INDONESIAN HEALTH JOURNAL
https://ihj.rivierapublishing.id/index.php/rp
Volume 3 Number 3 September 2024
P-ISSN: 2963-3044
E-ISSN: 2963-3036

RADIOGRAPHIC TECHNIQUES FOR ESTIMATING DENTAL AGE: A COMPARATIVE STUDY

Muhammad Salman Khan[1], Elza Ibrahim Auerkari[2], Antonius Winoto Suhartono[3]
Department of Oral Biology, Division of Forensic Odontology, Faculty of Dentistry, Universitas Indonesia, Indonesia
eiauerkari@yahoo.com

ABSTRACT

The determination of dental age using radiographic techniques has become a crucial method in forensic dentistry for estimating the chronological age of individuals, particularly in cases involving children and adolescents. This study aims to compare various radiographic techniques in estimating dental age based on tooth development. A comparative research method was employed, analyzing radiographic data from individuals aged 6 to 18 years. The data were collected using two primary techniques: panoramic and intraoral periapical, and analyzed using well-established methods such as the Demirjian and Nolla methods. The results showed that the Demirjian method had a higher accuracy rate compared to other methods, particularly in age estimation for individuals under 12 years old. The discussion highlights that differences in accuracy between techniques are due to better visualization of dental anatomical structures in some techniques. The conclusion of this study is that radiographic methods, especially the panoramic technique and the Demirjian method, are optimal choices for dental age estimation with high accuracy.

Keywords: Age estimation, Forensic odontology, Methods, Radiographic.

Coresponden: Elza Ibrahim Auerkari*
Email: eiauerkari@yahoo.com

INTRODUCTION

The significance of forensic odontology has grown in recent years, particularly in relation to the crucial task of determining the age of both living and dead persons. Dental age estimate techniques are valuable because to the teeth's strong resistance to mechanical, chemical, or physical influences and the passage of time (Zhang et al., 2019). Age systems have been extensively studied by anthropologists, as age frequently serves as a significant organizing concept. Age systems encompass various ways of categorizing individuals based on their numerical, social, and biological development (Doyle et al., 2019). Chronological age and biological age sometimes differ because of developmental changes. As a result, several indicators, including ‘dental age’, ‘bone age’, ‘mental age’, & other features, including 'menarche', 'voice change', 'height', and 'weight', are used as 'proxy' indicators for the purpose of assessing biological age and the development of the body (Walia et al., 2023). Various age estimate approaches are created by including either one or more age-related knowledge. The projected age predictions may assist legal authorities in determining the chronological age of persons with uncertain ages. Additionally, these predictions can enhance the accuracy of postmortem profiling for unidentified body remains (Hamed Abdel-Rahman et al., 2019). The assessment of dental age is considered crucial since tooth growth exhibits less variation compared to other developmental characteristics, and also demonstrates low variability with respect to ‘chronological age’(Verma et al., 2019).Teeth eruption is a key indicator of human development and maturity. Dental development occurs from birth until death. At every stage of development, dental structural changes might reveal age, gender, and race (Bolter & Zihlman, 2022). Teeth are very durable components inside the human body that often remain intact even after death, making them crucial for both comparative and reconstructive identification purposes (Erdoğan et al., 2021). ‘The International and Interdisciplinary’ "Study Group on Forensic Age

Diagnostics" was founded in ‘Berlin’ on ‘March’ ‘10’, ‘2000’, with the aim of achieving an agreement among scientists on the most appropriate methodologies to be used in certain situations. The group's objective is to develop protocols for ‘age estimation’ and implement mechanisms to ensure quality control in this domain (De Tobel et al., 2020).

RESEARCH METHOD

The methodology of this research adopts a qualitative approach with a descriptive strategy. The research design allows for a comprehensive exploration of the selected topic, capturing the depth and complexity of the phenomenon under investigation. This approach aligns with the objectives of qualitative research, which seeks to understand human experiences, behaviors, and interactions within their natural contexts. This study was conducted in a specific context, chosen based on its relevance to the research objectives. The location of the research holds significance due to the unique characteristics of the population and the setting, which directly influence the findings and their applicability to similar contexts. The research spanned a designated period to ensure thorough data collection, enabling the researchers to observe patterns, behaviors, and trends that are essential to answering the research questions. Data collection was carried out over several months, ensuring that seasonal or temporal variations did not influence the findings unduly. The research addresses multiple key aspects relevant to the topic. These aspects were chosen because they reflect the multifaceted nature of the research problem. For instance, in a study exploring the influence of social factors on behavioral change, aspects such as cultural context, socioeconomic status, and individual belief systems may be considered. The focus on various dimensions ensures that the research does not provide a one-dimensional analysis but rather offers a comprehensive understanding of the topic.

The population of this research consists of individuals or groups directly impacted by the research problem. In qualitative research, the goal is not necessarily to generalize findings to a wider population but to gain deep insights from the selected participants. The sample for this study was selected through purposive sampling, a common technique in qualitative research. This method ensures that participants are chosen based on their knowledge, experiences, or characteristics relevant to the research objectives. The sample size was determined based on the principle of data saturation, meaning data collection continued until no new significant information emerged from the participants. In this case, the sample included a diverse group to capture multiple perspectives on the issue being studied. The primary research instruments used in this study were interviews and observations, which are typical tools in qualitative research. Semi-structured interviews were conducted to allow for flexibility in the conversation, enabling the participants to share their experiences in their own words while also ensuring that the researcher gathered information on specific themes. The interview guide was designed to elicit in-depth responses, with open-ended questions that encouraged participants to elaborate on their thoughts and feelings. Observations were also conducted in natural settings to capture behaviors, interactions, and contextual factors that could not be fully explained through interviews alone.

