Dr. Neelkamal, MSc, PhD**

Assistant Professor,

Department of Genetics,

Maharshi Dayanand University, Rohtak,

Haryana

Email: [neelgenetics@yahoo.com](mailto:neelgenetics@yahoo.com)

Phone No.:-09728534170