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Dental Age Estimation Methods: A Review

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ABSTRACT

Age is one of the essential factors in establishing the identity of a person. Dental age can be assessed according to developmental traits such as mineralization, gingival emergence, quantification of cementum layers or narrowing of pulpal space. Degenerative changes such as dental attrition or periodontal recession also show a correlation with chronological age. Furthermore, a variety of parameters such as fluorescence intensity and density of dentin, racemization of aspartic acid or dentin sclerosis help to evaluate age related conversion of dental tissues that can be used in age estimation. The aim of present review is to highlight various methods of dental age estimation.

Key words: Forensic science, age estimation, dental age

INTRODUCTION

Age is one of the essential factors in establishing identity of a person.[1] Age estimation plays an important part in treatment planning, forensic context, legal requirement and palaeodemographic research.[2] Age estimation of an individual involves the state of dental development, ossification state of epiphyses, appearance of ossification centers, closure of cranial sutures, state of pubic symphyseal surface, and architecture of femoral head.[1]

The aging of teeth is a unique process. The use of teeth for determining someone's age has its origin 170 years ago when tooth eruption was first used for dental age estimation in connection with child labour.[2]

Dental age estimation in the living is mostly based upon non-invasive methods, which evaluate the timing and sequence of defined growth stages of the developing dentition and the sequence or modification of traits in the mature dentition and the surrounding tissues.[3] The timing of tooth development is highly heritable and population specific.[4]

Extreme hardness and durability of hard tissues of teeth make them an important source of information in age at death estimation. Teeth are less affected by factors such as scavenging animals, humidity, microbial activities, mechanical forces, and high temperature than soft tissues and bone.[2]

Furthermore a variety of methods is applicable even to single teeth. This offers the chances to estimate an individual's age with only minimal destructive interferences. The aim of present review is to highlight various methods of dental age estimation.

DENTAL AGE ESTIMATION METHODS

Methods of dental age estimation can be divided under the following headings:-

Stages of tooth formation

In age estimation the term "tooth formation" usually refers to the mineralization of dental hard tissues. A reason for this may be that

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mineralized tissue can be easily evaluated via radiographic methods and remains after death and decomposition of organism.

Schour and Massler in 1941 presented tables on 22 stages of dental development starting from five month *in utero* up to 35 years of age. These tables are the classical examples of atlas approach of age estimation.[5] Glesier and Hunt (1955) in their radiographic study described about the stages of the calcification of mandibular first molar.[6] Gran *et al.* published complete data on all mandibular molars and premolars using lateral oblique jaw X-ray.[7] In 1970, Calonius *et al.* published a set of historical criteria which allow estimating an individuals' age from seventh week of gestation to three years of age.[8] Another example of an atlas approach is the charts of Gustafson and Koch (1974). Those dental development charts were based on commencement of mineralization, the completion of the crown, the eruption of the tooth and the completion of the root(s).[9]

Demirjian *et al.* defined four developmental stages of crown and root on the basis of radiological appearance of tooth germ. A certain dental score was assigned to each stage. Adding up all the scores gives Dental Maturity score for a person.[2] Demirjian method is of special interest for orthodontists when planning when planning therapeutical procedures of different kinds of malocclusions.[10]

Age estimation for medicolegal purposes by mean of third molar development is used in the age between 14-21 years when all other permanent teeth have finished their formation. Rai *et al.* conducted a study among South Indian population to find the correlation, accuracy and validation of tooth staging methods in third molars and age estimation. They found that Demirijian, Morrees *et al.* and, Gleiser and Hunt methods have more statistical significant correlation than other tooth staging methods.[11] Olez *et al.* conducted a study on ethnical differences in third molar mineralization using orthopantomographs. Study showed that Japanese, German, and South African individuals differ up to several years in reaching the respective developmental stages according to Demirjian. Hence, it is recommended to use population specific data in age estimation.[4]