Data collection was carried out using multiple techniques to ensure the richness and depth of the data. These techniques included in-depth interviews, participant observations, and document analysis. The use of triangulation — collecting data through different methods — helped to enhance the credibility and reliability of the findings. Interviews were conducted either face-to-face or virtually, depending on the participants’ preferences and availability. All interviews were recorded with the participants’ consent and later transcribed for analysis. Field notes were taken during observations, capturing non-verbal cues, environmental context, and other significant elements that may influence the research findings. Document analysis involved reviewing relevant documents, such as policies, reports, or personal records, that provided additional insights into the research topic. Ethical considerations were paramount throughout the research process. Informed consent was obtained from all participants before

their involvement in the study. The participants were fully informed about the purpose of the research, how their data would be used, and their rights to confidentiality and anonymity. Any sensitive information shared during the interviews was handled with care, ensuring that participants' identities were protected. The researchers also ensured that the study adhered to ethical guidelines regarding voluntary participation, meaning participants could withdraw from the study at any time without any consequences. Ethical approval was obtained from a relevant ethics committee before the research commenced.

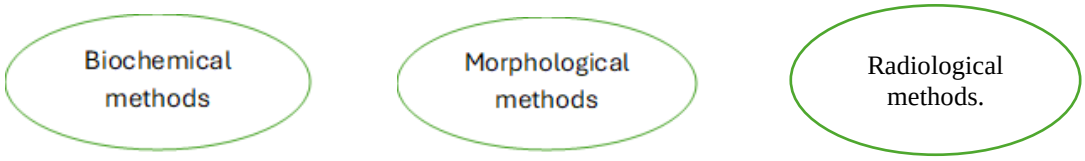
The data collected in this study were analyzed using thematic analysis, a common method in qualitative research for identifying, analyzing, and reporting patterns (themes) within data. The analysis followed a systematic process, starting with familiarization with the data through reading and re-reading the interview transcripts and observation notes. After this initial stage, the researchers began coding the data, assigning labels to pieces of information that were relevant to the research questions. These codes were then grouped into themes, which represented broader patterns of meaning within the data. The themes were reviewed and refined to ensure they accurately reflected the data and provided meaningful insights into the research problem. The final themes were then interpreted in relation to the research questions and existing literature. To ensure the trustworthiness of the findings, the researchers employed several strategies commonly used in qualitative research. One of these strategies was member checking, where participants were given the opportunity to review the findings and confirm that their views had been accurately represented. Peer debriefing was also used, where the researchers discussed the findings with colleagues or experts in the field to ensure that the interpretations were logical and consistent with the data. Additionally, the use of triangulation — combining data from interviews, observations, and document analysis — helped to increase the reliability of the findings by cross-verifying the information from different sources. As with any research, this study had its limitations. One limitation was the relatively small sample size, which is typical in qualitative research but may limit the generalizability of the findings. However, the depth of the data collected compensates for this limitation by providing rich insights into the research problem. Another limitation was the potential for researcher bias, as the data collection and analysis processes were subjective by nature. To minimize this bias, the researchers engaged in reflexivity, constantly reflecting on their own assumptions and how these might influence the research process.

RESULT AND DISCUSSION

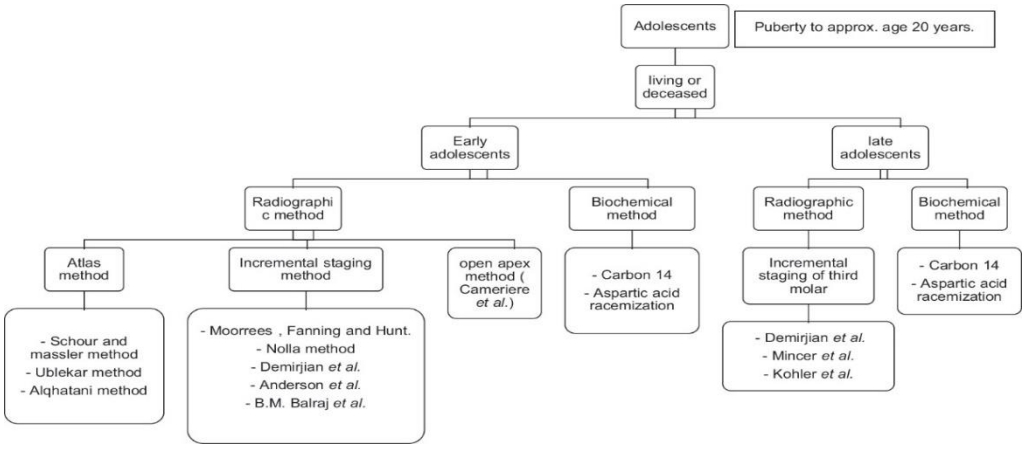
Age estimation techniques

England was the origins of the first known efforts to utilize teeth as a measure of age. Juvenile labor and crime were major societal issues in the early nineteenth century because of economic downturn brought on by the industrial revolution. In '1837', 'Dentist' 'Edwin' 'Saunders' became the first person to publish information on the correlation between teeth and age. He submitted a titled "Teeth A Test of Age" to the 'English parliament'(Acharya, 2010).

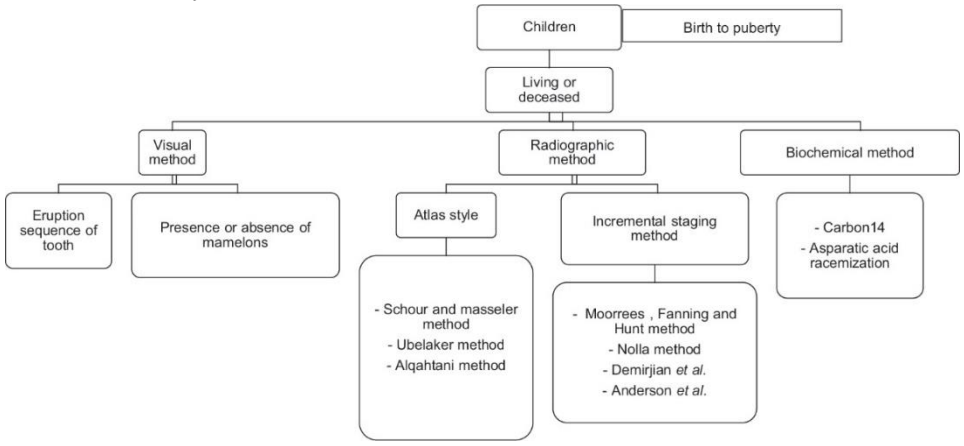
Techniques for Determining Age:



