A CURRENT PERSPECTIVE ON NOVEL METHODS FOR DETERMINING DENTAL AGE IN THE NEW GENERATION: A REVIEW

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Abstract

In forensic odontology, dental findings play a significant role in determining age and gender. Due to their anatomical structures and durability, teeth have a critical function in identification, even when exposed to mechanical, chemical, and physical effects. However, most of the estimated dental age determination methods are generally invasive, costly, and require procedures like tooth extraction. Additionally, misinterpretations can occur in 2-dimensional imaging due to distortions and magnifications. Recently, three-dimensional imaging technologies, especially Cone Beam Computed Tomography (CBCT), Computed Tomography (CT), and micro-CT, are being used to investigate the potential relationship between the volumetric data of the tooth and pulp and age. CBCT allows researchers to comprehensively evaluate pulp changes and explain the relationship between chronological age and pulp volume. With the 3D images obtained by CBCT, the volumetric measurements of the tooth and pulp can be objectively evaluated and can be used as a criterion for estimated dental age. This review aims to identify, investigate, and summarize the most reliable, practical, and accurate methods for age estimation based on current data and methods.

Introduction

In forensic analyses, estimating age and gender holds critical importance for obtaining information about an individual's biological profile. Such estimates are a commonly utilized method in civil law and for immigrants with incomplete identity information. Similarly, in criminal law, age estimation is employed to determine whether an individual is an adult and, in this context, to establish criminal responsibility (1). In cases of suspicious death, infant mortality, and individuals with mental health issues, determining age may be mandatory.

Moreover, in developing countries where population records are insufficient, accurately determining individuals' age bears significant importance (2). Forensic dentistry plays a critical role in identifying individuals whose identity cannot be determined and focuses on examining teeth to identify characteristics such as age, gender, and ethnic origin of living or deceased individuals. Teeth can contain essential information about an individual's identity. Dentists can play a crucial role in issues like medical malpractice, neglect, child abuse, and the use of dental records for diagnostic purposes (3). Teeth, due to their anatomical

structures and robustness, resist mechanical, chemical, and physical factors, serving a critical function in identity determination (4). In the field of forensic dentistry, 2-dimensional radiographic techniques commonly used can result in errors such as magnification and distortion. Due to these issues, modern three-dimensional imaging methods like Cone Beam Computed Tomography (CBCT) have begun to be preferred for dental age estimations. CBCT allows for obtaining more detailed and clear images compared to traditional radiographic methods, which enables a more detailed evaluation of the morphological features of the teeth. Therefore, in forensic dentistry practice, CBCT is recognized as a prominent method for identity and age determination (5). Research on dental age determination using dental radiographic images demonstrates variability specific to community and individual. Radiological age determination studies vary among different populations. Moreover, 2-dimensional images tend to be insufficient in providing volumetric information about teeth, escalating the need for 3-dimensional imaging technologies. The 3-dimensional images obtained through CBCT can create objective age estimation criteria through tooth and pulp volume measurements. Therefore, the aim of this review is to investigate and summarize the applicability of determining the most reliable, practical, and accurate methods in age estimation.

Dental Age Estimation Methods

Dental age estimation is a method used in various fields. It is commonly used in areas related to maxillofacial growth, particularly in pedodontics and orthodontics. This method is carried out by comparing the radiographic developments of the teeth with a certain standard. These standards are determined as a result of studies conducted on many individuals and show how much tooth development has been completed according to a certain age. The development process of the teeth shows differences according to different age groups, and therefore dental age estimation is an important tool in determining age. Factors such as tooth eruption dates or the degree of tooth calcification are among the other methods used in dental age estimation. The accurate application of these methods can assist in obtaining accurate and definitive results in forensic medicine and other health fields (6). Methods used in estimating dental age are categorized into 4 classes: clinical, radiological,

histological, and physical-chemical analysis methods. The clinical method relies on the current condition and visibility of the teeth in the mouth, while the radiological method determines the development stage of the teeth through radiographic examinations. The histological method involves examining tooth materials under a microscope and is frequently used, particularly in evaluating post-mortem cases. In the physical and chemical analysis method, age estimation is facilitated by evaluating changes in ion levels in the teeth. The effective utilization of these methods holds significant importance in forensic medicine practices and the field of forensic dentistry (7).

