MINI REVIEW

Dental Age Estimation Methods in Adults

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Abstract

Introduction: Age estimation plays a crucial role in forensic dentistry, particularly in cases involving adults. This abstract highlights the challenges of age estimation among adults, emphasizing the ethical concerns when dealing with living individuals.

Aim: The primary aim of this review is to discuss various age estimation methods applicable to adults in forensic dentistry. It evaluates the reliability and suitability of these methods based on legal questions and specific populations.

Materials and Methods: The review explores several age estimation techniques, including Gustafson's method, dentin translucency, pulp-tooth ratio, cementum annulation, attrition, amino acid racemization, and radiocarbon analysis of dentition. It also underscores the histological and biochemical approaches while acknowledging the ethical challenges associated with extracting tooth specimens from living individuals. The collaboration between forensic dentistry investigators and statistics experts is essential for achieving accurate and population-specific calculations.

Conclusion: In forensic dentistry, the objective of age estimation is not merely to provide an exact age but to determine a scientifically relevant age range. By employing various age estimation methods and presenting their results to the legal system, investigators can offer valuable insights into the age of individuals, considering the strengths and limitations of each approach. This collaborative effort ensures that the age estimation process is accurate and context-specific.

Keywords: Forensic, Dental, Age estimation, Hard and Soft tissues, Radiograph.

Introduction

Age estimation in adults involves the assessment of anatomical and biological changes in teeth and their associated structures. Although human dentition exhibits both similarities and unique characteristics, variations in growth occur among populations due to factors such as genetics, epigenetics, environment, disease, and nutrition.[1] The physical properties of dental tissues provide forensic dentists with valuable information for personal identification, including age, gender, and ethnicity.[2] Current research efforts are directed toward developing population-specific formulas for age estimation, recognizing that estimated age may deviate from chronological age within a range of ±10 years.

The application of dental age estimation in adults serves various legal purposes, both in cases involving living individuals and the deceased. In instances involving living individuals, age diagnosis may be required for legal confirmation, marriage regulations, insurance claims, or child labor laws. The International and Interdisciplinary Study Group on Forensic Age Diagnostics (AGFAD) has published guidelines for age estimation in living individuals, applicable to criminal, civil, asylum, old-age pension proceedings, and skeletal age determinations.[3] These recommendations are also relevant in criminal proceedings to determine criminal responsibility and the applicability of adult criminal law.[4] In cases requiring age estimation for legal purposes, forensic experts must be informed about the type and purpose of the examination. The primary objective of a forensic report is to provide the most likely age of the individual under examination and, where applicable, the degree of probability that their age corresponds to the relevant legal age limit.

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Age estimation in adults encompasses various methods, including clinical, radiographic, histological, and biochemical analyses. While a comprehensive discussion of all adult age estimation methods is beyond the scope of this essay, we will provide an overview of several relevant approaches, such as Gustafson's method, dentin translucency, pulp-tooth ratio, cementum annulation, attrition, and amino acid racemization.

Gustafson's Method

Gustafson's method employs regressive changes in teeth to estimate the age of adults, taking into account factors like attrition, secondary dentine deposition, periodontal ligament recession, cementum apposition, root resorption, and dentine translucency. This method exhibits an age estimation error rate of +3.6 years, but Indian studies have reported a higher error rate of +8 years.[5] Each of these parameters is assigned a grade ranging from 1 to 4, based on the extent of regressive alterations in the tooth. The total score (Y) is calculated by summing up the scores for these seven independent regressive alterations. The formula for this method is 11.43 + (4.56 x Y).

To improve upon Gustafson's analysis and rectify miscalculations, Johanson revised the original formula. He introduced a system with seven grades (0, 0.5, 1, 1.5, 2, 2.5, and 3) and employed multiple regressive analysis. The formula for the revised Gustafson's method is: 11.02 + (5.14 x a) + (2.3 x s) + (4.14 x p) + (3.71 x c) + (5.57 x r) + (8.98 x t). However, it's important to note that this analysis has limitations, as the use of multiple variables can lead to significant variations in calculations. Additionally, the process of tooth sectioning is time-consuming, and interpreters must possess knowledge of dental histology.