Dental age Estimation in adolescent flow chart



Age estimation in children flow chart



Radiographic Methods

Radiology is essential in determining the age of humans. Radiological examinations are used in the process of age estimation, a vital technology in the realm of ‘forensic science’ for identification purposes. Radiographic age assessment direct, ‘non-intrusive’, and dependable method that may be used to living humans & unidentified dead’s individual (Vila-Blanco et al., 2023). Radiographic pictures play a vital role in the process of determining the age of an individual. These images are often taken with several radiographic techniques, including as ‘intraoral’ ‘periapical’ ‘radiographs’, ‘lateral oblique radiographs’, ‘cephalometric radiographs’, ‘panoramic radiographs’, ‘digital imaging’, & ‘advanced imaging technologies’(Milošević et al., 2022). The ‘radiological age determination’ relies on the evaluation of the several characteristics, as outlined below: The formation of tooth germs becomes visible, The prenatal development of jaw bones, The earliest signs of mineralization, or the initiation of mineralization, can be detected, Mineralization of various deciduous teeth begins at an early stage during fetal development, The level of crown completion is assessed, The crown of the tooth emerges into the oral cavity, The extent of root completion is evaluated for both erupted and unerupted teeth, Assessment of the amount of resorption in primary teeth, Analysis of measurements of 'open apices' in teeth, Measurement of the 'volume of the pulp chamber' and 'root canals', as well as the development of natural secondary dentin, Dental ratio between the ‘tooth’ and the ‘pulp’, Maturation and spatial arrangement of the third molar (Cavallo et al., 2021). Age estimate is categorized into three stages: Antenatal, perinatal, and postnatal, Children and adolescents, Determining an Adult's Age.

Antenatal, perinatal, and postnatal age Estimation

Based on weather mamelons are present or absent

The prominent enamel extension present on the incisal edge of t in incisor teeth is known as mamelon. Depending on the situation or absence, we can identify that the teeth are permanent and deciduous. Alalwi at el conducted observational research. They aimed to identify and measure the occurrence of mamelons by considering age, gender, and biting relationship as covariates. The sample consisted of 518 patients of both sexes. The website randomizer.org was utilized for systematic random sampling to select the study participants. Qualified individuals performed a clinical examination using various dental tools, including a mouth mirror, latex gloves, a dental probe, and a dental chair light. They checked for mamelons on both jaws and assessed the relationships between the anterior teeth, looking for signs of open bite, functional contact, or other issues. The study involved 262 girls, accounting for 50.5% of the total, and 256 men, making up 49.4% of the total. Mamelons were observed to be more prevalent in females (84.7%) compared to males (79.3%). Irrespective of gender, the highest proportion of melons occurs during the first ten years of life.

However, as one ages, there is a noticeable decrease in the occurrence and size of mamelons. There are different types of occlusions associated with mamelons. These include open bite (prevalence of 90.0%), non-functional occlusion (edge-to-edge relation of 81.7%), and functional occlusion (prevalence of 75.5%). Until the age of 25, mamelons are more prominent in both males and females. However, as one gets older, they significantly diminish. In addition, it is worth noting that maxillary incisors often exhibit mamelons, unlike mandible incisors (Alalowi & Al-Jhany, 2020).The process of mineralization in 'deciduous incisors' may be seen using radiographic imaging, starting at around the 16th week of development within the womb. Before tooth formation begins, the ‘tooth germs’ may be seen as less dense areas on the ‘radiograph’. ‘Radiographs’ taken later will show the 'deciduous teeth' at ‘various stages of mineralization’, which may vary depending on the ‘age of the fetus’ (Uzuner et al., 2017).

Stages by Kraus and Jordan (1965)

Numerous ‘deciduous teeth’ and the ‘permanent first molar’ were subjected to the researchers' investigation to determine the first mineralization process. From I to X, the evolution is broken down into ten distinct phases, each of which is denoted by a Roman numeral. The Xth stage is comprised of five stages, while the IXth stage is comprised of three phases (Crumpton et al., 2023).

Children and adolescents Age Estimation

When determining the dental age of children and teenagers, the moment at which the tooth first appears in the oral cavity and the degree to which the tooth has calcified are taken into consideration. Radiographs of increasing dentition, especially in situations when there is no 'clinical evidence' ('2.5-6 years'), and clinical tooth emergence in distinct stages can help determine the child's age (Fitri Widayanti Roosyanto Prakoeswa et al., 2022).

Techniques used to determine the ‘age of children and adolescents’.

Schour and Masseler method (1941)

An investigation of the development of permanent teeth and deciduous teeth was carried out by Schour and Masseler in the year 1941. The authors offered a comprehensive explanation of twenty-one chronological phases, which ranged from four months to twenty-one years of age, and they also generated numerical charts to depict the progression of these stages. There is a lack of separate surveys for males and females in the data (Panchbhai, 2014)**.**

Ubelaker method

Age estimation in juveniles is an important procedure in judicial cases to determine imputability or for civil reasons when adopting children. The gradual growth and eventual eruption of teeth is highly valuable in determining the age of juvenile individuals. There is a limited amount of research that

focuses on studying and testing methods using a sample that is diverse in terms of population. the Ubelaker (1989) and London Atlas (2010) dental charts using a diverse sample from various population backgrounds. They determine how there is a need to develop population-specific standards based on these charts. The panoramic radiographs of 335 individuals from the James K. Economides Orthodontic Collection were carefully examined by the first and second authors. They conducted their analysis without any knowledge of the individuals' chronological age, sex, and ancestry. To ensure accuracy, the authors utilised dental atlases for scoring purposes. There was a tendency to overestimate the age of Native Americans and African Americans, which implied that their development occurred at a faster pace. European Americans and New Mexico Hispanics, although their success rates may not always be the highest, tended to be more aligned with the appropriate age compared to other ancestral groups. In Ubelaker's study from 1989, both observers achieved an impressive success rate of 80.00%. However, the London Atlas had a significantly lower success rate, ranging from approximately 21.79% to 23.28%. Accuracy rates showed no significant differences among ancestry groups, although distinct patterns emerged in terms of age under- or over-estimation (Adams et al., 2019).