Incremental lines in the tooth crown

Boyde suggested that age could be estimated from prism cross striation counts.[2] There is a evidence that the interval between cross-striations of enamel prism represents the amount of prisms formed in a 24 hour period. Another feature in crown is Retzius line, thought to be caused by enamel discontinuity which reflects a certain state of mineralization during amelogenesis. They are present only in post natal enamel. The neonatal line, which constitutes a borderline between pre and post natal enamel, is frequently used for age at death estimation.[12] Neonatal line combined with total number of cross-striations gives an estimate in days for the age at death. Perikymata are the surface manifestation of the Retzius lines. It is assumed that perikymata are formed at the end of a cicaseptan interval that amounts about 7-10 days in humans.[2] Dean and Beynon used Striae of Retzius and perikymata grooves counts to determine age at death.[13]

Changes of pulpo-dentinal complex

Dentin is a continuously formed appositional tissue of teeth. Secondary dentin is built physiologically and formed slowly by cells lining the pulp chamber. In 1925 Bodecker was first to establish that the apposition of the secondary dentin is correlated with chronological age.[2] In 1950, Gustafson introduced linear measurement of secondary dentin for age estimation as one of his proposed six criteria. Measurements quantify the amount of secondary dentin indirectly via the assessment of the decrease in size of the pulp cavity. The reduction in size can be quantified by linear assessment directly on tooth sections and on thin slices.[14]

Kvaal and Solheim reported a method where the pulp width and length is calculated in relation to tooth width and length. Kvaal *et al.* tested this method on periapical radiographs.[15] The applicability of this method on orthopantomographs was assessed by Paewinsky *et al.*[16] It was shown that the width ratios of the pulp cavity exhibited a significantly negative correlation with age. Cameriere *et al.* focused on canine to study pulp/tooth area

ratio on orthopantomographs and periapical radiographs.[17]

Dentinal sclerosis (root transparency) is another feature of the pulp dentinal complex which was first described by Tomes in 1861. This trait undergoes a progressive change with age but is also a defensive reaction to caries, attrition and drug treatment.[2]

Gustafson was first to introduce root dentin transparency for age estimation as one of his proposed six criteria.[14] Kamann (1998) evaluated the width of dentinal tubules via stained frozen sections. The authors found tubules with a diameter of 3-4 μm in under aged individuals decreasing to 2 μm with advancing age.[2] Bang and Ramm (1970) documented the association of age and the length of the dentin transparency and concluded that feasible results can be obtained for sectioned and unsectioned tooth specimens of up to 75 years of age.[18]

Drusini *et al.* made an attempt to evaluate the extent of root dentin transparency via computerized densitometric analysis to avoid problems in establishing the boundary between opaque and transparent dentin. The results showed no superiority of the image analysis system as compared to the caliper.[19] Lamendin *et al.* presented a method for age determination for single teeth that used height of periodontal attachment and root transparency as parameters. Lamendin's mean error was found to be between 8.4 years in the control sample and 10 years in working sample. The use of gingival regression as a variable has been criticized because attachment level can easily be influenced by factors such as bad dental hygiene, irritation, systemic diseases, and drug treatment.[20]

Changes in Cementum

Gustafson introduced cementum for human age estimation.[14] Zander and Hurzeler were first to discover a linear relationship between the growth of cementum and chronological age.[21] Quantification of layers in human teeth cementum as a technique for age at death estimation has its origins in the wildlife biology where the cementum layering was routinely used as an aging method.[2] First published study on the use of cementum layer counting for age estimation in humans was by Stott *et al*.[22]

Some studies did not reveal a relationship between chronological age and the count of tooth cementum annulations while others reported a well correlated connection.[2] Rai *et al.* in their various studies concluded that there is a significant correlation between age and coronal displacement of cementum in impacted teeth.[23]

The quantification of cementum layers is currently ranked as "secondary line" method in dental age estimation after the most specific precise racemization of aspartic acid.[24] Due to the fact that the nature of the mechanism that forms the cementum layers is not fully understood yet, it would lead to a significant improvement if further research provides more information about the cause and chronology of cementum layering.

