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Computed Tomography Use on Age Estimation in Forensic Dentistry: A Review

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Abstract

Computed tomography is an alternate imaging modality which can be used to estimate age and to aid on human identification in Forensic Dentistry. This paper proposes to review the literature about the computed tomography (CT) use on age estimation in Forensic Dentistry. The searched database was PubMed for the terms: 'computed tomography' AND 'age estimation' AND 'forensic dentistry'. Eighteen listed studies were analyzed. They should be research that analyzed anatomical structures related to Dentistry without alteration of these structures and they had been written in the English language. Then thirteen studies were reviewed and the others were excluded. The computed tomography use to estimate age through dental age estimation methods and calculations to obtain the ratio between pulp volume and tooth volume displays significant accuracy.

Keywords: Computed tomography; Age estimation; Forensic Dentistry

Introduction

Forensic Dentistry has become an integral part of Forensic Sciences over the past 100 years that utilizes dental or orofacial findings to serve the judicial system. This has been due to the dedication of many researchers that established the essential role that Forensic Dentistry plays, mainly in the identification of human remains [1].

The data obtained from the oral cavity can contribute to estimate age and to determine sex of an unknown individual or provide information needed to Justice and security. It requires interdisciplinary knowledge. Furthermore, these data can narrow the search range of an individual and play a key role in the victim identification [2].

Classic methods for forensic dental identification are the clinically used radiological documentation techniques such as dental periapical radiographs, bitewing films and panoramic x-ray. In these methods, dental changes related to age like tooth eruption, tooth calcification, attrition, periodontal diseases, secondary dentin deposition, root translucency, cementum apposition, root resorption, color changes and increase in root roughness are analyzed [3-60].

An alternate imaging modality that is beginning to make inroads into medicolegal death investigation around the world is computed tomography (CT) [61-63]. The clinical introduction of cone-beam CT creates new opportunities to get 3-dimensional (3D) tooth radiographs. It has been shown that CT scans cause no magnification errors due to geometric distortion, which is a common problem in conventional radiography [64,65]. Typically, extraction and sectioning of teeth are required to quantify morphological changes, for obtain data like age and sex, but is not always a viable option. CT, however, provides a noninvasive alternative [66].

The aim of this study was to review the literature about the CT use on age estimation in Forensic Dentistry.

Material and Methods

The searched database was PubMed for the terms: 'computed tomography' AND 'age estimation' AND 'forensic dentistry'. All listed studies were analyzed. They should be research that analyzed anatomical structures related to Dentistry without alteration of these structures and they had been written in the English language.

Results

Eighteen listed studies were analyzed. Five studies were not according to descriptions in Material and methods were excluded. Then thirteen studies were reviewed (Table 1).

Authors	Age range (years)	Teeth/ anatomical region	Analysis type	Key points
Aboshi, Takahashi and Komuro (2010) [67]	20-78	Mandibular first and second premolars	Ratio between pulp volume and tooth volume.	The coronal one third of the root showed significant correlation at all age groups.
Bassed, Briggs and Drummer (2011) [68]	15-25	Mandibular third molar	Compare the developmental scores obtained from both CT images and conventional OPT* - Demirjian method [69].	It was found excellent agreement of Demirjian scores between CT images and conventional OPT* [69].
Brough, *et al.* (2014) [70]	0-18	Mandibles and maxillas	Age estimations based on CT data compared with those using OPT* - QMUL† method and Demirjian method [13,69,71,72].	It was obtained almost perfect agreement between mean estimated age using CT and mean estimated age using OPT*.
Cantekin, Sekerci and Buyuk (2013) [73]	9-25	Mandibular third molar	Tooth development and relation to chronological age on CT images – Demirjian method [72].	Strong correlation between age and third molar development.
Graham, *et al.* (2010) [74]	Up to 15	Second permanent molar	The last stages of its root - MFH‡ method. [75,76]	The MFH method was found to systematically underestimate the chronological age [75,76].
Lalys, *et al.* (2011) [77]	Fetuses: 19-41 WA,	Germs of deciduous teeth and mandibles	Relationships between fetal age and deciduous germ measurements.	The most precise age evaluation obtained, so greater accuracy is still needed.
Pinchi, *et al.* (2015) [78]	10-80	Maxillary left central incisor	Ratio between pulp volume and hard tissues volume.	This ratio was statistically significant as a predictor for age estimation.
Sakuma, *et al.* (2013) [79]	14-79	Left or right mandibular first premolars	Ratio between pulp volume and tooth volume.	Estimated age correlated significantly with the pulp cavity to tooth volume ratio.
Someda, *et al.* (2009) [80]	12-79	Mandibular central incisors	Volumes of enamel, dentin, and pulp cavity.	The whole tooth and the crown region presented slightly higher correlations for ratio between pulp volume and tooth volume with enamel excluded.
Star, *et al.* (2011) [81]	10-65	Incisors, canines and premolars	Ratio between pulp volume and tooth volume.	This ratio was strongest related to age on incisors.
Tardivo, *et al.* (2011) [82]	14-74	Canines	Ratio between pulp volume and tooth volume.	Negative correlation between this ratio and age.
Vandevoort, *et al.* (2004) [83]	24-66	Incisors, canines and premolars	Ratio between pulp volume and tooth volume.	Rather weak correlation between this ratio and biological age.
Yang, Jacobs and Willems (2006) [66]	23-70	Incisors, canines and premolars	Ratio between pulp volume and tooth volume.	Moderate correlation between this ratio and biological age.