Moorrees, Fanning, and Hunt method

Moorrees et al. conducted a longitudinal study on children ranging in age from birth to 20 years. This method presents information on the chronological age assessment of the permanent mandibular posterior teeth (C-M3) and the developmental stages of the permanent maxillary and mandibular incisors (I1 and I2). The development process is divided into two schemes: one for single-rooted teeth with 13 stages, and another for mandibular molars with 14 stages. This technique involves the odontologist accurately identifying the tooth, evaluating its stage of morphological development, and then interpreting the mean age and standard deviation from the gender-specific graph. This method is a comprehensive radiographic study (Moorrees et al., 1963a).

Mincer's method

In India, Mincer et al.'s technique using third molar mineralization phases based on Demirjian's developmental stages is less tested. This research evaluated third molar development and validated Mincer et al.'s approach in Western India. We analyzed 306 orthopantomograms (OPGs) from 128 men and 178 females, with a mean age of 16.89 years ± 3.68. The development of 1100 third molars was recorded using Demirjian's A-H staging. Mincer et al.'s mean age of achievement for American Whites (Caucasian) boys and females from stages #18 and #38 was used. Both #18 and #38 somewhat overestimated chronological age (CA). Women had more accurate estimated age (EA) than men. Mincer et al.'s third-molar development approach is useful for age determination. Western Indians may utilize Mincer et al.'s mean age of accomplishment with a residual value of 0.21 to 0.25 years.

Kohler's method

Specifically, Kohler et al. examin the growth and maturity of all permanent third molars is the foundation around which this approach is built. It is a modification of the system of grading first molars that was developed by Gleiser and Hunt (1955). The method of scoring is comprised of 10 steps, with three stages devoted to crown development and seven stages devoted to root creation specifically. In comparison to previous approaches, it has placed a greater emphasis on the growth of the root given that the root is finished developing at the age of around 23 years. Using logistic regression formulae, this approach provides a high level of accuracy when determining whether a person is a juvenile or an adult (defined as someone who is at least 18 years old). The age estimate of persons between the ages of 14 and 22 may also be accomplished with its help (Chaudhary & Doggalli, 2018).

Anderson method

In the field of dental age estimation methods for children and adolescents, the Anderson method is not recognized by many people in the Indian context, especially during later childhood and early adolescence. The objective of this study was to evaluate the efficacy of Anderson's approach in children

between the ages of 6 and 17 in India. Digital Orthopantomograms of 104 subjects were examined to evaluate the development of maxillary and mandibular teeth using Moorrees method of staging. The mean dental age provided by Anderson's method was used to determine the dental age. According to the findings, Anderson's method was more accurate compared to other methods. It slightly overestimated the age by 0.04 years for the mandibular arch, and underestimated the age by 0.43 years for the maxillary arch and 0.19 years for the combined maxillary and mandibular arches.In addition, the study found a strong link between dental age and chronological age in both males and females. This suggests that the method used is reliable for estimating the age of Indian children and adolescents.

The results highlight the potential of Anderson's method in forensic and clinical contexts, indicating the need for additional research and validation in various populations (Chaudhary et al., 2019). According to Anderson, the following are the ways in which variability decreases: 1st bicuspid and 3rd molars have greater height than 2nd bicuspid and 2nd molars, and cuspid is higher than incisors and 1st molar in males. For females, the third molars are the first to appear, followed by the second molars, then the cuspid and bicuspids, then the incisors, and finally the first molar. Because of this, it is possible to see that the first molar is dependable in terms of providing the most precise data. It is regarded an alternate study to the one conducted by Moorrees et al. since the data from Anderson's research begin at a later stage in life than the data from Moorrees et al.'s study. This means that Anderson's study may be used in later childhood and early adolescent (Moorrees et al., 1963b).

Balaraj Method

Radiographs taken by Balaraj and Nithin around the 14–16 year old mark showed that the apical foramen of both permanent mandibular second molars had closed.Their research follows Demirjian's protocol, which describes the phases of tooth development from apical closure to full root creation. As a result of the research, it was determined that:

a. Closed apical foramina was present in 94% of the males at 15 years and 5 months of age.
b. Closed apical foramina was present in 95% of the females at the age of 14 years and 9 months.
c. The ages of the boys and girls will be more than fifteen and fourteen, respectively, if the apical foramen is sealed.

If the apical foramen is opened, the age of the males will be less than 17 years and that of the girls will be less than 16 years. Therefore, the odontologist may ascertain the 14 and 16-year-old ages that are pertinent to medicolegal matters by using a single criterion, namely, the radiographic image of the closure of the apical foramen of the roots (Balaraj & Nithin, 2010).

Nolla's method (1960)

Ten separate stages were used to evaluate the 'mineralization of permanent teeth' using the 'Nolla' experiment. Following the assignment of a reading to each individual tooth, the total number of maxillary and mandibular teeth is computed. A comparison is then made between this total and the table that Nolla has supplied. (Singh et al., 2020).

Moorees, Fanning and Hunt method (1963)

The dental growth of single-rooted and multirooted teeth was analyzed using this method, which included the evaluation of 'dental development' throughout the 14 stages of mineralization development. The age at which teeth that are permanent are first identified was determined. (Alotaibi & Alqahtani, 2023)**.**

Estimating age with open apices (the Cameriere approach)

Research conducted by several types of researchers has investigated the relationship between age and the measurement number 'open apices' in teeth. The evaluation was performed on the seven 'permanent mandibular' teeth. Total count (N0) was determined for the teeth that had fully completed root formation, with completely closed apical ends. For teeth that have not fully developed roots, specifically those with open apices, the measurement (A) was taken by determining the distance

between the inner sides of the open apex. Calculating the total distance between the inner surfaces of the two 'open apices' of teeth that had two roots was a part of the assessment process. To excluding the influence of magnification, the length of the tooth (L) was divided by the measurement of the 'open apex or apices' (if the tooth has several roots). Following the normalization of these seven teeth' measures, an age evaluation was carried out using them. The dental maturity was calculated by adding the number of teeth with completely grown roots (N0) to the number of teeth that had normalized open apices (s) To arrive at an estimate of age, the values that were supplied are input into the following regression method.

