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Original Research

Imaging: An indispensible tool in age estimation

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ABSTRACT:
Age is one of the essential factors to establish the identity of a human being. One of the interesting applications of forensic odontology is age estimation by means of teeth. Age assessment proves to be a critical factor in the victim identification process. Teeth and bone display a number of observable age-related variables, and they tend to remain intact under the circumstances, which might alter or obliterate the rest of the skeleton. Different methods are used to estimate age. The purpose of this review article is to familiarize about different techniques used to by means of teeth and bone.
Keywords: Forensic age estimation, bones, teeth, forensic odontology.

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INTRODUCTION

The ability to assign accurate age estimates to human remains and living individuals is becoming an increasingly important element of forensic practice. In mass fatality events, where many people lose their lives and are often unable to be visually identified, being able to separate
individuals based on their age as determined by skeletal and/or dental development is a vital part of the Disaster Victim Identification (DVI) operation. For example, in the tragic bushfire disaster which struck Victoria in February 2009, of the 164 victims who lost their lives and were subject to the DVI process, 25 were under the age of 20 years, and many of these were located in commingled circumstances.[1,2] Forensic age estimation also plays an increasingly important role in the assessment of living individuals of unknown age who have entered a foreign jurisdiction with- out identification papers, or with suspect identification documents. It is necessary to be able to determine the age status of these individuals for a number of reasons, including school entry and year level age requirements, and also for assessment of legal adulthood or childhood. Determination of an unknown age individual's status as either an adult or a child is vital in terms of how that person will be treated by the law in not only criminal prosecutions, but also in immigration hearings, licensing applications and, increasingly importantly, determination of refugee status. Age assessment of living individuals is conducted by using various medical imaging modalities, such as conventional X-ray and CT scanning, in order to capture images of the developing skeleton and the dentition. The anatomical sites most commonly imaged are the hand/wrist region for assessment of skeletal development, the dentition for assessment of dental age, and more recently the use of CT scanning to capture images of the developing clavicle and the dentition.[3,4] This imaging necessarily involves the use of ionising radiation with concomitant exposure to various tissues. This exposure is not at a level sufficient to cause immediate harm, but does raise the total lifetime dose of radiation experienced by the individual

concerned. There are medical ethical and legal considerations involved in conducting radiological procedures on living people, with no definite medical need, that are yet to be properly addressed. Various methods have been constructed and tested to estimate the age of young individuals.[5,6] Among them are the physical examinations using anthropometric measurements, [7,8] skeletal maturation, [9] dental age estimation, [10] a combination of dental development and anthropometric measurements [11] and a combination of skeletal and tooth eruption. [12]Age estimation is an important step in constructing a biologicalprofile from human skeletal remains. The goal of the forensicanthropologist is to assist medico legal officials with identificationby presenting a probable age range of the deceased. Inadults, this is typically done by examining various skeletal traitswhich have been shown to degenerate with age in a predictablemanner. [13] Estimation of age at death and determination of sex of the victim or remains are important guides that help in the process of identification. Teeth are among the most reliable tools in the process of identification of age, especially in the first and second decades. The stages of development can be considered as one of the most dependable indicators in assessing the age of the victim. Developmental stages of dentition and craniofacial skeleton are well established. Any disturbances during this period produce changes in these tissues and serve as lifelong permanent record. Even after the complete development of dentition and craniofacial skeleton certain physical, chemical and biological changes takes place which aid in the age estimation.[14]

WHY BONE AND TEETH ESTIMATED?

Due to the severity of the fires and the condition of many of the remains it was only possible to identify a number of these by assessment of their age using dental and skeletal development.[15] Teeth are among the most reliable tools in the process of identification of age, especially in the first and second decades. The stages of development can be considered as one of the most dependable indicators in assessing the age of the victim.[16]

BASED ON HAND WRIST RADIOGRAPHS

Reliable indicators of individual skeletal maturity are three: increase in statural height,9skeletal maturation of the hand and wrist, and changes in morphology of the cervical vertebrae.

