Recent Advances in Estimation of Age From Tooth: A Review

Partha Pratim Mukhopadhyay
Associate Professor Department of Forensic and State Medicine Burdwan Medical College, Burdwan, West Bengal 713104

Abstract

Age estimation from tooth has been a subject of research since 1950. This article traces the history of developments and critical components of the methods (both morphological and biochemical) to calculate age at death for forensic purpose.

Key words: forensic, tooth, age estimation, Morphology, biochemical methods.

Introduction

Age is an important data for positive identification of an individual. Unknown human dead bodies are often presented for forensic casework. Estimation of age from tooth is thus a vital tool for forensic, criminology and archaeological investigation. Given the tensile properties and durability, a tooth possesses immense evidential value. A lot of medico legal information can be derived from a tooth. Of these the age of the said person has been of great interest.

This paper attempts to trace the historical developments and the critical components of the methods of estimation of age from tooth since 1950.

Structure of Tooth

Anatomical and physiological considerations.

There are 20 primary (deciduous) teeth with 10 in each jaw and are later replaced by secondary (permanent) teeth. There are 32 permanent teeth with 16 in each jaw. By the age of 14 years there are 28 teeth (seven in each quadrant). From front to back the teeth are, central incisor, lateral incisor, canine, first and second premolars, first and second permanent molars. The third molar erupts between 17-25 yrs. It shows great variability in eruption, and development. Some individuals have un-erupted third molars.

Correspondence
Dr. PP Mukhopadhyay, Associate Professor Department of Forensic and State Medicine Burdwan Medical College, Burdwan, West Bengal 713104.

A tooth has three parts. The crown is the part covered with enamel and projects into the oral cavity (the visible part) the root is covered with cementum and embedded in the jaw. The constricted junction of the two parts is called the neck. The irregular projections on the occlusal surface (chewing) are called cusps. The tip (deepest) part of the root (or roots) is the apex. Some teeth are single rooted while others have two.

A mature tooth has a central core called the pulp, which is myxomatous and contains blood vessels and nerves. A zone of odontoblasts surrounds the pulp. Surrounding these two is a zone called dentin. Dentin forms most of the tooth. It is composed of tubular structure containing long cellular process of odontoblasts. The dentin contains nearly 20% organic matrix (collagen mainly). About 90% of matrix is collagen that is primarily type-I. About 95% of the collagen molecule, is triple helical structure. Covalent cross-links are present to stabilize the structure. The dentin of crown is covered by enamel (hardest material in the body, composed almost entirely of hydroxyapatite). The dentin of the root is covered by a bone like material called cementum, which is attached to the jawbone by fibers of periodontal ligament.

Methods of Estimation of Age

It was in 1950 that G. Gustafson 1 published a paper in the Journal of American Dental Association entitled. “Age determinations on teeth.” Since then forensic literature has been replete with works on such attempts to accurately estimate the age from morphology and macro structural change in teeth.

Gustafson’s Method

After the developmental stage is over, a tooth exhibits certain physiological consequence of aging. The basic principle was to correlate the morphological changes with the age of the subject. Gustafson worked on the macro structural changes of teeth with aging and developed a scoring system for such calculation. He assigned points upon an ascending scale of 0 to 3 according to the degree of the change. Gustafson considered six observable age related changes in the original work. They were –

1. Attrition: Wearing of the enamel of the occlusal surface.
2. Secondary dentin apposition: - Age related build up of dentin on the walls of the pulpal chamber.
3. Periodontosis: - The irregularity in the form of cementum and root dentin caused by ongoing repositioning of the periodontal ligament.
4. Cementum build up: Extra layers of cementum.
5. Root resorption: Gradual resorption of the root apex.
6. Root transparency: Transparency of the root dentin to transmitted light found in 300 mm thin sections from apex upwards (termed sclerotic dentin).