'Age = 8.971 + 0.375 g + 1.631 × 5 + 0.674 N0 – 1.034 s – 0.176 s N0'

In this case, the variable g is set to 1 for boys and 0 for girls.

Benefits

In certain communities, such North Indian and Iranian people, the modern Cameriere formula has shown to be more accurate than the old one. Additionally, when comparing the classic Cameriere formula to machine learning-assisted approaches based on the Cameriere's maturation phases, the latter proved to be a more accurate predictor of dental age (Shen et al., 2021).

Determining an Adult's Age

Radiographic age estimate becomes more challenging following the eruption of the third molar, which typically occurs between the ages of 17 and 21 years, clinically completes the development of permanent dentition (Sindi et al., 2023). Evaluating tooth volume and tracking the growth of the third molar are the two most typical approaches.

1. Evaluation of tooth volume.
    - The Kvaalb technique uses the 'pulp-to-tooth ratio'.
    - 'Coronal pulp cavity index'
2. Growth of the third molar.
    - The 'Harris and Nortje approach'
    - The 'Van Heerden system'.

Determine the volume of the teeth

A 'radiological' evaluation of the reduction in size of the pulp cavity brought on by the deposition of secondary dentine, which is directly proportional to the individual's age, may be utilized to arrive at an estimate of the age of an adult (Panchbhai, 2011).

a. The Kvaalb technique uses the pulp-to-tooth ratio.

The central and lateral incisors, the 'maxillary second premolars', the 'mandibular lateral incisor', the 'mandibular canine', and the 'first premolar' are the teeth that are discussed. The pulp to tooth ratios is used in the age determination technique that was created by 'Kvaal et al.' to arrive at the age information.(FD & E Kaygısız, 2018).

'Age = 129.8 – (316.4 × m) (6.8 × [W-L]'

b. Index of the cavity of the coronary pulp

This method provides a quantitative examination of the correlation between the shrinkage of the 'coronal pulp cavity' and the progression of chronological age. 'Mandibular premolars' and 'molars' were the only teeth that were considered for inclusion in the study. (Nayyar et al., 2016) Particularly in comparison to the maxillary teeth, these teeth are shown in a more conspicuous manner. It is possible to determine the 'length of the tooth crown' (CL)' and the height of the 'coronal pulp cavity' (CPCH)' in millimeters (mm) using panoramic radiography. Following the calculation of the 'tooth-coronal index (TCI)' for each individual tooth, the correlation between the actual age

of the sample and the 'TCI' is then determined by using the formula that has been stated. (Gotmare et al., 2019).

$$(TCL = CPCH * \frac{100}{CL})$$

Development of the Third Molar

After the age of 17, using radiographic methods to estimate age becomes difficult since all permanent teeth, including the third molar, have fully erupted by that age. Therefore, the development of the third molar may be a trustworthy sign for identifying the age of the individual included in the study.

Van Heerden system

The age was determined by assessing the growth of the 'mesial root' of the 'third molar' using a 'panoramic radiograph'. In this technique, five phases were examined (Nayyar et al., 2016).

The Harris and Nortje approach

The researchers have provided a classification of five phases for the development of the 'root of the third molar', together with the 'average age's and 'average length' associated with each stage (Chinna et al., 2020).

Demirjian, Goldstein, And Tanner Method (1973)

'Demirjian (1973)' proposed the DemI973 technique, which use the left side of the 'mandible' to estimate chronological age by examining the growth of seven specific teeth. This approach closely resembled the one used by 'Tanner, Whitehouse', and 'Healy', who assessed the chronological age by evaluating the development of the hands and wrists (Kala & Prasad, 2019).'Demirjian, Goldstein, and Tanner' observed that the phases are often characterized by distinct tooth forms, starting from the initial calcification phase, and progressing to the fully developed mature form. It is important for the phases to be clearly identifiable and consistent, so that every individual's tooth goes through the identical stages. Because the stages function as indicators of maturity rather than 'size,' it is not possible to properly define them using any absolute length measurements. The final scores for each tooth, which were previously restricted to a maximum of one hundred, are now allowed to undergo fluctuations. On the other hand, the sum or average of all of the tooth values must still be equal to 100. The different ages at which girls and boys attain different degrees of dental development may be attributed to this factor.(Hegde et al., 2018).

Determining the ratings

1. The following is the order in which the permanent teeth of the mandible are ranked: Specifically, the canine, the lateral incisor, the central incisor, the second molar, the first molar, the second bicuspid, and the first bicuspid.
2. On a scale from A to H, each tooth is ranked. To determine the grade, one must meticulously adhere to the detailed written standards for each step while also comparing the tooth in question to the provided X-ray images and diagrams. There are one, two, or three written criteria labelled a, b, and c for each step. In cases where there is just one criterion, that must be fulfilled for the stage to be considered reached. It is sufficient to fulfill the first of the two requirements for the stage to be recorded as having been achieved in situations when there are two criteria. In cases where there are three criteria, the first two must be fulfilled for the stage to be considered reached. In addition to meeting the requirements for the current level, all prerequisites from prior stages must also be met. The first stage is always assigned in instances that are questionable.
3. It is not possible to take any definitive measurements. You can easily compare the respective lengths (crown/root) using only two dividers. No magnifying lens is required to discern the phases of apex closure. Only the human eye should be used to make the evaluations.