* OPT - orthopantomography
† QMUL - London Atlas of Human Tooth Development and Eruption
‡ MFH - method proposed by Moorrees, Fanning and Hunt

Table 1: Reviewed studies from PubMed database for the terms: 'computed tomography' AND 'age estimation' AND 'forensic dentistry'

Discussion

Age estimation is one of the main data that aid in human identification process. The dental changes quantification generally had used destructive methods such as the extraction and sectioning of the tooth that are unsuitable in living subjects and even for specific religious, cultural, or scientific reasons. Therefore, conservative techniques for age estimation like two dimensional images (conventional radiography) and mainly three dimensional images (CT) have been most studied [78].

CT has been gradually accepted due to aid and the potential replacement from conventional radiography by reproducing and augmenting of the information available. This has generated suitable resolution and high quality image reconstructions in multiple planes and three dimensional modelling of slices. Hard tissues images like teeth and bones are assessed using CT in any plane without invasive procedures, offering considerable practical and aesthetic benefits [70].

The reviewed studies demonstrated to estimate age through CT images applying dental age estimation methods which determine stages of teeth development and eruption.

Bassed, Briggs and Drummer, Brough, *et al*. and Cantekin, Sekerci and Buyuk used Demirjian method to analyze and to determine the score [68-70,72,73]. The first and second studies compared CT images to OPT of deceased individuals and human remains respectively, and found excellent agreement and almost perfect agreement, respectively, between these imaging modalities [68,70]. The third study evaluated CT images from patients' records and it was showed strong correlation between age and third molar development [73]. The differences among these studies are teeth/anatomical region and age range according to Table 1.

An important observation from the second study is that also used QMUL method [71] and found the same agreement. Moreover Graham, *et al*. used a different age estimation method compared above authors, a method proposed by MFH and they observed systematically underestimate the chronological age [74-76].

The four studies which used dental age estimation methods three carried out postmortem evaluation and two of these demonstrated significant agreement between CT images and conventional OPT [11,13,14,17,18,68,70,73,74].

The other reviewed studies calculated the ratio between pulp volume and tooth volume [9,20-25]. The choice of this method is due to the perception of the reduction of the pulp chamber volume concerning to deposition of secondary dentin related to age in radiological images like radiographs and CT [67,78-83].

Aboshi, Takahashi and Komuro and Sakuma, *et al*. evaluated mandibular premolars and found the coronal one third of the root showed significant correlation at all age groups at the first study and the estimated age correlated significantly with the pulp cavity to tooth volume ratio according to second study [67,79].

Pinchi, *et al*. and Someda, *et al*. analyzed maxillary and mandibular central incisors, respectively, and obtained the ratio between the pulp volume and the hard tissues volume was statistically significant as a predictor for age estimation and the whole tooth and the crown region presented slightly higher correlations for ratio between pulp volume and tooth volume with enamel excluded, respectively [78, 80].

Star, *et al*. selected incisors, canines and premolars and noted the ratio between pulp volume and tooth volume was strongest related to age on incisors [81]. On the other hand, Tardivo, *et al*. selected only canines and observed a negative correlation between this ratio and age [82].

Vandevoort, *et al*. and Yang, Jacobs and Willems studied incisors, canines and premolars and found rather weak and moderate correlation, respectively, between the ratio pulp volume and tooth volume and biological age [66,83].

Lalys, *et al*. developed a different study analyzing fetal age through deciduous germ measurements and they showed the most precise age evaluation obtained, so greater accuracy is still needed [77].

The nine studies which calculated pulp volume and tooth volume ratio, one carried out postmortem evaluation and the others evaluated CT images of extracted teeth or patients [21,66,67,78-83].

Computed tomography is capable of providing accurate and measurable 3-dimensional images of different teeth, maxilla and mandible like the studies analyzed in this review [70].

Most studies evaluated teeth which assume a primary role in the identification of remains when postmortem changes, traumatic tissue injury, or lack of a fingerprint record invalidate the use of visual or fingerprint methods. The identification of dental remains are of primary importance when the deceased person is skeletonized, decomposed, burned, or dismembered. The main advantage of dental evidence is that, like other hard tissues, it is often preserved after death. Even the status of a person's teeth change throughout life and the combination of decayed, missing, and filled teeth is measurable and comparable to any fixed point in time. Teeth can survive virtually intact long after other soft tissue and skeletal tissue have been destroyed by decay or incineration [1].

Therefore computed tomography is important, in order to capture anatomical features images of the dention and skull to assess age estimation [68].

Conclusion

The computed tomography use to estimate age through dental age estimation methods and calculations to obtain the ratio between pulp volume and tooth volume displays significant accuracy.

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