Dental Age Estimation Methods in Egyptian Studies: Systematic Review

Amal A El-Bakary

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ABSTRACT

Age estimation is fundamental in personal identification, especially in cases undergoing criminal proceedings, immigrants, or those requesting asylum. Variation in dental development among populations is reported in the literature without clear explanations. In the absence of population-specific standards, data from other populations will be used as a reference without considering whether they are appropriate or not. The main objective of dental age estimation methods is to obtain the best-standardized method for legal age estimation. Hence, age estimation methods must be simple, reliable, and can be applied to both living and dead individuals. In this document, I tried to shed light on the published Egyptian studies discussing different methods for dental age estimation. Unfortunately, a little number of Egyptian studies could be found in this field. Eight dental age estimation methods were reported in 19 Egyptian studies. The commonest evaluated method was the Pulp/Tooth Area Ratio (5 studies) followed by that of Demirjian et al. (1973) (4 studies). It is recommended to adopt the idea of establishing a validated Egyptian study that introduces Egyptian- specific standards.

Introduction

Age is a very important cultural, religious, and social matter (Chudasama et al., 2012). From the forensic point of view, age estimation is the cornerstone in the identification of unknown bodies and skeletal remains (Willems et al., 2002). Indicators used for age assessment are usually those related to somatic, sexual, skeletal, and dental maturity (Schmeling et al., 2004). From these methods, teeth provide several reliable parameters for age prediction (Wahdan et al., 2017).

[1] *Forensic Medicine and Clinical Toxicology, Mansoura University, Egypt.*

As age estimation is a challenging task, the main objective is to obtain the best-standardized method for both legal and medical age estimation. Thus, it must be simple, reproductive, and can be applied both ante- and post-mortem (Jayaraman et al., 2011).

The first published scientific study that proved the use of teeth as an age indicator was presented in 1837 by Edwin Saunders (Stavrianos et al., 2008). Later, several techniques have been introduced for dental age estimation. Methods can be divided into four main categories: clinical (visual), morpho-histological, biochemical, and radiological methods. The clinical (visual) method depends on the eruption of teeth. The age at which the teeth erupt, is greatly related to the growth and development of the child (Alnemer et al., 2017).

Morpho-histological methods are based on the assessment of dental regressive changes microscopically thus require extracted teeth e.g. Gustafson (1950). In this method, each of the criteria has a score ranging from 0 to 3. The grade value of each age change is then added to give a total score. The error of age estimation was ± 3.6 years. However, these methods are not acceptable due to ethical, religious, and scientific reasons.

The biochemical method depends on the racemization of amino acids. L-aspartic acids are converted, in a time-dependent manner, to D-aspartic acids. So, the levels of D-aspartic acid in enamel, dentin, and cementum could be correlated with age (Stavrianos et al., 2008).

Radiographic assessment of age is a non-invasive, simple, and reproducible method that can be employed for both living and dead bodies. These methods depend on the assessment of teeth mineralization and development stages. Various radiographic images were used in age identification as panoramic, peri-apical, cephalometric, and lateral oblique radiographs in addition to advanced imaging technologies (Panchbhai, 2011).

The chart (*atlas*) introduced by Schour and Massler (1941) was the 1st attempt at scientific dental age estimation that is based on a survey. The chart is based on direct comparisons with radiographs. They gave twenty stages of teeth development from four months in utero to 21 years of age. There were no separate surveys for males or females.

In Nolla's method (1960), the *mineralization of permanent dentition* was divided into ten stages. Each tooth is given a reading and a total is made that is compared with a table provided. Girls and boys are dealt with separately.

Demirjian et al. (1973), a widely used method, is based on the development of the seven left permanent mandibular teeth that are divided into eight stages from the beginning of calcification to the final mature form. Each tooth has a stage that can be converted into a sex-specific maturity score. The sum of the scores provides an estimate of the subject's dental maturity, measured on a scale from 0 to 100. In 1993, Mincer et al. modified Demirjian et al. (1973) method by including the 3rd molar in the maturation score. Regression formulas and empirical probabilities were provided.

Willems et al. (2001) also made some modifications to Demirjian's method. Developmental stages described in Demirjian's technique were expressed directly in years for each of the seven left mandibular teeth for boys and girls. All scores are summed up to give dental age in years directly using the reference tables.

Other methods assessed the volume of teeth in correlation to age. Ikeda et al. (1985) calculated the *tooth coronal index (TCI)* by measuring the coronal pulp cavity length and tooth crown length on the radiographs of incisors and molars. Meanwhile, Kvaal et al. (1995) used the *pulp-to-tooth ratio* as an indicator of age. This method depends on the fact that secondary dentin deposition, by aging, reduces the size of the dental pulp cavity. By applying linear regression analysis, the measurement of this reduction was correlated with age.

After the ages of 15, the maturity of the third molar is one of the few quantitative biological indicators used for age estimation. Harris and Nortje (1984) suggested five stages for root development in the third molars that were correlated with age.