4. The crown height is the greatest measurement taken from the cementoenamel junction to the tip of the cusps. The highest point is the place where the buccal and lingual cusps meet if they do not meet at the same level (Liversidge, 2012).

Phases of Tooth Development

If there is no evidence of calcification, a grade of 0 is assigned: The creation of the crypt is neglected.
Outline of the Stage: An inverted cone or cones create the first calcification site at the uppermost level of the crypt in both teeth with one radicle and those with multiple radicles. This calcified point does not fuse, A consistently defined occlusal surface is formed when one or more cusps are fused together by the calcified tips, At the occlusal surface, enamel production is complete. There is a clear indication of its convergence towards the cervical area, A dentinal deposit's early stages are seen, Pulp chamber contours have A curved form is seen at the occlusal border of the pulp chamber's contour, The cementoenamel junction is the last stage of crown creation, An obvious curvature may be seen at the top border of the pulp chamber in uniradicular teeth, which then becomes concave in the cervical region. When it comes to molars, the pulp chamber is shaped like a 'trapezium', and the' protrusion' of the pulp's curved form at the occlusal border horns, if there are any, provides a shape that is like an umbrella, A spicule marks the beginning of root development.
Teeth with a single radius: The pulp chamber's top border curves sharply and becomes concave in the cervical region of uniradicular teeth. An umbrella-like structure is created by the protrusion of the pulp's curved shape at the occlusal border horns, if any, and the trapezium-shaped pulp chamber that molars possess, ‘Molars’: At first, the radicular bifurcation looks like a semi-lunar shape or a calcified point, The increasing height of the crown is at the expense of the unchanged length of the roots.
Uniradicular teeth: Currently, the pulp chamber's walls are roughly forming an isosceles triangle. A funnel shape is formed at the very top, In this case, the root length exceeds the crown height by at least one centimeter, Molars: Since its semi-lunar stage, the calcified bifurcation area has progressed downward, giving the roots a more defined appearance with funnel-shaped ends, The length of the root is larger than the crown, or at least equal to it.
The root canal's walls are now perpendicular, and its apex remains slightly open
The root canal is fully sealed at its apical end: All the way around the tooth's root and tip, the periodontal membrane is the same width(Uzuner et al., 2018).

Utilizing the Scoring System

1. Using the method outlined, we may assign a letter grade (A–H) to each tooth.
2. The score is then determined by comparing it to the appropriate table for boys or girls.
3. To reach the maturity score, you total up the points for all seven teeth.
4. Centile charts may be used to plot the maturity score (for boys or females, depending on the appropriateness) when the child's age is known.
5. To convert the maturity score to a dental age, one may simply use the age at which the 50th percentile reaches the maturity score value on the horizontal scale, or one can use a table that has been constructed using these approaches (Qudeimat & Behbehani, 2009).

Benefits

The orthopantomogram-based approach developed by Demirjian and Goldstein is straightforward, as is its potential to provide more trustworthy standardization, as well as its high levels of repeatability and intra- and inter-examiner dependability (Phulari & Dave, 2021). This method's widespread appeal is due, in part, to its generally applicable maturity grading system, even if the conversion to dental age differs across studied demographics. In addition, by comparing various

populations, we may get to an equal dental age with relatively few local samples, allowing us to do this translation.

Constraints

1. The Demirjian approach use orthopantomograms, which provide challenges in obtaining for young infants owing to technological limitations, as well as legal and ethical concerns.
2. Due to the need for simultaneous examination of all seven left mandibular teeth, this procedure cannot be performed on children who are missing any of these teeth, whether due to a congenital condition or acquired later in life.
3. This approach may not accurately indicate the absence of teeth, abnormal delay in dental growth 'excluding third molars', and the presence of systemic disorders and different phases of tooth development (Rózyło-Kalinowska et al., 2008).
4. Due to the subjective nature of choosing a tooth's growth stage, accurate assessment of its progress may become challenging.
5. Individuals under the age of 4-4.5 years are not included in the maturity scores for stages 1-4 of the first molar, central incisor, and lateral incisor since this approach does not provide such scores (Khorate et al., 2014).

New Variations on Demirjian's Approach

In 1976, Demirjian developed three further methods. The first two, DemI976 and DemI976PM, used the same set of seven teeth; the third, Dem1976IN2, followed suit with the same set of four teeth, namely the 'second incisive' (12), 'first premolar (PM1)', 'second premolar' (PM2), and 'second molar' (3M2) (Ambarkova et al., 2014).

CONCLUSION

This study aimed to compare various radiographic techniques in estimating dental age based on tooth development. The main findings indicate that the Demirjian method has a higher accuracy rate compared to other techniques, especially in age estimation for individuals under 12 years old. The superior visualization of dental anatomical structures is a key factor in the differences in accuracy between techniques. This study contributes to the forensic literature, particularly by reinforcing the evidence that radiographic methods, especially the panoramic technique and the Demirjian method, are optimal choices for dental age estimation with high accuracy. The study also provides new insights into the strengths and limitations of each technique across different age groups, which can assist forensic practitioners in selecting the most appropriate method for specific cases. The primary limitation of this study is its reliance on a specific sample that may not be fully representative of other populations, making it necessary to be cautious when generalizing the results to a broader population. Additionally, this study is limited to commonly used radiographic techniques and does not include newer methods like 3D imaging, which may offer more accurate results. For future research, it is recommended to conduct studies with more diverse populations to test the validity of these findings across different ethnic groups and geographic regions. Moreover, the development and evaluation of more advanced radiographic techniques, such as 3D digital imaging, could improve the accuracy of dental age estimation and expand its applications in forensic dentistry.

