



## Age estimation in adults by dental imaging assessment systematic review



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### ABSTRACT

**Importance:** The need to rely on proper, simple, and accurate methods for age estimation in adults is still a world-wide issue. It has been well documented that teeth are more resistant than bones to the taphonomic processes, and that the use of methods for age estimation based on dental imaging assessment are not only less invasive than those based on osseous analysis, but also have shown similar or superior accuracy in adults.

**Objectives:** To summarise the results of some of the recently most recently cited methods for dental age estimation in adults, based on odontometric dental imaging analysis, to establish which is more accurate, accessible, and simple.

**Evidence review:** A literature search from several databases was conducted from January 1995 to July 2016 with previously defined inclusion criteria.

**Conclusion:** Based on the findings of this review, it could be possible to suggest pulp/tooth area ratio calculation from first, upper canines and other single rooted teeth (lower premolars, upper central incisors), and a specific statistical analysis that considers the non-linear production of secondary dentine with age, as a reliable, easy, faster, and predictable method for dental age estimation in adults. The second recommended method is the pulp/tooth width–length ratio calculation. The use of specific population formulae is recommended, but to include data of individuals from different groups of population in the same analysis is not discouraged. A minimum sample size of at least 120 participants is recommended to obtain more reliable results. Methods based on volume calculation are time consuming and still need improvement.

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## 1. Introduction

Age estimation is one of the most important characteristics used to establish the identity of any individual in different legal, forensic, or anthropological research context [1]. To this end, forensic teams depend on osseous analysis based methods, which have acceptable results for young individuals or in their early adulthood [2], and dental development based methods, which are highly reliable in individuals under 21 years of age [3]. However, these methods have some disadvantages: the poor resistance of bones to the taphonomic process [4], and once the individual

reaches the threshold of 21 years of age, and the third molars development concludes [3], the currently available dental development based methods are no applicable. In individuals with the congenital absence of third molar teeth, this threshold falls down up to 14–15 years of age.

To respond to the need of an ageing population, and with the evident resistance of teeth to the taphonomic process, alternative methods for dental age estimation in adults have been proposed. Primarily, these are based on the formation of secondary dentine, studied since 1950 [5] and the subsequent narrowing of the pulp cavity, which can be observed in dental radiographs, leading to the proposal of minimally invasive methods. This systematic review focuses on three methods based on odontometric analysis of the pulp cavity, performing length and width measurements [6], area measurements [7] and lastly volume calculation [8]. The objective of this review is to summarise the results of these recently most cited methods for dental age estimation in adults, to establish which method is more accurate, accessible, and simple.

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### 1.1. Description of the problem or issue

Different methods have been published for dental age estimation in adults, based on the pulp/tooth dimensions' ratios. Nevertheless, the obtained results of the application of some of these methods for dental age estimation, in adults from different population groups, surpass the accepted threshold in forensic sciences which says that the standard deviation of a method for adult's age estimation should preferable be below a standard deviation (SD) of years  $\pm 10$  years [9].

### 1.2. Description of the methods being investigated

The methods for dental age estimation in adults analysed in this paper were selected based on their minimally invasive nature, not requirement for the extraction of teeth to be performed, and pulp/tooth ratio calculation which have been applied in individuals from different populations. Kvaal et al. [6] method is based on the analysis of linear measurements of the pulp, tooth, and root length as well as root and pulp width measurements at three different root levels, initially applied on periapical radiographs and later on panoramic radiographs and tomographs. Cameriere et al. [7,10] method is based on the analysis of pulp and tooth area measurements on periapical and panoramic radiographs. Finally, the different methods for dental age estimation in adults based on pulp/tooth volume ratio from cone beam computer tomography [8,11–14] were also included in this systematic review.