The scores were summed up and a regression line was obtained from a sample of known age. He claimed an error of ± 3.63 yrs and the equation of the said line was.

$$Age = 11.43 + 4.56\ x$$

Where x is the total score obtained from the count.

Post-Gustafson Studies on Age Estimation From Teeth

The original data and calculations of Gustafson were subjected to subsequent critical examination. Maples and Rice 2 in 1979 found that the estimated error was ± 7.03). Gustafson's paper had several statistical shortcomings. Maples and Rice used the data and regressed age as the dependent variable and the score as the independent variable and obtained an equation.

$$Y = 4.26x + 13.45$$

Contrary to the Gustafson's linear regression, in1971 Johanson 3 used multiple regression of each variable against age taking all the six changes. In the same year 1970, Bang and Ramm 4 used only the root transparency as the indication of age. The estimated error was between 7 and 13 years.

More rigorous statistical reasoning and calculations by Lucy and Pollard 5 in 1995 have shown that the error in the estimate was ± 15.9 yrs.

Apart from such scoring systems, some workers used direct measurement of age related changes.

Lamendin's Adult Dental Aging

In the year 1992 Lamendin et. al.6 proposed a technique of age estimation for adults. Single rooted teeth were used in the study from autopsy samples of French population. The researchers used only two of Gustafson's factor for their estimation. Age was expressed as a function of (1) Transparency of the root and (2) Periodontosis (gingival regression).

$$A = 0.18 \times P + 0.42 \times T + 25.53$$

Where A = age in years.

P = Periodontosis height x 100/root height

T = Transparency height x 100/root height

Estimated mean error was ± 10 yrs.

Applying the same technique on a mixed population Prince and Ubelaker 7 in 2002 obtained satisfactory results. They derived separate formula for the different ethnic groups. For white male the new formula professed was

$$A=0.15(RH)+0.29(P)+0.39(T)+23.17$$

The critical component of this method include –

a. The possibility of error with individual case.

b. Sex should be considered when employing this method.

c. It is more accurate for the 30 to 69 year olds. Mean error becomes higher outside this range.

d. Inter-observer variations were considerable.

Age Estimation By Occlusal Tooth Wear

(KIM'S SCORING SYSTEM)

Though affected by various factors, tooth wear is a dependable physiological consequence of aging. Attempts were made to correlate the wear with aging but it was marred by lack of universally accepted method and quantification of tooth wear. Kim et. al 8 in 2000 published a work on the age related change of occlusal wear of tooth.
The scoring system so developed was on the basis of

1. Point like wear
2. Linear wear
3. Surface like wear
4. Band like wear

The scoring was from 0 to 9 (ascending order) based on the degree of occlusal wear. Kim 's scoring was based and considered two categories of occlusal wear

1. Presence or absence of dentin exposure (vertical factor)
2. The area of tooth wear (horizontal factor).

Improved upon earlier scoring system, the Kim's method have demonstrated that the technique is simple, reliable and can be successfully applied to estimate age of individuals in any age range.

Further large-scale studies need to be undertaken to assert the applicability in a wide population. Earlier works in 1996 by Kashyap and Koteswar Rao 9 has shown that the maximum error was 9.94yrs at 95% confidence level. They used four markers namely attrition, secondary-dentin, secondary-cementum and root transparency. Studies by Indian researchers showed that Gustafson's method could be modified10 using four markers. Regression analysis revealed the following formula. Age = (Sum of point values +2.45) divided by 0.8.

Again in 2006 Rai et al 11 worked on Indian samples with five markers to estimate age from related morphological changes. Their research was based on the modification of Gustafson's aging method with using five markers: the degree of attrition, the secondary dentine, the secondary cementum, & the resorption and the transparency and made the regression equations for age determination of Indian population. The results of age estimation were obtained using the Gustafson's aging method and Kilian's method after multiple regressions of all studies was applied (absolute mean error of estimation 4.95 years — 95% CI ± 2.04).