REFERENCES

Acharya, A. B. (2010). A new digital approach for measuring dentin translucency in forensic age estimation. *American Journal of Forensic Medicine and Pathology, 31*(2), 133–137. https://doi.org/10.1097/PAF.0B013E3181CF328D

Adams, D. M., Ralston, C. E., Sussman, R. A., Heim, K., & Bethard, J. D. (2019). Impact of population-specific dental development on age estimation using dental atlases. *American Journal of Physical Anthropology*, *168*(1), 190–199. https://doi.org/10.1002/AJPA.23735

Alalowi, M., & Al-Jhany, N. (2020). Frequency of Mamelons in Relation to Age, Gender and Occlusion among the Saudi Population. *Arab Journal of Forensic Sciences and Forensic Medicine*, *2*(2), 1 06–110. https://doi.org/10.26735/VGLP5383

Alotaibi, N. N., & Alqahtani, S. J. (2023). Performance of different dental age estimation methods on Saudi children. *The Journal of Forensic Odonto-Stomatology*, *41*(1), 27. /pmc/articles/PMC10319098/

Ambarkova, V., Galić, I., Vodanović, M., Biočina-Lukenda, D., & Brkić, H. (2014). Dental age estimation using Demirjian and Willems methods: Cross sectional study on children from the Former Yugoslav Republic of Macedonia. *Forensic Science International*, *234*, 187.e1-187.e7. https://doi.org/10.1016/J.FORSCIINT.2013.10.024

Balaraj, B. M., & Nithin, M. D. (2010). Determination of adolescent ages 14–16 years by radiological study of permanent mandibular second molars. *Journal of Forensic and Legal Medicine*, *17*(6), 329–332. https://doi.org/10.1016/J.JFLM.2010.05.003

Bolter, D. R., & Zihlman, A. L. (2022). Evolution of human growth. *Human Growth and Development*, 425–448. https://doi.org/10.1016/B978-0-12-822652-0.00016-X

Cavallo, F., Mohn, A., Chiarelli, F., & Giannini, C. (2021). Evaluation of Bone Age in Children: A Mini-Review. *Frontiers in Pediatrics*, *9*, 580314. https://doi.org/10.3389/FPED.2021.580314/BIBTEX

Chaudhary, R. K., Bhandari, M., & Doggalli, N. (2019). *The Less Known Anderson Method for Dental Age Estimation in Indian Scenario: A Pilot Study*. https://doi.org/10.4172/2157-7145.1000438

Chaudhary, R. K., & Doggalli, N. (2018). Commonly used different dental age estimation methods in children and adolescents. *International Journal of Forensic Odontology*, *3*(2), 50. https://doi.org/10.4103/IJFO.IJFO_18_18

Chinna, S., Gandhi, R., & Chinna, R. (2020). Dental Age Estimation By Using Demirjian Method In Adults-A Review. *Article in World Journal of Pharmacy and Pharmaceutical Sciences*, *8*. https://doi.org/10.20959/wjpps20194-13430

Crumpton, M. W., Mileusnic-Polchan, D., Lewis, J., Heidel, R. E., & Marks, M. K. (2023). Fetal Age Assessment From Primary Teeth and Long Bones. *American Journal of Forensic Medicine and Pathology*, *44*(1), 42–51. https://doi.org/10.1097/PAF.0000000000000804

De Tobel, J., Bauwens, J., Parmentier, G. I. L., Franco, A., Pauwels, N. S., Verstraete, K. L., & Thevissen, P. W. (2020). Magnetic resonance imaging for forensic age estimation in living children and young adults: a systematic review. *Pediatric Radiology*, *50*(12), 1691–1708. https://doi.org/10.1007/S00247-020-04709-X/FIGURES/3

Doyle, E., Márquez-Grant, N., Field, L., Holmes, T., Arthurs, O. J., van Rijn, R. R., Hackman, L., Kasper, K., Lewis, J., Loomis, P., Elliott, D., Kroll, J., Viner, M., Blau, S., Brough, A., Martín de las Heras, S., & Garamendi, P. M. (2019). Guidelines for best practice: Imaging for age estimation in the living. *Journal of Forensic Radiology and Imaging*, *16*, 38–49. https://doi.org/10.1016/J.JOFRI.2019.02.001

Erdoğan, K., Tatlisumak, E., Ovali, G. Y., Pabuşçu, Y., & Tarhan, S. (2021). Age- and Sex-Related Morphometric Changes and Asymmetry in the Orbito-Zygomatic Region. *Journal of Craniofacial Surgery*, *32*(2), 768–770. https://doi.org/10.1097/SCS.0000000000007008

FD, U., & E Kaygısız. (2018). *Post Mortem Examination and Autopsy: Current Issues From Death to Laboratory* . *Google Books* (Vol. 6).

Fitri Widayanti Roosyanto Prakoeswa, B., Kurniawan, A., Chusida, nisaa, Istiqomah Marini, M., Novia Rizky, B., Sylvia Margaretha, M., Utomo, H., Darmawan, zaaz, Kamilia Nur Aisyah, A., Alias, A., Ratna Wahjuni, O., & Marya, A. (2022). *Children and Adolescent Dental Age Estimation by the Willems and Al Qahtani Methods in Surabaya, Indonesia*. https://doi.org/10.1155/2022/9692214

Gotmare, S. S., Shah, T., Periera, T., Waghmare, M. S., Shetty, S., Sonawane, S., & Gite, M. (2019). The coronal pulp cavity index: A forensic tool for age determination in adults. *Dental Research Journal*, *16*(3), 160. https://doi.org/10.4103/1735-3327.255743

Hamed Abdel-Rahman, R., Gamal AbdAllah Amr, S., & Abdel-Galil Khalil, A. (2019). Sexual Dimorphism of Anthropometric Measurements of Periorbital Soft Tissues in a Sample of Egyptian Adults. *Mansoura Journal of Forensic Medicine and Clinical Toxicology*, *27*(1), 13–25. https://doi.org/10.21608/MJFMCT.2019.46706

Hegde, S., Patodia, A., & Dixit, U. (2018). The applicability of the original and revised Demirjian standards to age estimations of 5-15 year old Indian children. *The Journal of Forensic Odonto-Stomatology*, *36*(1), 1. /pmc/articles/PMC6195945/

Kala, N., & Prasad, H. (2019). Accuracy of two dental age estimation methods in the Indian population. *JFOS – Journal of Forensic Odonto-Stomatology*, *37*. https://www.researchgate.net/publication/345317866_Accuracy_of_two_dental_age_estimation_methods_in_the_Indian_population