FISHMAN'S METHOD

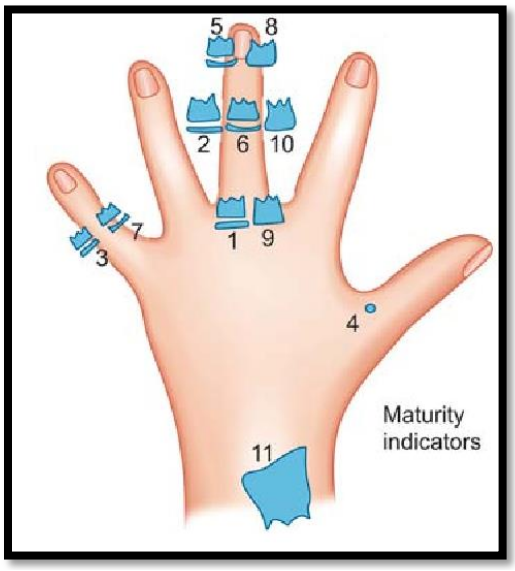
Skeletal maturity indicators (SMI) introduced by Fishman, an American orthodontist, in 1981 are widely used for the assessment of skeletal maturity in orthodontic patients. (Figure 1)

Table 1- Example of dental age estimation using the Demirjian et al. method

Tooth	31	32	33	34	35	36	37
Stage	G	G	F	E	E	G	E
Score	8.2	11.7	10.0	11.0	12.0	17.0	12.5
Dental maturity score (DMS)	82.4						
Dental age (DA)	8.80 years						
Chronological age (CA)	8.66 years						
DA - CA	Overestimation = 0.14 years						

***** *DMS=Dental maturity score; DA=Dental age; CA=Chronological age*

Figure 1- Fishman's eleven discrete indicators six anatomical sites



ATLAS METHOD

The Radiographic Atlas of Skeletal Development of the Hand and Wrist' by Greulich and Pyle. (GP) has been widely recognized. This atlas consists of separate reference images for boys and girls aged 0-18 (boys) or 0-19 years (girls) in various intervals (3 months-1 year). Images are accompanied by an explanation of the gradual age-related changes in the bones at a given age and separate BAs calculated for each bone.

BJORK'S METHOD

Bjork and Helm used four stages of bone maturation, all found at five anatomical sites located on the thumb, second finger, third finger, and radius. However, eight discrete adolescent skeletal maturity indicators covering the entire period of adolescent development are found on these five sites.[17]

BASED ON CERVICAL VERTERBRAE MATURATION

The level of craniofacial skeletal maturity in a given patient is important in identifying the optimal time to initiate orthodontic/orthopedic treatment of certain craniofacial skeletal imbalances.

HASSEL AND FARMAN'S METHOD

In 1995, Hassel and Farman were the first to propose the use of the CVM method based on three vertebrae. They stated that these vertebrae were selected because C3 and C4 could be visualized even when a thyroid protective collar was worn during radiation exposure.[18]

BACCETTI'S METHOD

Baccetti et al. optimised Hassel and Farman's technique by analysing the same cervical vertebrae in six consecutive lateral cephalograms of 30 patients and published five CVM stages (CVMS).[19]

BASED ON DENTAL RADIOGRAPHS

A viable alternative for estimation of individual age is would be Dental Age Estimation (DAE) and establishment of its correlation with chronological age (CA). DAE is an integral part of forensic odontology. The techniques routinely employed for DAE are based on gingival emergence, eruption sequence of the teeth, or developmental stage analysis using radiographs.

DERMIJIAN'S METHOD

The original Demirjian tables provide with a chart representing the calcification stages and separate scoring tables for boys and girls, assigning a particular score to each calcification stage, the sum of which is then compared with the tables provided for DAE, separately for boys and girls.[20] Thus, a total of three tables are required to be considered at a particular time while estimating the age of a person.

GUSTAFSON'S METHOD

Gustafson's method for age determination from teeth is based on the evaluation of ground sections of teeth. Six age-associated parameters are evaluated in the ground section and are compared to a regression curve of age versus the age-associated changes. Two of these changes, transparency of radicular dentin and secondary dentin, have the highest correlation with age.

CAMERIERE METHOD

In 2006, Cameriere et al. published a method of age estimation based on the measurement of the ratio between the length of the projection of the open apices and the length of the tooth axis major (known as the open apices method). Briefly, the method uses the seven left mandibular teeth. However, the mean difference between chronological and dental age, as estimated by this method, has been shown to be variable in different studies, with some of them having been performed on similar populations.

CONCLUSION

Age estimation presents a complex problem and requires considerable experience in recognizing significant changes and allowing for their variability within any particular population. Teeth are particularly useful in age evaluation because they display a number of observable age-related variables and they tend to remain intact under circumstances which might alter or obliterate the rest of the skeleton.

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