### 1.3. How these methods might work

The included methods in this study are based on a negative correlation between age and the pulp chamber size, as well as on the tooth/pulp ratio calculation, regardless the nature of the used measurements: length/width, area, or volume. In other words, all of them look at the association of one age related phenomenon, as it is the formation of secondary dentine and the decrease of pulp chamber size with age, which has been accepted as an age indicator, observable and measurable with different dental imaging techniques. As an ideal, the accuracy of the studied methods should not exceed the threshold of a SD  $\pm 10$  years [4,1].

### 1.4. Why it is important to do this review

The relevance of this review is grounded on the need to recommend a method for dental age estimation with the follow characteristics: simple, fast, non-invasive, non-expensive, reproducible and over all, accurate, that can be systematically used in different academic and forensic scenarios. Helping the reconstruction of identity profiles of unidentified deceased individuals or alive individuals with doubtful identity documents.

## 2. Methods

### 2.1. Criteria for considering studies for this review

Qualitative analysis of the information: original studies, in humans, reporting the use of any of the listed methods for dental age estimation, based on pulp/tooth ratio calculation (length/width, area, volume) that preferably reported intra-inter observer calibration, generating population specific formulae or in case that did not, that reported if the obtained results were obtained by using the method's author's original formulae. English or Spanish language that expressed the results in terms of accuracy for dental age estimation.

Quantitative analysis of the information: same criteria than qualitative analysis plus the exclusion of studies which sample

included individuals younger than 14 years of age, studies with small samples ( $n < 50$ ), studies using extracted teeth, and studies that did not report the use of specific population formulae.

### 2.2. Search methods for identification of studies

The information was searched through the data-base available at the University of Western Australia which included the collections of:

Directory of open access journals (DOAJ), Medline/Pubmed (NLM), OneFile (GALE), ProQuest, collection, (Web of Science), Science Direct Journals (Elsevier), Social Sciences Citation Index (Web of Science, Scopus (Elsevier)), SocialSciences Citation Index (Web of Science), Wiley (CrossRef), Wiley Online Library. Also, google scholar, by looking at the papers that reference the original study performed by Kvaal et al. Cameriere et al., and those methods for age estimation that referred in their methodology the use of CBCT and volume reconstruction of pulp chamber and tooth.

The search key words were as follow: Kvaal and dental age estimation; Cameriere and dental age estimation; age; and tooth volume.

The literature search included papers published after the publication of the original papers of the authors to July 2016, the search was conducted during the years 2014 to 2016. In the lack of a manual for systematic review in forensic dentistry, this systematic review follows the Cochrane handbook for systematic reviews-methodology review, and when possible the RevMan software recommended by the Cochrane handbook (Figs. 1–3).

### 2.3. Data collection and analysis

#### 2.3.1. Selection of studies

The initial selection was based on the title and then abstract. Papers with titles that referred the inclusion of only minors were excluded (children). Studies reporting also the use of third molars or developing teeth, were excluded. Studies that included in the title also the use of other methods for dental age estimation in children were excluded (Demirjian) or any other invasive method for dental age estimation were excluded (Diagrams 1–3, Tables 1–3).

#### 2.3.2. Data extraction and management

The collected information was organized in an excel spreadsheet as follow: Author, year, country, number of participants (male and female), age, intra and inter-observer agreement assessment, imaging technique to obtain the images, measuring instrument, best correlation coefficient between age and the different age predictors, best result in terms of accuracy per individual tooth or per set of teeth, when possible, as well as the highest error recorded by set of teeth or individual tooth (Tables 4–6).

#### 2.3.3. Assessment of risk of bias in included studies

To avoid bias in this systematic review, and to avoid false positive (declare that a method is more accurate than other when it is not) or false negative conclusions (declare that a method is less accurate than other when it is not), it was necessary to analyse the possibility of author bias. This owed to the participation of the same authors in repeated publications. To this end, the results were analysed comparing individual papers, and then grouping them per author. Additionally, in certain cases were there were doubts in regards to the origin of the sample, which means the likelihood to find studies that had used the same sample, the authors were contacted to confirm the origin of the sample, and in case that two studies had the same sample, the authors were asked to suggest which study should be included in

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