AGE ESTIMATION METHODS IN FORENSIC ODONTOLOGY

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ABSTRACT
Age estimation has wide application in forensic medicine. It is used in the crimes, accidents as well as in the determination of deceased person. Teeth are stable parts of the body and least affected by environmental challenges. The estimation of age of skeletal remains is one of the most complex challenges for anthropologists. The most common macroscopic methods are based on dental wear and histological evaluation of bone remodeling. These methods are often qualitative, require great technical expertise.

KEYWORDS Age Estimation, Forensic Odontology, Radiograph, Dentin Translucency

INTRODUCTIO - Age estimation is the final step in the triad of dental profiling after identification and sex determination. It has wide application in forensic medicine, and used not only for identification of deceased person but also in connections with crimes and accidents.¹ The two types of macroscopic parameters that are useful indicators of biologic age are; epiphyseal closure throughout the skeleton and dental age estimation. The developing dentition is thought to be a useful indicator of maturation and hence the biological age, because the teeth are less affected than other body tissues by environmental insults² Dental age estimation is one of the few measures of physiologic development that is uniformly applicable from infancy to late adolescence. After attaining maturity, teeth continue to undergo changes, making age estimation possible among adults.³

Dental Age Estimation Methods
Dental age estimation makes use of morphologic, radiographic, histological, and biochemical methods to examine age dependant changes in teeth.

A. Age Estimation in Prenatal, Neonatal and Postnatal Period
The primary tooth germ begins to form at seven weeks in utero (IU), and the enamel formation of all deciduous teeth is usually complete by the first year. Among the permanent teeth, the first molar shows germ formation at about 3.5-4 months IU. Age estimation in this group of individuals can be very accurate. It makes use of histological techniques, which enable observation of tooth mineralization up to 12 weeks before it is actually apparent on radiographs. The ‘neonatal line’ is considered as an indicator of birth. According to Ciapparelli, the neonatal line may take up to three weeks after birth to form. Hence, Bowers warns that a false result may be produced when one concludes that the absence of the neonatal line proves that the individual was ‘stillborn’.³

B. Age Estimation in Children and Adolescents
Two events that may be used to measure dental age in children and adolescents are tooth emergence or ‘eruption’ and tooth calcification. It involves visual assessment of teeth present in the mouth. The use of tooth emergence for age estimation should, however, be limited to deciduous teeth. Their emergence is under genetic control and is relatively regular, commencing approximately at six months and completing by about 2.5 years. In permanent teeth, the evaluation of radiographs to assess tooth calcification is a much better alternative, since calcification of teeth can be observed from radiographs for a period of several years. It is not altered by local factors such as lack of space, infection, etc. The study of tooth calcification also lets one assess age at periods when no emergence takes place (2.5 - 6 years and > 12 years).³
Atlas Approach  The use of radiographs is characteristic of techniques using the atlas approach where the morphologically distinct stages of mineralization that all teeth share, are observed. Tooth mineralization stages are less affected by variation in nutritional and endocrine status and therefore developing teeth provide more accurate indication of chronological age.\(^1\)

a. Schour and Massler's Method: The chart, or atlas, of Schour and Massler is a classic example of an atlas approach and was probably the first attempt at scientific dental age estimation. They described 20 chronological stages of tooth development starting from four months IU until 21 years of age. The chart is based on histological sections which permit direct comparisons with radiographs\(^1\) these charts were improved by Ubelaker, who included data from additional population studies. Bowers has stressed that Ubelaker's improved charts should be used for age assessment, since the original Schour and Massler chart had serious drawbacks.\(^3\)

b. Moorrees Method: Moorrees et al divided dental maturation of the permanent dentition into 14 different stages ranging from “initial cusp formation” up to “apical closure complete” and designed different tables for males and females. Anderson et al further developed the system of Moorrees for all the teeth including the third molars. The tables they compiled are considered very comprehensive and can be applied to a much larger age range of juveniles.\(^1\)

Scoring System (Demirjian's Method): Demirjian et al tried to simplify chronological age estimation that assesses the mandibular left side teeth. The development of mandibular left teeth was divided into 10 stages and numbered ‘0’ – ‘9’. Stage 0 denotes that tooth calcification is yet to begin, stage 5 indicates crown completion while stage 9 represents completion of tooth calcification (complete formation of root apex). Based on statistical analysis, they provided different maturity ‘scores’ for each tooth for different developmental stages and differentiated for boys and girls. The scores assigned for each 8 teeth are added and a total maturity score is obtained. The total is substituted in regression formulas to derive the chronological age.\(^1\)

C. Age Estimation in Adults

Age estimation in adults is challenging when compared to younger age groups. Following completion of growth, changes in the dentition used to estimate age are influenced not only by the age of the individual, but also by numerous endogenous and exogenous factors, such as disease, nutrition, and physical strain.

