REVIEW ARTICLE

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A Review on Clinical and Forensic perspective of Dental Age Estimation in Children

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Abstract

Dental age assessment is one of the most reliable methods of age estimation used for criminal, forensic, and clinical purposes. Visual, radiographic, chemical, and histological techniques can be used for dental age estimation. The visual method is based on the teeth' eruption sequence, morphological changes caused by attrition, and changes in color with age. Radiographs of the dentition can be used to determine the stage of dental development of the teeth, from initial mineralization of a tooth and crown formation to root apex completion. Histological methods require the preparation of the tissues for detailed microscopic examination. The histological and chemical methods are invasive methods requiring extraction/sectioning of the tooth. In this paper, the different techniques considered studies were overviewed in conjunction with their advantages and disadvantages.

Keywords: Age estimation, Chronological age, Dental age, Dental age estimation of children, Dental maturation, Juvenile dental age estimation.

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Introduction

Teeth play an important role in age estimation. Teeth are durable as they are constructed of enamel and dentin, resisting destruction or decay in adverse conditions.[1] With minimal remodeling, permanent and deciduous teeth' maturity continues over a long period and is less affected by dietary changes, environmental change, and endocrine disorders.[2] Human dentition follows a developmental sequence, beginning about four months in utero to the complete formation of permanent teeth at approximately 25 years of age, and this growth is reliable and predictable.[3] Dental age assessment techniques have long been established as the most accurate indicators of chronologic age in children, and age assessment techniques utilized within this age interval rely upon evaluation of the maturation and development of the primary and permanent dentitions.[4-6] Age estimation is commonly carried out in medico-legal and child labor cases, forensic investigation, disaster victim identification, identification of dead bodies and skeletal remains, and civil and criminal litigation.[3,7-10] From a clinical point of view, the correlations between dental, skeletal, and chronological age are relevant for preventive measures in dental treatment when there is an abnormal eruption sequence and also for orthodontic treatment planning, which may lead to shorter treatment duration and more stable results.[11,12]

Clinical Considerations in Dental Age Estimation

Dental age is of great interest, particularly in diagnosing and managing different malocclusions concerning maxillofacial growth. Dental age can be measured at different stages of tooth development. Every stage shows observable changes that have its clinical consideration:

Appearances of tooth germs

Diseases that present with anodontia, hypodontia as in ectodermal dysplasia, pose problems in estimating the dental age of an individual.

Mineralization of tooth

Diseases like amelogenesis imperfecta and dentinogenesis imperfecta might interfere with accurate dental age estimation.[13]

Degree of completion of unerupted tooth

Often, in endodontic treatment of young children, open apices need different treatment modalities like apexification and apexogenesis. Accurate age estimation helps the dentist to treat the child accordingly.

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Eruption and shedding sequence of teeth

All primary teeth are present in a child's mouth for 3 years. Untimely eruption and shedding of teeth pose challenges for correctly identifying teeth. Correlating the chronology of eruption of a tooth gives a clue to correctly identify the tooth and also accurate age of the child.

Dental age estimation techniques in children can be classified into visual method, Radiographic method, Biochemical method, Histological method.

Visual Method

Tooth eruption follows a specific chronological pattern. With age, there are changes in tooth structure due to wear/attrition & erosion, changes in periodontal status, and changes in tooth color due to stains.[14] These factors aid in information on an individual's dental maturation and age. This method does not need invasive procedures such as tooth extraction or tissue preparation. Considering the limitations of this method, few local factors like premature extraction of primary teeth affect the dental eruption pattern. Dental maturation is also affected by hereditary, functional, environmental, nutritional, and metabolic factors.[15] Tooth wear is also influenced by various factors, including functional (eating and chewing habits) or parafunctional habits, mandibular movement patterns, bite force, saliva, diet, medication, diseases, geographical location, occupational and habitual environment, and gender.[14,16]

Radiographic Method

Dental age estimation techniques in children can be done through an illustrative representation of the developing tooth structures with their eruption pattern, called the atlas method. On the contrary, some methods require incremental staging or scoring of the developing teeth. All the techniques in both categories are dependent on radiographs to retrieve dental age based on dental development and maturation. This pattern of tooth development, called dental maturity, is considered to be more reliable with high heritability and doesn't affect by environmental and nutritional factors as well as endocrine status.[10,11,17] The radiographic method of age estimation is a simple, non-invasive and reproducible method that can be used for children-adolescents whether living or dead, where the dentition is in a developmental phase, so assessment is done from initial mineralization in a tooth bud, formation of crown and root, an eruption of the tooth into the oral cavity and closure of root apex.[15,18]