Several articles have been published describing the use of three-dimensional imaging techniques in dental age estimation methods. These include: Computed Tomography (CT) came in 1972, Micro Computed Tomography (Micro-CT) in the early 1980s, Magnetic Resonance (MR) came in 1985 and Cone-Bean Computed Tomography (CBCT) in 1996 (Bjørk and Kvaal, 2018). Also, automatic software was developed that uses referable morphological and radiological techniques (Willems, 2000).

Another principle used open apices for age estimation is the Cameriere method (2006). The *distance of open apices* was correlated with age through a linear regression formula. The ratio of the height of teeth and the width of their 'open' apex is measured; this allows compensating magnification and angulation errors induced during radiography.

In 2008, Cameriere et al. applied *the third molar maturity index* (I3M) as an indication of the age of 18 years. The I3M depends on the measurement of the width of the open apices of the mandibular third molars. A threshold (cutoff) value of I3M was identified discriminating adults from the minors.

In this review, I tried to put my hands on most of the published Egyptian studies discussing different methods for dental age estimation. This can help to find the gaps, problems, and advantages which can lead us to further research.

Methods

A literature search of PubMed, Google, Google Scholar, Egyptian Knowledge Bank, and Research Gate databases was conducted to identify all eligible published studies discussing dental age estimation in Egyptians. Keywords were age estimation, dental age, and Egyptian. Criteria for the selection were restricted to original articles, published in English and on the Egyptians. The articles discussing sex identification from teeth were excluded. The articles were analyzed and the characteristics of each article were systemized to give a short overview of the main points.

Results

Nineteen articles were retrieved through electronic search using the chosen keywords. Two studies were excluded as age estimation was through mandibular indices. Table (1) illustrates that the evaluated methods were Pulp/Tooth Area Ratio (5 articles), Demirjian et al. (1973) method (4 articles), coronal index (2 articles), the emergence of teeth (2 articles), cemental incremental lines (one study) and the third molar maturity index (one study). Meanwhile, two studies were comparative.

Table (1): Characteristics of Egyptian studies for dental aging

Methods	Reference articles	Study sample	Age of subjects
1. Emergence of teeth	Soliman et al. (2011)	1132 infants Selected from different governorates of Egypt	4–36 months
	Elhiny et al. (2018)	978 children Fayoum Governorate (to the west of Cairo)	6-12 years
2. Demirjian method	Hassan and Abo Hamila (2007)	380 (214 males and 166 females) from the middle Delta region.	8 - 26 years
	Azzawi et al. (2016)	400 children from Tanta City (the middle Delta region)	5–13 years
	Ali et al. (2019)	160 children from Minia Governorate, Upper Egypt	3-10 years
	El-Shenawy et al. (20١٤)	200 children from Cairo	8-10 years
3. Coronal index	El Morsi et al. (2015)	234 subjects (119 males and 115 females) Mansoura City, from the middle Delta region.	8 - 74 years
	Wahdan et al. (2017)	170 Egyptians, Tanta City, from the middle Delta region.	---
4. Pulp/Tooth Area Ratio (PTR)	Ahmed et al. (2013)	48 cases; 24 males and 24 females, (CBCT). Minia Governorate, Upper Egypt	14-45 years
	Abd El-Wahab et al. (2013)	600 digital orthopantomogram, from Cairo.	---
	Afify et al. (2014)	500 panoramic radiographs (262 males and 238 females), from Cairo	18-71 years
	Elmoazen et al. (2017)	150 individuals (262 males and 238 females (CBCT)	18-70 years
	Afify et al. (2019)	150 individuals (CBCT) from Cairo	14-68 years
5. The third molar maturity index (I_{3M})	El-Bakary et al. (2019)	247 orthopantography (97 boys and 150 girls), Mansoura City, from the middle Delta region.	13-24 years
6. Comparative studies	El-Bakary et al. (2010)	286 panoramic radiographs (134 boys, 152 girls), Mansoura City, from the middle Delta region.	5 -16 years
	Rabie et al. (2018)	310 panoramic radiographs (183 girls and 127 boys), Mansoura City, from the middle Delta region.	5-16 years
7. Cemental Incremental Lines	Hassan and Shehab (2004)	82 mandibular first premolar teeth	---

CBCT: cone-beam computerized tomography

Discussion

This systematic review article emphasizes published research for dental age estimation in Egyptians. Two studies were reported discussing **teeth emergence** as a tool for age estimation in Egyptians. It was clear that the date of emergence of teeth is different from international values as shown in tables 2 and 3. This dissimilarity may be mainly attributed to the variation in race and ethnic background. The Egyptian population is rich in different ethnic backgrounds depending on the geographical location (Elhiny et al., 2018).

Table (2): Dental emergence times (mean ± SD) of the left, right and both sides of dentition for the maxillary and mandibular arches (n: 1132), (Soliman et al., 2011).