Morphological Techniques

Gustafson's Method: In 1950, Gosta Gustafson developed a method for age estimation based on morphological and histological changes of the teeth. They assessed regressive changes such as: Attrition (A), Secondary dentine deposition (S), Loss of periodontal attachment (P), Cementum apposition at the root apex (C), Root resorption at the apex (R), Dentine translucency (T).\(^4\), \(^5\), \(^6\) For each of these regressive changes or variables, different scores ranging from 0-3 were assigned. This applies that attrition could have anyone of four scores (AO, A1, A2, or A3) and similar one of four scores for the other variables. Adding the allotted score for each variable (e.g. A3 + S2 + P2 + C1 + R2 + T1 = X), a total score (X) was obtained. It was found that an increase in the total score (X) corresponds to an increase in age. Age was estimated using the formula: Age = 11.43 + 4.56 X. However, the improvements made by Johanson are widely accepted. Instead of the original four grades (0-3), he proposed seven grades (0, 0.5, 1, 1.5, 2, 2.5, and 3). Using these seven grades, the formula Age = 11.02 + (5.14A) + (2.3S) + (4.14P) + (3.71C) + (5.57R) + (8.98T) was suggested.\(^1\)

Dentine Translucency: In 1970, Bang and Ramm used only one parameter for estimating age i.e. dentine translucency and reported significant increase in root translucency with age.\(^5\) Root dentine starts to become translucent during the third decade of life, beginning at the apex and advancing coronally. The alteration may be due to the decreased diameter of dentinal tubules caused by increased intratubular calcification. Hence, the difference in refractive indices between intratubular organic and extratubular inorganic material is equalized, resulting in increased translucency of the affected dentine. Based on tooth type, a number of regression formulas have been provided for age estimation.\(^1\)

Age Estimation from Incremental Lines of Cementum: Kagerer and Grupe suggested the possibility of age estimation from acellular cementum incremental lines. This made use of mineralized, unstained cross-sections of teeth, preferably mandibular central incisors and third molars. The authors claimed an accuracy of within 2 to 3 years of the actual chronologic age.\(^8\) In addition to age, hypomineralized bands in these incremental lines

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Radiological Techniques

Dental Age by Panoramic Radiographs: Dental age was assessed by panoramic radiographs according to the methods proposed by Nolla (1960) and Nicodemo et al. (1974). In the Nolla method, the stage of development of the mandibular left teeth of each child was analyzed and then compared to a series of standardized drawings depicting 10 stages of tooth calcification for each gender. Therefore, dental age estimation was obtained for each patient. A similar procedure was used for the method proposed by Nicodemo, et. al. (1974). However, this method did not take the patient’s gender into consideration. Kurita LM et al. (2007) conducted a study to evaluate the applicability of the methods proposed by Nolla and by Nicodemo and colleagues for assessing dental age and its correlation to chronological age in Brazilian population. They found that when the Nolla method was applied, the mean difference between true and estimated age for males and females was underestimated. The use of the method proposed by Nicodemo and colleagues also resulted in underestimation, although it was more evident in male subjects. They concluded that although both methods proved to be reliable in estimating age, the use of correction factors is recommended.

Kvaal’s Method: Kvaal and associates developed a method that used pulp size measurement of six teeth (maxillary central and lateral incisor, second premolar; mandibular incisor, lateral incisor, canine, and first premolar) observed on periapical radiographs. The measurements included several length and width ratios such as pulp-root length (P), pulp-tooth length (R), tooth-root length (T), pulp-root width at CEJ (A), pulp-root width at mid-root level (C), pulp root width at mid-point between level C and A (B). The mean value of all ratios excluding T (M), mean value of width ratios Band C (W) and mean value of length ratios P and R (L) were derived. When six teeth (right or left side) from both jaws are available, the following regression formula can be used: 

