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. 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. 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. 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. Foresnic 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.” Although various methods for age estimation exists in literature but a universal system has not been achieved.

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. 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.
LITERATURE REVIEW

IMPORTANCE OF TEETH AS AGE INDICATOR

Development pattern of teeth is very predictable in nature because they are tightly constrained by genetics\cite{22,23,24,25}. 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\cite{22,23,24,25}.

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\cite{26,27}. 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\cite{28}. 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\cite{29}.

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)\cite{30}. There are many features which can be assessed i of age\cite{31,32,33,34,35}.

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 Physiological 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)\cite{36}:

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\cite{37,38}. Karus and Jordan categorized the mineralization degree of primary teeth into 10 stages\cite{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\cite{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\cite{40}. Moorees, Fanning and Hunt classified the tooth development into fourteen stages\cite{41}. Demirjian, Goldstein and Tanner described tooth development into eight stages\cite{42,43,44}. Chaillat and Demerjian have derived a modification in original method and divided the calcification of teeth into ten stage\cite{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\cite{46}.

THIRD PHASE

Age assessment in Adults: radiographic age estimation becomes complicated in adults as all permanent teeth got erupted in the oral cavity\cite{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\cite{48,49,50}. Van Heerden and Harris described the development of the mesial root of the third molar in five stages using dental radiographs\cite{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\cite{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\textsuperscript{[33]}. 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 orthopantamographs (OPG) \textsuperscript{[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\textsuperscript{[59,60,61]}.

**ADVANCED RADIOGRAPHIC TECHNIQUES\textsuperscript{[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\textsuperscript{[63,64]}.

**CONCLUSIONS**

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.

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