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Dental Science

TEETH AS A TOOL IN AGE ESTIMATION: A REVIEW

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ABSTRACT Age estimation is essential in the field of forensic sciences for the identification of diseased victims and also for crimes and accidents. Dental maturity plays an important role in estimating the age of individuals because of the low variability of dental indicators. Chronological age, recorded by registration of birth date, is referred throughout an individual's life. Age is an essential factor not only in clinical practice & research but also in the court of law. Dental age is vital as tooth development shows less variability than other developmental features and hence the different age estimation methods using dental tissues and their eruption sequence of the teeth became crucial in establishing the age of an individual especially those persons in the interest of forensic science. This paper discusses different methods of age estimation using teeth as possible indicator for the biological age, growth & development of the body.

KEYWORDS : Chronological age, Dental age, Radiographic method.

INTRODUCTION

Teeth are instrumental in estimation of age and the formation of deciduous teeth begins in utero at about four months, while permanent teeth[1] complete the configuration at approximately 25 years of age[2]. Usually chronological age is recorded by registration of date of birth and age is an essential factor in clinical practice[3], research and court of law. Various methods have constructed and tested to determine the age of young individuals[4]. Among them include the physical examinations using anthropometric measurements[5], skeletal maturation[6], dental age estimation, a combination of dental development and anthropometric measurements, and a combination of skeletal and tooth eruption.

Need for Dental Age Estimation[1]

Age estimation is an essential step in constructing a biological profile from human skeletal remains, also widely used in estimating the chronological age of children of unknown birth records and for medico-legal purposes. Estimation of age at death and determination of gender of the victim or remains are essential to help in the process of identification[2]. A distinction is there between forensic age estimation of unidentified corpses and skeleton for identification purposes on one hand and on living persons on other hand. In case of living persons, genetic and geographic origin and concomitant socio-economic status must also be taken into account. In case of corpses, crucial factors are the quality and quantity of the mortal remains. In the process of identification of age, usually in the first and second decades, teeth are the most reliable tools.

Dental Age Estimation Methods

Based on the technique used for the determination of the age[2], the dental age estimation methods are classified as follows: Visual or Clinical, Radiographic, Histological, Chemical and Physical analysis.

Visual or Clinical Method:

Visual observation of the stage of the teeth eruption and evidence of changes due to functions like attrition, changes in color can give an approximate estimate of age. With this method approximate age estimation can be done, based on the evaluation of the dentition, considering the tooth wear/attrition, tooth color and stains, periodontal status, etc. which can provide valuable information of an individual's development and age[3]. However, tooth wear may not be reliable in age estimation, as tooth wear is influenced by various factors that include functional or parafunctional habits, patterns of mandibular movement, bite force, saliva, diet, medication, diseases, geographical location, occupational and habitual environment and gender.

Radiographic Method:

The most commonly used method aiding in age determination over a long period, using the radiographs of the dentition by determining the stage of development of the teeth. Various radiographic aids used in age estimation are intraoral periapical radiographs, lateral oblique radiographs, cephalometric radiographs, panoramic radiographs along with the digital imaging and advanced imaging modalities. The radiographic method[2,3] is a simple, non-invasive and reproducible method that can be employed both on living and unknown dead. In adults, following completion of the growth period, the accuracy of age estimation by radio graphical method becomes insufficient.

Histological Method:

The histological methods determine more accurately the stage of development of the dentition and can detect the mineralization before being detected in the radiographs. This technique is more appropriate for postmortem situations and is also significant in the estimation of age of early development. However, histological methods[3] require the tissue preparation necessitating the extraction or avulsion of teeth for the microscopic examination.

Chemical and Physical Analysis:

Formation of tooth involves continuous deposition of ions at different ages. Hence, alteration in the ion levels can be used for age estimation by chemical and physical methods[2,3]. While these techniques are not of great value to the forensic odontologist, future developments may provide an adjunctive of collecting evidence of value.

Based on the age of the individuals, the estimation methods can be categorized into age estimation in prenatal, neonatal & early postnatal child, in children & adolescents and in adults.