While the variables in Gustafson's method are valid, continued use of all six variables is discouraged due to potential statistical inaccuracies. To address this concern, Maples revisited the original method and incorporated two variables—secondary dentine deposition and dentine translucency—into the calculation. The advantage of using two variables is that they can be applied even when crowns are broken, there is no evidence of periodontal attachment, or the cementum is damaged.

Kashyap and Koteswar Rao modified Gustafson's method by considering attrition, secondary dentin, cemental apposition, and root transparency. The age estimation formula for this method is 21.57 + 0.08[A] + 0.18[C] + 0.33[D] + 0.5[T]. Here, the index values of attrition, cemental apposition, secondary dentin, and root transparency are represented as [A], [C], [D], and [T].[5]

Dentin Translucency

Radicular dentin begins to exhibit increased transparency starting from the third decade of life, progressing from the apical third of the root towards the coronal third with advancing age. This phenomenon is attributed to a reduction in the diameter of dentinal tubules due to the accumulation of intratubular calcification. As aging occurs, variations in the refractive indices between the intratubular organic and extra-tubular inorganic constituents become equalized, resulting in the increased translucency of dentin. Notably, non-vital teeth do not display signs of transparency in root dentin. Research has demonstrated a close association between the aging process and dentinal sclerosis.

Traditionally, dentin translucency is assessed by measuring histologically sectioned teeth with calipers. However, contemporary digital methods have been employed to quantify dentin translucency using multiple regression formulas. In this process, the preserved tooth specimen is embedded in autopolymerizing acrylic for bucco-lingual sectioning at 250 μm using a hard-tissue microtome. The sectioned tooth image is then digitized using a photo scanner and subjected to analysis using Adobe Photoshop or Gimp software.[6,7]

Pulp-tooth ratio [PTR] method

Kvaal introduced a non-extraction-based age estimation method that involves measuring the radiolucent area of the pulp chamber. This measurement serves as an indirect assessment of secondary dentine deposition. The Kvaal method was further refined by introducing the measurement of radiographic dimensions in the ratio of tooth and pulp area.[8] Initially, this method focused on the ratio of the maxillary canine, but it was later expanded to include the second molar and mandibular canine. Age prediction using this method typically falls within the range of 3 to 4.5 years. One notable advantage of this approach is its applicability among living individuals, as it does not require tooth extraction. Recent studies have explored the use of cone-beam CT technology to calculate the ratio of pulp and tooth volume by performing voxel counting for age correlation.[9]

Cementum annulation

Cementum annulation rings are characterized by alternating thin dark and light bands, typically measuring between 80-100μm, as observed in histological sections of cementum under microscopic examination. The significance of cementum annulation in age estimation has been well-documented, yet the association between the biological rhythm of cementum annulation and biochemical metabolism, as well as its ultrastructural nature, remains not entirely understood.[10] Each pair of dark-light cemental lines forms a single annulation, and age calculation involves the summation of annulation counts and the consideration of normal tooth eruption. For instance, if forty-seven cementum annulations are identified on a mandibular first premolar, the annulation count is added to the eruption range, resulting in a calculation of (47 + 11.0 + 1 = 58.0 + 1.0).

Critiques of the use of cementum annulation in age estimation often revolve around the variability of these lines in different regions of the cementum (middle versus apical), which can lead to confusion when identifying the appropriate region for counting.[11] Reproducible counting differences also present a challenge, casting doubt on the reliability of cementum annulation as an age estimation method. Additionally, it's worth noting that this technique necessitates tooth extraction, which raises ethical concerns in cases involving both living and deceased individuals.

Attrition

The clinical method of evaluating attrition involves the examination of molar cusps, specifically focusing on the ten stages (0-9) mentioned by Chunbiao and Guijin in 1995.[12] These stages reflect varying degrees of attrition, ranging from no attrition to exposed dentine or secondary dentine. The calculation for this method involves scoring the attrition of first and second molars in both the maxillary and mandibular regions.