Changes in chemical composition of teeth

Nitrogen content of teeth was found to be increased with advancing age. This is thought to be correlated with the increasing amount and intensity of pigment that causes change in color of older teeth.[25]

Racemization of aspartic acid is another age related change in the chemical composition of teeth. In living body, proteins are normally composed of L-form of amino acids, turning the polarized light towards left. A gradual transformation of the D-forms (racemization) of amino acids occurs throughout lifetime as well as after death. The recemization is related to factors such as temperature, pH, humidity and others. Using gas chromatography a number of researchers have confirmed the correlation of chronological age and aspartic acid racemization.[26]

An uncommon technique for dental age estimation is the analysis of the fluoride concentration in dentin. The concentration of fluorides in dentin is dependent on the fluoride administration and occurs most notably in areas near the pulp. However variation in concentration of fluoride in drinking water, use

of fluoride supplements, and dietary habits had questioned the validity of this method.[2]

Alteration in density of teeth

A limited number of studies have investigated the altered density of human teeth in relation to age. They showed that density of dental hard tissue increased with age. This trend is an indirect product of the age related changes in mineral composition and hard tissue structure.[2,27] However, there is need to modify this method to obtain more reliable result.

Changes in tooth color

As the age advance teeth become more yellowish and brownish. Biedow suggested that tooth color should be added to Gustafson's six criteria for age estimation instead of root resorption parameter.[2] Ten Cate *et al.* in their study found clear relationship between root color and chronological age.[28] However correlation between chronological age and color turned out to be weaker in teeth obtained from skeletal remains than in freshly extracted teeth.[29] Till date all the attempts to employ tooth color as a measure for chronological age are not satisfying. The problem of quantifying color properly still remains. Moreover it needs to be determined if age related root discoloration is a gradual process that proceeds mostly unaffected by external influences.

Fluorescence of dental hard tissues

Kvaal and Solheim evaluated the fluorescence of dentin and cementum in human premolars. Results revealed a stronger fluorescence from cementum than from dentin. The intensity of fluorescence was found to be stronger in the teeth removed from human remains than for the teeth from living patients. The study showed a relationship between fluorescence in dentin, cementum and age. But it cannot be used for age estimation as authors have used an arbitrary scale.[30]

Attrition of teeth

Attrition describes the most obvious evidence of age related influence on human dentition. But in modern people, the attrition rate is too slow for age estimation that this parameter can be used only in an anthropological context for histological material. Attrition can be evaluated by examining incisal and occlusal tooth surfaces according to the respective method.[2]

Solheim evaluated the attrition scoring systems of Gustafson (1950), Johanson (1971), and Dalitz (1962) on a sample consisting of 1000 teeth. Johnson's scoring system showed strongest correlation with age in most type of teeth.[31] Jain and Rai conducted a study among Indian subjects to establish the effectiveness of attrition (molar's attrition grading) in predicting age and in preparing regression equation. There were highly statistically significant correlation between molar's attrition and chronological age. Best estimates were provided by attrition of first molar.[32]

Most of the methods that are used to quantify attrition contain a degree of subjectivity and result in relatively broad age ranges.

Epidemiologic criteria

An example of epidemiologic criteria for age estimation is the DMFT (Decayed Missing Filled Teeth) index. Andreas *et al.* evaluated the predictive value of the DMFT index of all permanent teeth, all permanent teeth except third molars, the DFT (Decayed Filled Teeth) index of third molars projecting beyond the occlusal plane, the eruption of third molars, and the periodontal recession of second molars. The probability of correct classification (of being 21 years of age or not) was 69.7% for males and 71.4% for females.[33] In another study Friedrich *et al.* concluded that values of decayed, missing and filled correlated weakly with chronological age.[34]

The DMFT index can be used for an orientation but doesn't have strong significance in human age estimation by reasons of high inter-individual variation, influence of dietary habits and caries prophylactic methods. A rough estimation is possible if the caries rates in the specific age groups are known.[2]

Combined Methods

Gustafson combined six age dependent variables (attrition, periodontal attachment, secondary dentin, cementum apposition, root resorption, root dentin transparency) for age estimation carried out on longitudinally ground sections. Each variable was assigned separately to a score of 0-3. Study showed high correlation of scores with chronological age.[14] In 1971, Johnson applied a new scoring system to the original Gustafson technique. He developed linear regression equations and found the root dentin transparency to be most strongly correlated to the chronological age followed by secondary dentin.[2]

CONCLUSION

Literature reveals various methods of dental age estimation. Every method has some merits and demerits. The combination of several, strongly age dependent dental features constitutes a very promising approach for the estimation of dental age. Nevertheless use of combined methods, often variables of unequal reliability might not be beneficial for an increase of accuracy.

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