Age Determination in Prenatal, Neonatal & Early Postnatal Stage:[1,2]

Age estimation in this group can be accurate as it can be correlated with the development of deciduous & permanent teeth. The primary tooth germ begins to form at seven weeks in utero (IU). Determination of age during the development of dentition obtained with an accuracy of "plus or minus one year," and during the early part of this period,

microscopic examination of teeth may provide the age with an accuracy of "plus or minus few days." The histological methods are used to assess the stage of tooth development during the mineralization period in prenatal, natal, and neonatal periods. One of the earliest studies by Kraus and Jordan (1965)[3] elaborated various stages of early mineralization of the deciduous teeth and first permanent molar during intrauterine development.

Kraus and Jordan stated that the calcification proceeded faster mesiodistally than vertically. The Kraus and Jordan method[3] categorized the development into 10 stages, while each stage is denoted by Roman numerals I to X; the IXth stage consists of three stages, and the Xth stage consists of five stages.(figure 1)

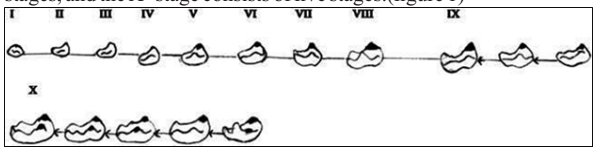

Figure 1. The Kraus And Jordan Method Of Staging

STACK'S METHOD of age determination from tooth in infants and fetus is based on weight of the erupting teeth of infants and fetuses. According to him by weighting the teeth, age estimation can be done but only with the age in between 5 months in utero to postnatal age of 7 months.

In **BOYDE'S METHOD** of age estimation in infants, counting the cross striations on the enamel of the tooth (also known as incremental lines) from the neonatal line onwards were used to depict the age of dead infant.

Dental Age Estimation in Children and Adolescents:
Dental age estimation in children and adolescents[1] is based on the tooth calcification and time of emergence of the tooth in the oral cavity.

Schour and Masseler Method: Schour and Masseler[7] studied the development of deciduous and permanent teeth in 1941, describing 21 chronological steps starting from 4 months to 21 years of age, and published the numerical development charts. It was originally intended just as a guide for dentists, but later it has been widely used for the age estimation in archaeology. This method is sufficiently accurate to estimate dental age of children (5-16years) and can be used acceptably.

C M Nolla[8] in 1960 developed a method in which development of each tooth was divided into ten recognizable stages and categorically numbered 1-10. By this method, the development of each tooth of the maxillary and mandibular arch could be assessed. It can be applied to an individual with or without the third molar and that girls and boys are dealt with separately. The increased number of stages may complicate the assessment and decrease accuracy of the method.

Moorees, Fanning and Hunt Method: In this method, the dental development was studied in the 14 stages of mineralization for developing both single and multi-rooted. Mean age and the permanent teeth for the corresponding stage were determined. This method mainly uses the IOPAR of mandibular canines. This method[9] is useful to assess the child's dental development with regard to the skeletal developmental stage and for planning orthodontic treatment. They have also been used for age estimation of skeletal remains.

Cameriere's Method: In this method[10], the dental age can be calculated based on the relationship between the age and measurement of open apices in teeth. The number of teeth with closed apical ends and complete root development noted as N0. The distance between the sides of the open apex is measured (A) in the teeth, with incomplete root development. The values substituted in the following formula.

$$\text{Age} = 8.971 + 0.375g + 1.631 \times 5 + 0.674\,N0 - 1.034s - 0.176s\,N0$$

The g is a variable equal to 1 for boys and 0 for girls, and many authors had found Cameriere's method with some modifications based on the ethnic & geographic distribution of the sample population to be the most accurate method of age estimation. This method can be used for assessing age in forensic as well as legal contexts and based on these variables chronological age can be determined. However the third molar was excluded in this method.

Haavikko Method: Based on the cross-sectional data obtained from radiographs of 1162 Finnish children between the age of 2 and 21 years, twelve radiographic stages of 4 permanent were given by Haavikko[11] in 1974 to evaluate the dental age and this method is useful where some of the permanent teeth may be congenitally missing.

Demirjian, Goldstein, and Tanner Method: In 1973, Demirjian introduced a method that estimated chronological age based on the development of seven teeth from the left side of the mandible. This method is similar to that of Tanner[4], Whitehouse[7], and Healy[12], who estimated chronological age based on the maturity of hands and wrists.