Khorate, M. M., Dinkar, A. D., & Ahmed, J. (2014). Accuracy of age estimation methods from orthopantomograph in forensic odontology: A comparative study. *Forensic Science International*, *234*, 184.e1-184.e8. https://doi.org/10.1016/J.Forsciint.2013.09.020

Liversidge, H. M. (2012). The assessment and interpretation of Demirjian, Goldstein and Tanner's dental maturity. *Annals of Human Biology*, *39*(5), 412–431. https://doi.org/10.3109/03014460.2012.716080

Milošević, D., Vodanović, M., Galić, I., & Subašić, M. (2022). Automated estimation of chronological age from panoramic dental X-ray images using deep learning. *Expert Systems with Applications*, *189*, 116038. https://doi.org/10.1016/J.ESWA.2021.116038

Moorrees, C. F. A., Fanning, E. A., & Hunt, E. E. (1963a). Age Variation of Formation Stages for Ten Permanent Teeth. *Journal of Dental Research*, *42*(6), 1490–1502. https://doi.org/10.1177/00220345630420062701/ASSET/00220345630420062701.FP.PNG_V03

Moorrees, C. F. A., Fanning, E. A., & Hunt, E. E. (1963b). Age Variation of Formation Stages for Ten Permanent Teeth. *Journal of Dental Research*, *42*(6), 1490–1502. https://doi.org/10.1177/00220345630420062701/ASSET/00220345630420062701.FP.PNG_V03

Nayyar, A. S., Anand Babu, B., Krishnaveni, B., Vaishnavi Devi, M., & Gayitri, H. C. (2016). Age estimation: Current state and research challenges. *Journal of Medical Sciences (Taiwan)*, *36*(6), 209–216. https://doi.org/10.4103/1011-4564.196348

Panchbhai, A. S. (2011). Dental radiographic indicators, a key to age estimation. *Dentomaxillofacial Radiology*, *40*(4), 199. https://doi.org/10.1259/DMFR/19478385

Panchbhai, A. S. (2014). Dental radiographic indicators, a key to age estimation. *Https://Doi.Org/10.1259/Dmfr/19478385*, *40*(4), 199–212. https://doi.org/10.1259/DMFR/19478385

Phulari, R. G. S., & Dave, E. J. (2021). Evolution of dental age estimation methods in adults over the years from occlusal wear to more sophisticated recent techniques. *Egyptian Journal of Forensic Sciences*, *11*(1), 1–14. https://doi.org/10.1186/S41935-021-00250-6/TABLES/3

Qudeimat, M. A., & Behbehani, F. (2009). Dental age assessment for Kuwaiti children using Demirjian's method. *Annals of Human Biology*, *36*(6), 695–704. https://doi.org/10.3109/03014460902988702

Rózyło-Kalinowska, I., Kiworkowa-Raczkowska, E., & Kalinowski, P. (2008). Dental age in Central Poland. *Forensic Science International*, *174*(2–3), 207–216. https://doi.org/10.1016/J.FORSCIINT.2007.04.219

Shen, S., Liu, Z., Wang, J., Fan, L., Ji, F., & Tao, J. (2021). Machine learning assisted Cameriere method for dental age estimation. *BMC Oral Health*, *21*(1). https://doi.org/10.1186/S12903-021-01996-0

Sindi, M. A., Al-Sebaei, M. O., & Bamashmous, M. S. (2023). Radiographic assessment of third molar development and its relation to dental and chronological age in the Saudi Arabian population. *Egyptian Journal of Forensic Sciences*, *13*(1), 1–7. https://doi.org/10.1186/S41935-023-00342-5/TABLES/3

Singh, H. V., Kalra, N., Tyagi, R., & Khatri, A. (2020). Dental age assessment of North Indian origin children using Nolla's method in mandibular second molar. *Egyptian Journal of Forensic Sciences*, *10*(1), 1–7. https://doi.org/10.1186/S41935-020-00194-3/TABLES/4

Uzuner, F. D., Kaygısız, E., & Darendeliler, N. (2018). Defining Dental Age for Chronological Age Determination. *Post Mortem Examination and Autopsy - Current Issues From Death to Laboratory Analysis*. https://doi.org/10.5772/Intechopen.71699

Uzuner, F. D., Kaygısız, E., Darendeliler, N., Uzuner, F. D., Kaygısız, E., & Darendeliler, N. (2017). Defining Dental Age for Chronological Age Determination. *Post Mortem Examination and Autopsy – Current Issues From Death to Laboratory Analysis*. https://doi.org/10.5772/INTECHOPEN.71699

Verma, M., Verma, N., Sharma, R., & Sharma, A. (2019). Dental age estimation methods in adult dentitions: An overview. *Journal of Forensic Dental Sciences*, *11*(2), 57. https://doi.org/10.4103/JFO.JFDS_64_19

Vila-Blanco, N., Varas-Quintana, P., Tomás, I., & Carreira, M. J. (2023). A systematic overview of dental methods for age assessment in living individuals: from traditional to artificial intelligence-based approaches. *International Journal of Legal Medicine 2023 137:4*, *137*(4), 1117–1146. https://doi.org/10.1007/S00414-023-02960-Z

Walia, M., Bhati, K., & Gullaiya, J. (2023). Application of Dental Age Estimation: A Review. *Research Journal of Pharmacy and Technology*, *16*(5), 2513–2516. https://doi.org/10.52711/0974-360X.2023.00413

Zhang, Z. yong, Yan, C. xia, Min, Q. mei, Li, S. qing, Yang, J. si, Guo, Y. cheng, Jin, W. fan, Li, L. jiang, Xing, P. F., & Li, J. (2019). Age estimation using pulp/enamel volume ratio of impacted mandibular third molars measured on CBCT images in a northern Chinese population. *International Journal of Legal Medicine*, *133*(6), 1925–1933. https://doi.org/10.1007/S00414-019-02112-2/Figures/4