A study on age estimation in Indian individuals utilizing attrition has proposed formulas for maxillary and mandibular teeth.[5] For the maxillary first molar, the formula is 36.39 + 1.93 M1, while for both the first and second maxillary molars, it is 25.99 + 2.09 M1 + 1.39 M2. In the case of the mandibular first molar, the formula is 24.58 + 3.78 M1, and for the mandibular second molar, it is 22.16 + 4.26 M2. To estimate the age based on both mandibular molars, the formula is 20.08 + 2.46 M1 + 2.15 M2.

Amino acid racemization

Age estimation through the biochemical measurement of D- and L-forms of aspartic acid in enamel and dentin is a valuable method. Initially, enamel was considered for age estimation based on the D/L aspartic acid ratio, but this method was found to have an error rate due to attrition and contamination from carious enamel. To improve accuracy, the D/L aspartic acid ratio is now employed on extracted dentinal protein, resulting in a reduced age estimation error rate within a range of ±3 years.[13]

Radiocarbon analysis

The concentration of the carbon-14 isotope (14C) in the atmosphere experienced significant changes due to nuclear bomb testing in 1955. This alteration in 14C concentration in the atmosphere is reflected in enamel tissue at the time of birth. Therefore, radiocarbon dating can be utilized to determine an individual's period of birth.[14]

Problems associated with dental age estimation of living and dead adults:

Cunha et al. conducted a comprehensive review addressing the challenges associated with age estimation in both deceased and living individuals. They reported that in cases involving skeletal remains, the Lamendin method exhibits high reliability for age estimation within the range of 40 to 60 years.[15] However, it is important to note that age estimation may be influenced by the presence of periodontal disease. Lamendin and colleagues introduced a general technique for estimating the age of adults at the time of death by considering periodontal disease and the translucency of tooth roots.[16] They emphasized that age estimation should be applied to a skull with teeth and suture closure, with dental wear serving as a general indicator but not an accurate method. Tooth wear can be influenced by factors such as disease, medication use, or occlusal disturbances, making it a confounding variable in age estimation. Furthermore, consistent challenges in pulpal changes were associated with vascularization in both young and elderly groups.[17] Nevertheless, this issue is mitigated through the calculation of the ratio of the chamber to the tooth.

Recommendations in COVID infected cases:

When conducting forensic dental age estimation through radiographic methods, it is imperative to adhere to universal precautions and use appropriate personal protective equipment (PPE). These measures are crucial for the safety of both the examiner and the patient. The recommended PPE includes a disposable surgical gown that covers the entire body, a Class 2 or 3 particulate filtering face mask, surgical head caps, eye goggles, a face shield, latex or nitrile gloves, and foot covers.[18,19]

In cases where individuals require forensic dental age estimation through radiographic methods, extraoral radiographic techniques such as panoramic radiography and extra-oral periapical radiographs should be employed. It is worth noting that recent guidelines for oral and maxillofacial imaging during the COVID-19 pandemic have also recommended the use of extra-oral periapical radiographs for patients who require radiographic diagnosis related to pulpal or periodontal conditions.[19] These measures are essential to ensure the safety and well-being of both patients and healthcare professionals while conducting forensic dental examinations.

Conclusion

Estimating the dental age of living adults presents a more challenging task compared to subadults. Currently, there is no universally recommended method specifically designed for this purpose. However, certain methods, such as Kvaal's and Cameriere's analyses, including the pulp-to-tooth ratio (PTR), have proven to be useful tools for age estimation in living adults. Another relevant method is amino acid racemization. However, it's important to note that this method has limitations, as the potential damage or destruction of the tooth may raise ethical concerns. The accurate estimation of age in individuals is a critical objective in forensic investigations, particularly when involving adults. Dental age estimation, in particular, can be a challenging task in the adult population. The applicability of age estimation methods depends on the specific circumstances, whether they involve deceased or living individuals. Therefore, it is essential to thoroughly validate the underlying concepts of a chosen method before its application. It is important to emphasize that the primary goal of age estimation methods is not to provide an exact age but rather to offer an estimated age range, taking into account potential variations.

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