Demirjian and Goldstein together in 1976, have modified this method, where seven left permanent mandibular teeth are analyzed and divided into eight developmental stages. With the assessment of the formative stages of the left mandibular teeth, the individual scores are summated.

Demirjian and Goldstein's method is simple, as it is an ortho pantomogram based method and it enables more reliable standardization and has good reproducibility and intra-examiner/ inter-examiner reliability. The evaluation cannot be applied in children lacking teeth. This method may not express the retardation of dental development [excluding third molars] due to systemic diseases.

A study on the Belgian Caucasian population and formed new tables for dental maturity for boys and girls, considered as modification of **Willem's method[3].** This method is also simple and retains the advantage of Demirjian's method, and there was a reduction in the overestimation of the dental age.

Gustafson's Method(1950): Gustafson(1950)[13] and Thoma (1944) described the age changes occurring in the dental tissues and noted six changes related to age. They are: Attrition of the incisal or occlusal surfaces due to mastication(A), Periodontitis(P), Secondary dentin(S), Cementum apposition(C), Root resorption(R), Transparency of the root(T).

Gustafson suggested the last two changes. In the method proposed, each sign was ranked and allotted 0, 1, 2, 3 points. The point values of each age-change are added according to the following formula:
$A_n + P_n + S_n + C_n + R_n + T_n = \text{points}$.

The exact equation calculated was: y = 11.43 + 4.56x, where, y = age and x = points according to the formula above. The error of estimation as calculated by Gustafson (1950) was ±3.6 years. This mehod cannot be used in living person.

Dalitz Method(1962): Dalitz[13] re-examined Gustafson's method and suggested a 5-point system from 0-4, instead of the 4-point system that was previously used. This change was proposed in order to give a slightly greater accuracy. The results showed that root resorption and secondary cementum formation could be disregarded. Dalitz suggested this below formula.

$$E = 8.691 + 5.146A + 5.338P + 1.866S + 8.411T$$

Maples Method(1978) suggested the use of only two criteria of the total six Gustafson recommended (secondary dentine formation and root transparency), in order to make the method[14] more simple and accurate. As it does not evaluate the attrition, the bias due to the dietary differences is expected to be decreased.

Solheim Method(1993): Solheim13 used five of the changes that Gustafson recommended (attrition, secondary dentin, periodontitis, cementum apposition, and root transparency) and added another three new changes that showed a significant correlation in different types of teeth. The three new age-related changes were surface roughness, color, and sex.

Miles Method: Miles[15] believed that root dentin translucency (DT) correlated most strongly with age among the six parameters used by Gustafson and when used alone, DT may serve as a single best parameter for age estimation.

Bang and Ramm Method: Bang and Ramm[16] presented a simple and accurate method for age estimation based on the measurement of only one criterion: the length of the apical translucent zone of only incisors and cuspids. However, it was difficult to make accurate measurements in molars and bicuspids.

Age Estimation in Adults[2,3]:
Clinically, the development of permanent dentition will be completed with the third molar eruption at the age of 17 to 21 years, after which the radiographic age estimation will become difficult. The methods commonly followed are
1. Volume assessment of teeth
a. Pulp-to-tooth ratio method by Kvaal.
b. Coronal pulp cavity index
2. Development of the third molar
a. Harris and Nortje method.
b. Van Heerden system

Volume Assessment of Teeth:
The age estimation in adults, achieved by radiological determination of the reduction in the pulp cavity size resulting from a secondary dentine deposition, which is proportional to age of the individual.

a. Pulp-to-tooth Ratio Method by Kvaal[17]:
In this method, the pulp-tooth ratio calculated for six maxillary and mandibular teeth. The age is derived by the formula

$$Age = 129.8 - (316.4 \times m)(6.8 \times [W\text{-}L])$$

b. The Coronal Pulp Cavity Index[13]:
This method calculates the correlation between the chronological age and the reduction of the coronal pulp cavity. Only mandibular premolars and molars are considered. For each tooth, the tooth-coronal index (TCI) is computed and regressed on the real age of the sample by using the formula.