Tooth	Age of teeth emergence (months)					
	Boys			Girls		
	Left side mean (SD)	Right side mean (SD)	Both sides mean (SD)	Left side mean (SD)	Right side mean (SD)	Both sides mean (SD)
Maxilla						
Central incisor	9.9 (2.0)	9.7 (2.0)	9.8 (2.0)	9.8 (4.8)	10.0 (4.8)	9.9 (4.8)
Lateral incisor	11.6 (3.4)	12.3 (4.1)	12.0 (3.8)	13.1 (5.1)	13.3 (4.9)	13.2 (5.0)
Canine	19.5 (3.8)	19.3 (3.8)	19.4 (3.8)	20.0 (4.3)	19.9 (4.3)	19.8 (4.3)
1st deciduous molar	17.2 (3.8)	17.0 (3.6)	17.1 (3.7)	17.2 (4.4)	16.8 (4.5)	17.0 (4.5)
2nd deciduous molar	25.5 (2.3)	25.2 (3.6)	25.4 (3.0)	27.8 (4.9)	29.9 (6.3)	28.9 (5.6)
Mandible						
Central incisor	7.9 (2.0)	8.1 (2.1)	8.0 (2.1)	7.9 (5.2)	7.8 (5.5)	7.9 (5.4)
Lateral incisor	12.7 (3.7)	13.2 (4.2)	13.0 (4.0)	13.6 (6.1)	12.7 (4.5)	13.2 (5.3)
Canine	20.4 (4.5)	20.2 (4.4)	20.3 (4.5)	19.8 (4.2)	19.3 (4.1)	19.6 (4.2)
1st deciduous molar	17.0 (4.4)	17.0 (4.2)	17.0 (4.3)	16.6 (4.7)	16.8 (4.6)	16.7 (4.7)
2nd deciduous molar	25.4 (3.6)	25.7 (3.6)	25.6 (3.6)	29.9 (6.3)	26.3 (5.0)	28.1 (5.7)

SD: standard deviations

Table (3): Means and standard deviations of emergence times of permanent teeth in years in both arches in a group of Egyptians in Fayoum governorate (n: 978), (Elhiny et al., 2018).

Tooth	Times of emergence							
	Lower				Upper			
	Males		Females		Males		Females	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Central Incisor	7.01	1.48	6.65	1.61	7.42	1.48	7.35	1.88
Lateral Incisor	7.34	1.57	7.56	1.58	8.11	1.66	8.25	1.71
Canine	10,42	1.48	10.28	1.32	11.17	1.41	10.98	1.37
First Premolar	10,18	1.90	10.36	1.44	10.67	1.39	10.25	1.26
Second Premolar	11,03	1.35	11,96	1.31	10.74	1.61	10.66	1.29
First molar	6.62	1.59	7.34	1.52	6.89	1.50	6.51	1.91
Second molar	11.40	2.11	11.78	2.15	11.72	1.69	11.73	1.44

SD: standard deviations

Demirjian et al.'s (1973) method was evaluated by four studies on Egyptians. They showed an overestimation of age with different accuracy values between studies. These encouraged Ali et al. (2019) to generate a formula for the prediction of age using logistic regression analysis. While **the coronal index** was assessed by two studies, a regression equation was proposed by Wahdan et al. (2017) that utilized mandibular permanent 1st molars TCI. Meanwhile, El Morsi et al. (2015) proposed a regression equation relating 2nd right premolar tooth coronal index to age.

As for the **pulp/tooth area ratio**, the most accurate model for the determination of age was different between the reported five Egyptian studies. While, Ahmed et al. (2013) found that the most accurate model was the *maxillary* first premolar tooth; r=97% (compared to incisors and canine; r=90%), Afify et al. (2014) indicated that the *mandibular* 2nd premolar (r=-0.947) (compared to canine (r=-0.941) and 1st premolars (r=-0.914)) was the most closely correlated with age. Differences in results may be related to the accuracy of the radiological technique used. Ahmed et al. (2013) used cone-beam computerized tomography while Afify et al. (2014) used panoramic radiographs. Also, differences in sample size may contribute to different results.

On the other hand, **the third molar maturity index (I_{3M})** proposed by Cameriere et al. (2008) was evaluated only by one study. The authors concluded that I_{3M} can discriminate between individuals who are ≥ 18 years and those under 18 with the proportion of correctly classified boys 97% while it was 59% only in girls (El-Bakary et al., 2019).

Only two **comparative studies** (El-Bakary et al., 2010 and Rabie et al., 2018) were reported. Demirjian et al. (1973), Willems et al. (2001), and Cameriere et al. (2006) methods were compared. Willems et al. (2001) were the most accurate in both studies. While an overestimation of age in Demirjian’s and Willem's methods was detected, an underestimation of age in Cameriere’s method was observed.

Meanwhile, **cemental incremental lines** were evaluated in one study (Hassan and Shehab, 2004)) that showed an average error of more than 3 years.

Different results in evaluating the same method in the same ethnic group may be due to different and/or small sample sizes, different age groups, different radiological techniques used (panorama versus CT), and/or different statistical analytical methods. So, it is recommended to evaluate the reported most accurate studies in a large representative sample of Egyptians, suggesting formulae more appropriate for Egyptians and studying ages for teeth eruption standardized for Egyptians.

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