Panoramic radiographs, which are frequently used for dental age estimation, are widely utilized in determining dental age because they display all the teeth in a single image and are easily accessible. Particularly in children, panoramic radiographs are often preferred due to the difficulties and distortion risks of intraoral radiography (8).

Various methods are used for dental age estimation, and the most popular among them are radiographic methods. These include different techniques like Demirjian's(9), Willems's(10), and Cameriere's methods. Panoramic radiography is often preferred in children due to its accessibility and the ability to display all teeth in a single image. These methods are among the most reliable methods used in estimating dental age. However, each method has its own advantages and disadvantages, and the method to be preferred can vary depending on the dentist or specialist's experience (11, 12). In a review, an examination found that there is a high rate of variability in age estimation in forensic dentistry, suggesting that for a more reliable age estimate, several of all possible techniques should be used together (13).

Traditional 2-dimensional dental radiography techniques, although frequently used in dental practice, have given way to three-dimensional imaging systems, especially Cone Beam Computed Tomography (CBCT), with modern technological advancements. CBCT allows for a more detailed and 3-dimensional examination of the orofacial area and teeth (14).

Recently, with the widespread use of 3-dimensional images in clinical dental practice, the potential relationship between dental age and pulp volume is being investigated. Thanks to Cone Beam Computed Tomography (CBCT), 3-dimensional images of teeth can be obtained without magnification and distortion. CBCT

is used as an important tool in providing objective data of pulp and tooth volume values for age estimation (15).

Methods of Estimating Dental Age Based on Pulp and Tooth Volume

Teeth undergo physiological processes that vary according to age. Another significant physiological change that occurs after root development is completed with age is the accumulation of secondary dentin. This situation leads to a reduction in the volume of the pulp chamber, which is a criterion used for calculating the estimated dental age. Additionally, the pulp may recede due to mechanical stimuli or aging. With aging, the decrease in the volumetric size of the pulp becomes more prominent due to the increase in collagen fibers (16, 17). Different methods can be used to examine the size of the pulp chamber with tooth sections or radiographs, and can be used in determining dental age. However, the drawback of radiographs is that they are 2-dimensional, preventing the simultaneous evaluation of mesio-distal and bucco-lingual dimensions (18). Among 2-dimensional techniques to measure the volume of the pulp chamber are periapical and panoramic radiographs, while 3-dimensional techniques include computer tomography, micro-CT, and CBCT (Cone Beam Computed Tomography). CBCT has advantages such as not causing magnification, providing more detailed information, having fewer artifacts, and having a lower radiation dose than CT (19). The advancement of technology has increased the demand for 3-dimensional volumetric measurements, enabling us to better understand the accumulation of secondary dentin in teeth. Researchers have published studies related to determining the estimated dental age by calculating tooth and pulp volume measurements using micro-CT and CBCT images (20).

In recent times, 3D imaging technologies, particularly CBCT, CT, and micro-CT, have been utilized to explore the potential relationship between the tooth and pulp volume ratio and age. It has been indicated that the pulp/tooth volume ratio of single-rooted teeth might be more suitable for the analysis of estimated dental age. Nonetheless, further studies are needed in this area, and regression formulas may yield different results due to the different geographic origins or age distributions of the population (21). Moreover, it has been reported that estimating age from the permanent 1st molars, which have multiple roots, could also be a valid

option (22). Previous research demonstrates that the CBCT technique possesses sufficient accuracy to evaluate the anatomy of the pulp cavity of teeth and can be used as a non-invasive method since it does not require tooth extraction. CBCT is recognized as the method providing the most accurate and clear results for measuring tooth volume (23).