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\text{Age} = 129.8 - 316.4 \times M - 66.8 \times (W-L) \]

The application of Kvaal’s dental age calculation technique on panoramic dental radiographs was studied by Bosmans N et al. (2004). The researchers concluded from the study that the application of regression formula on data obtained from panoramic radiographs may lead to age estimations which are comparable to those based on the original technique i.e. periapical radiographs. Meidl A et al. (2007) aimed the study to explore whether the previously presented regression formulas could lead to statistically sound results and to appropriate repeatability when applied to young individuals. They concluded that the regression equations reported by Paewinsky et al and Kvaal et al cannot be applied to a young sample. The use of these formulas led to age estimations that are far away from the real chronological age.

Biochemical Methods

Amino Acid Racemization (AAR): Helfman and Bada first suggested a relationship between dentinal age and the extent of aspartic acid racemization in dentine. Subsequently, others including Ritz and collaborators as well as Ohtani and associates have explored this biochemical method and found it suitable for ageing. All humans use amino acids exclusively in protein synthesis. Aspartic acid is an amino acid that has a rapid rate of racemization, i.e. it gets spontaneously converted from one type (L-aspartic acid) to another (D- aspartic acid) with increasing age. Therefore, there is a constant change in the ratio of L- and D-aspartic acid at different ages and this D/L ratio may be used for age estimation. Due to constant replacement of proteins in metabolically active tissues (such as liver), no measurable amounts of D-aspartic acid is found. However, the D/L ratio can be measured in those proteins that are synthesized early in life and are not replaced. Such proteins are found in brain cells, crystalline lens, bone and teeth. Racemization rate of aspartic acid is high in root dentine, and therefore, teeth are a valuable source for ageing using this method. A study was done by Ohtani S et al. (1998) to estimate the age using AAR in a case of pink teeth. They found that age estimated using deeply pink involves risk of underestimating the correct age but an age closer to the actual one after adequate cleaning. In a study by Ogino T and Ogino H (1988) the researchers used the AAR method in unerupted and supernumerary teeth for the estimation of age and concluded that the method is suitable for the estimation of age by impacted teeth while in supernumerary teeth the estimated age deviated significantly from the true age.
considerably from the actual age. In another study Ohtani S et al. (2003) studied the correlation between the level of D-aspartic acid in dentin and the period of dentin formation in different types of teeth from the same individual. They reach on a conclusion that in elder people racemization in teeth that have been situated deep in the oral cavity for a long time, is more influenced by the environmental than by the period of tooth formation.

Other Methods

Age Determination by Pulp/Tooth Ratio (PTR) in Upper Canines in Skeletal Remains: Certain dental methods investigate the apposition of secondary dentine, in the study of tooth cross-sections, and X-rays to study width, height, and pulp area. The study conducted by Cameriere R et al. (2006) showed that the PTR method, is not only a useful technique to assess the chronological age of living persons, but it is also a reliable tool in the determination of age at death in skeletal remains. Specifically, age estimation was very precise in eight mummies aged less than 72 years. The method can be used to provide age estimation of old subjects, who died over 50, with great reliability. Therefore, for simplicity and reliability, this method can also be proposed for age estimation of historical subjects.

Correlation between Age and Coronal Movement of Cementum in Impacted Teeth: In impacted teeth, depending on age, cementum had a tendency to overlap the enamel. This may be related to continually erupting forces which affect the impacted teeth and may be a mechanism by which the teeth are protected at the cemento-enamel junction (CEJ). A study was conducted by Bocutoglu O and Yakan B (1997) on 48 impacted and 51 erupted maxillary permanent canine teeth extracted from healthy patients aged 13-73 years. They found a linear correlation between age and coronal displacement of cementum in impacted teeth while there was no correlation between age and coronal displacement in erupted teeth. Results of the study indicated that the cementum in impacted teeth migrated coronally during the ageing process. The authors suggested that this phenomenon could be used in forensic dentistry to determine age.

Age Estimation by Occlusal Tooth Wear: Yun JI et al. (2007) found that the modified Kim’s scoring system had excellent reliability, and that occlusal tooth wear had a positive correlation with age. Estimated ages were within 5 years of actual ages in 63.5% of male subjects, and 64.0% of female subjects. The accuracy of age estimation was increased when the subjects were divided into two age groups and data were re-analyzed.

REFERENCES