TCI = length of coronal pulp cavity height (CPCH) × 100/crown length (CL)

These methods are limited, as there will be a certain amount of distortion when the curved arch of the jaws is projected on to a flat film. Rotated teeth, teeth with enamel overlap, restorations, cavities, attrition and periapical pathological process cannot be used in this method, as well.

Estimation of age based on development of the Third Molar:
The radiographic age estimation with accuracy after 17 years of age may not be feasible as the eruption of permanent teeth completes by that age with the third molar eruption. Later, the development of the third molar[19] can be taken as a guide to determine the age of the individual.

a. Harris and Nortje Method: Five stages of root development of the third molar with corresponding mean ages and mean length is given by them.

b. van Heerden system: The development of the mesial root of the third molar assessed to determine the age using a panoramic radiograph.

Age Estimation using Deposition of Secondary Dentine:
The size of the pulp chamber indicates the amount of secondary dentine formation. **Moore** used pulp diameter to crown diameter ratio for calculating age.

Human Dentinal Structure as an indicator of Age:
Microscopically observed aging changes are seen in the shrinkage of the pulp tissue, the presence of a pre-dentin layer, or in the dense dentinal tissue[5] which, is observed by scanning electron microscopy (SEM). The origin of these changes may usually be found in the structural changes of dentine.

Age Estimation from Incremental Lines of Cementum:
Cementum[4] is continuously deposited at the root end and seen as incremental lines. Many researchers have used cemental annulations to determine age of adults. However, it is not always easy to count. Miller et al. reported that determining chronologic age in humans from cementum annulations is not possible.

Age Estimation using Color of the Teeth:
Age estimation from changes in tooth color[2] has been suggested by many; however, the use of dental color for age estimation in forensic odontology has limited due to the difficulty of measuring color objectively.

Age Estimation in Dental Pulp DNA based on Human Telomere Shortening:
Tomoya Takasaki et al.(2003) conducted a study for the estimation of age based on evidence found in teeth, which has received considerable attention within the field of forensic science. They determined the terminal restriction fragment length, as telomere[20] length, to estimate age. Using dental pulp DNA, they found that the average TRF length showed a tendency to shorten with aging. Their findings show that telomere shortening, which is based on dental pulp DNA is a useful approach in estimating age of the subject at the time of death.

Aspartic Acid Racemization[2,20]:
Amino acids are the building blocks from which proteins[19] are formed, and they exist in two forms L enantiomers and D enantiomers, which are non-super impossible mirror images of each other. Gradual transformation of the L-form of amino acids in proteins into the D-forms (racemization) occurs and this chemical reaction is influenced by various factors such as temperature, humidity, pH, etc., and this racemization also occurs in metabolically bradytrophic tissues such as teeth, lenses, vertebral discs and parts of the brain. D-aspartic acid increases correspondingly with age in dentin of teeth; hence, good indicator of age. However, the mentioned method is invasive and expensive and also requires specialized equipment and expertise. In addition, it is not suitable in living individuals.

Softwares used in Age Estimation[21]
AutoCAD is a software application for 2D and 3D computer aided design (CAD) and drafting available since 1982.

Adobe Photoshop is a graphics editing program developed and published by Adobe Systems. Adobe Photoshop CS6 is the 13th major release of Adobe Photoshop having 3D image creation, motion graphics editing, and advanced image analysis features, etc.

Image J is a public domain, Java based image processing program developed at National Institute of Health (NIH), which is a technique to check the correlation between cementum thickness and actual age using Image J software, version 1.43s.

Materialise Interactive Medical Image Control System (MIMICS®) is an image processing software which is used to create 3D surface models, 3D design, 3D measurements.

CONCLUSION:
Age is one of the essential factors, which play an important role in every aspect of life. Person identification is an important aspect of forensic medicine and dentistry. Teeth are the least influenced bioindicators and hence used for accurate age estimation. With advancements in digital radiography, the calcification status can be determined precisely. The main objective of age estimation is to obtain the best-standardized method for medicolegal purposes, that should be reproducible, reliable, simple and can be applied in living and dead. The present paper of age estimation based on tissues pertaining to the odontogenic apparatus depending on the corresponding stage of development & maturity were reviewed and suggested that the appropriate method can be adopted to estimate the age of the diseased or corpses depending on the availability of the resources.

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