If examples from literature studies in this field are to be provided; Vandevoort et al., in 2004, developed a volumetric analysis software using micro-CT to estimate the pulp/tooth volume ratio of single-rooted teeth of different shapes, and based on the results of the research, its relationship with age has been defined and it has been suggested as a usable method in dental age calculation (24). Aboshi et al., have measured 40 mandibular premolar teeth in 4 segments as the crown of the tooth, and the cervical, middle, and apical thirds of the root, using data obtained from micro-CT images. According to the obtained pulp/tooth volume ratios, it has been reported that the correlation with age is stronger in the cervical region of the root compared to other segments and decreases towards the apex area (25). In the research conducted by Someda et al., volumes have been calculated by taking slices of 155 mandibular incisor teeth with micro-CT, and regression models have been created. The standard deviation has been determined as 10.26 years for men and 8.09 years for women, and it has been determined that the estimated dental age for women contains a higher accuracy rate compared to men. However, it has been emphasized that different equations need to be formed for both genders (26).

In Yang et al.'s research, a linear regression relationship between tooth-pulp volume ratios and chronological age was found, and the standard error between estimated dental age and chronological age was determined to be ±8.3 years (27).

In a study conducted by Star et al., in dental age estimations made with CBCT, the standard error rates for canine, incisor, and premolar teeth were determined to be 13.10 years, 12.86 years, and 8.44 years, respectively. In the same study, no significant difference was found between males and females in these estimates (28).

In another study, an estimated dental age model was created based on the pulp volumes of the upper and lower first molar teeth of Chinese individuals. The study found a logarithmic relationship between pulp volume and estimated dental age, and this relationship could vary depending on gender and tooth position (22).

A meta-analysis has shown an inverse correlation between age and the volume of the pulp chamber with CBCT data. The mandibular first molar tooth has the strongest correlation, while the third molar tooth has the weakest. Additionally, this relationship is more pronounced in women than in men (29).

3D Software Programs Used for Dental Imaging and Evaluation

In addition to sectional and volumetric imaging techniques, 3D modeling software supports volume calculations. The boundaries of tissue can be determined manually through density differences, a process referred to as "segmentation." Segmentation involves grouping pixels and voxels. Volume measurements can be made manually, automatically, or semi-automatically based on grayscale differences (30, 31).

Cone beam computed tomography (CBCT) images are analyzed using specialized software. This software includes sectional imaging programs such as OnDemand3D (CyberMed, Seoul, Korea), InVivo-Dental (Anatomage, San Jose, Calif), Mimics Innovation Suite (Materialise, Leuven, Belgium), Dolphin3D (Dolphin Imaging & Management Solutions, Chatsworth, Calif), 3D Slicer (http://www.slicer.org), 3D Doctor (Able Software Corp, Lexington, MA, USA), ITK-SNAP (www.itksnap.org), I-Dixel (J. Morita Mfg. Corp), and MATLAB (The MathWorks, Inc., Natick, MA, USA). These programs, in addition to allowing for tooth and pulp volume measurements, facilitate 3D modeling processes. With the advancement of medical imaging techniques, when CBCT is used for tooth and pulp volume, a DICOM format has been established for data management. This format stores patient and device information, scanning details, and sectional data. A key feature of CBCT software is its ability to organize and rearrange the acquired data in DICOM format (32-34).

CONCLUSION

Evaluations conducted regarding dental age determination necessitate volumetric examinations to obtain the most objective result. Therefore, using cone beam computed tomography (CBCT) images, pulp and tooth volumes can be measured and an objective criterion can be established for dental age determination. With the widespread use of 3D images in clinical dental practice, it becomes evident that more research is needed to investigate the potential relationship between age and pulp volume and to contribute to developments in this field.

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