According to the works of Brkic et al (12) the best of the several methods was proved to be that of Johanson using analysis of the root and the root canal from the X-ray analysis of six parameters on each teeth, where the coefficient of correlation was 0.85, $p<0.001$.They opined that the teeth of the maxilla are more convenient for the age determination than the teeth of mandible.

A study on Iranian population (13) however showed that among the different mandibular teeth, the sum of ranks of the first premolar factors had the best correlation coefficient with age. The

sum of the dental factors presented a better model than each of the factors alone. The first premolar is recommended as the first step in the estimation of age.

Recent work on Indian sample using the method of Bang and Ramm has been documented .The paper showed that age estimates in Indians was less accurate compared to the original sample. (14) Translucency measurements were subjected to regression analysis, and India-specific formulae were derived. They applied a new formula to a control group and the estimated age was found to be was marginally better the work validating to some extent the use of population-specific formulae in forensic age estimation.

Computer Aided Techniques

Studies with digitization of panoramic view has been effectively used to estimate age from pulp/tooth ratio. This method is only suitable for single rooted tooth. Working on Indian sample, Sashidhar S and Sharada P (15) have shown that this non destructive method of assessing chronological age with the change in pulp /tooth area ratio yielding high correlation coefficient.

Biochemical Markers For Age Estimation

Besides morphological changes some biochemical markers of dental tissue have been successfully used in methods of estimation of age. (16,17,18,) Tooth dentine is considered one of the best target tissues. Alternatively analysis of ostocalcin and elastin has also provided accurate results.

1. Aspartic acid racemization was used as a marker in works published between 1985-1995. The laevo/dextro proportion or the degree of racemization of aspartic acid.16 Deoxypyridinoline content in human dentin is linearly related to age. This was shown by the working Martin de lass Heras et.al.17 in 2000.
2. Gelatinase-A (a Matrix metalloproteinase or type IV collagenase / 72kda Gelatinase.) Enzyme catalyzes the remodeling of collagen in human dentin. A tooth is ground, crushed and the dentin extracted. The matrix so obtained is subjected to electrophoresis to study the enzyme. Gelatinase-A if present in the extract of the dentin matrix, suggests younger age group less than 20 years. Gelatinase-A decrease with age. Studies by Martin de la Heras et al. 2000 have shown that Gelatinase-A was present in 67% of extract of those who were younger than 40 yrs whereas it's percentage decreased to 50% in those who were over 41 yrs.

The use of biochemical markers can be regarded as useful alternative method of age estimation from teeth. (18)

Concluding Remarks

In final analysis it can be emphatically said that teeth is important biological evidence in forensic casework. Estimation of age from teeth is possible up to a certain amount of accuracy. Today it is a fact that each type of tooth must have its own formula. This is because teeth do not age at

the same speed. Only one tooth or type of tooth from each individual can be used for constructing a method. Further, population specific formulae are equally important.

Every method has its shortcoming technical and theoretical (Table 1). The degree of error in estimating the age can be minimized by using combination of methods. Usually complementary methods like morphological and biochemical markers are of great value in research and practical purpose.

Table 1: Comparison of the methods of estimation of age from morphological changes in tooth

Research	Year	Method	Estimated error (+ or - years)
Gustafson	1950	Morphological changes	3.63
Bang and Ramm	1970	Morphological changes in root only	7 to 13
Maple and Rice	1979	Gustafson s method	7.03
Lamendin et al.	1992	Gustafson s method	10
Lucy and Pollard	1995	Morphological	15.9
Kashyap And Rao	1996	Morphological	9.94
Kim	2000	Occlusal wear	6.5
Rai et al	2007	Morphological (five markers of original Gustafson)	4.95

One can conclude with the remark that more concerted, broad based and further research is necessary on a large group of diverse population to maximize the precision of the methods of age estimation from teeth. Forensic odontology has great scope and utility as a superspeciality.

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