Atlas Method

According to a study by *Kraus and Jordan* on the early mineralization of deciduous teeth and permanent first molar in intrauterine life, they describe the growth of teeth in ten stages designated from I to X (in roman); 3 stages in the IXth and 5 stages in the Xth.[19] *Schour and Masseler*[19-21] described 21 chronological stages ranging from 4 months up to 21 years. There are a few drawbacks as these charts do not have gender differentiation, and the mean age range of 2–5 years is put at 6 months which is too narrow and later modified by Ublekar. This chart is based on studies of Logan & Kronfeld, who made histological sections of the jaws of a relatively very small sample size of institutionalized, chronically ill, and malnourished children.[22-24] *Moorees et al*. evaluated the dental development/mineralization in the 14 stages, demonstrating 'cusp formation' up to 'root apex closure' in permanent teeth. He used the study's intraoral, lateral, or oblique jaw radiographs, and gender differences were considered. The study estimates an age from 6 months up to third mandibular molar development.[25] *Anderson et al*.[26] later modified the methods and expanded the age range and comprehensive tables from the study of Moorees *et al*.[25] The *Ubelaker* chart describes the dental age assessment from 5 months in utero up to age 15 with statistical age interval.[27,28] The London Atlas published by *Al-Qahtani* takes consideration of both tooth development and alveolar eruption from 30 weeks in utero up to 23.5 years, comprising of a total of 31 diagrams depicting the median dental development, among which eight portray third molar development starting at 16.5 years. The study data were obtained from 176 individual skeletal remains from the collections at the Natural History Museum, London, United Kingdom, and the Royal College of Surgeons of England; and dental radiographs of 528 living individuals of Bangladeshi and British origin with almost equal gender distribution.[29] Though this atlas has a high level of accuracy and repeatability, a statistical age interval is not provided for individual demonstration. The *WITS Atlas by Esan and Schepartz* is a population-specific atlas of the permanent tooth of Black Southern Africans. The study data was obtained by collecting panoramic radiographs of 642 Southern African Black school children aged from 5 years up to 20 years. It comprises 13 illustrations showing dental development from 5.5 years to 17.5 years.[30]

Scoring Method

Nolla assessed the development of teeth from radiographs of boys and girls obtained from the files of the University of Michigan child development laboratories.[31] The radiographs of maxillary and mandibular teeth were studied, and each tooth's development was graded on a scale from 0 to 10. *Moorrees et al*. provided a chronological age assessment of the mandibular deciduous dentition,[32] permanent mandibular posterior teeth, and the later developmental stages of the permanent maxillary and mandibular incisors.[33] Separate development stages are present for single rooted teeth illustrating 13 stages as well as for the molars having 14 stages of development. *Demirjian et al*. introduced a method that estimated chronological age based on dental maturity of seven teeth from the left side of the mandible (central incisors to second molar) based on eight tooth mineralization stages, defining morphological tooth development from first radiographic appearance of mineralization of crown structure up to complete closure of the root apex on a panoramic radiograph. The teeth are staged according to their development and assigned a self-weighted score. The addition of the seven self-weighted scores gives a maturity score which is cross-referenced in a table to the

corresponding age.[34] *Willems* modified Demirjian's method using data on the Belgian Caucasian population considering gender variation. He calculated chronological age based on the cumulative score of first premolar, second premolar, first molar, and second molar with more accurate results.[35,36] *Haavikko's* method assesses four permanent teeth into twelve radiographic stages, among which six stages relate to the crown formation, and the remaining six demonstrate root formation. He used cross-sectional data from radiographs of 1162 Finnish children between the ages of 2 years up to 21 years.[37] This method is for cases of congenital absence of permanent teeth. *Cameriere et al.* measured open apices of the seven left permanent mandibular teeth of 455 Italian white children (213 boys and 242 girls) aging between 5 years up to 15 years. They developed a regression formula to get a linear relationship between open apices and age. For teeth with one root, the distance between the inner sides of the open apex is measured, and for two roots, the sum of the distances between the inner sides of the two open apices is evaluated.[38] *Mincer et al.* used third molar radiographs to estimate age in juveniles and adults, providing age standards for American whites. He studied 823 cases with age ranging from 14 years up to 24 years.[39]

Biochemical Methods

Amino Acid Racemization

Stereoisomers or chirals or enantiomersare two asymmetrical geometric mirror-image forms of the same molecule designated as the L or D forms based upon their optical characteristic. The racemization is the unconstrained cycle wherein one enantiomer of a compound changes to the other. Aspartic acid has the fastest racemization rate among the amino acids, and it is ideal for age determination[40]. The biochemical methods determine alterations in calcium/phosphorus ratio in peritubular dentine with age. The rate of racemization of D and L enantiomers of aspartic acid residues in the collagen of dentin is also age-dependent.[41] A study by *Ohtani*[42] indicated that the measured D/L ratio for the dentin of deciduous teeth was highly correlated with real age. However, there are disadvantages to these methods. These methods are invasive, so they are not suitable for living individuals. The methods often require expensive instruments.

Radioactive 14C (Carbon Dating)

The carbon dating technique depends on the cycle of 14C, which is naturally formed by the interaction of neutrons with nitrogen 14 in the atmosphere. The neutrons required for this reaction are produced by cosmic rays interacting with the atmosphere. 14C present in molecules of atmospheric carbon dioxide enters the biological carbon cycle. It is absorbed from the atmosphere by plants and then passed on through the food chain.[23,43] Analyzing the remaining amount of 14C in the sample and comparing it with the half-life, determines the sample's age. According to Spaulding *et al*., dental age can be estimated on tooth enamel using carbon dating with a standard deviation of 1.6 years.[44]

Gravimetric Method

In the prenatal stage till 6 months, dentin and enamel are radiolucent; therefore, radiologically dental age can't be determined. *Stack's method*,[45] therefore, seems to be the most suitable method for the determination of dental age. It correlates the dry weight of mineral content of tooth cusp to the approximate age of the child. A linear relation of the square root of weight mineralized tissue in the deciduous anterior teeth during the last trimester and fetal age has been demonstrated. Studies by Deutsch *et al*. implied that both the weight and crown height of the anterior tooth relate to fetal age.[46]

Histological Method

Prenatal dental development can be studied by alizarin staining of fetal tooth germs. Initiation of mineralization occurs in the first permanent molars between 28 to 32 fetal weeks, with the mandibular germs being slightly in advance than those of the maxilla.[47] The enamel of the deciduous teeth matures partially before and after birth. An Incremental line of Retzius marks the demarcation between the two portions of enamel in the deciduous teeth called the neonatal line. This phenomenon can be used for assessing the amount of pre-and postnatal enamel formation and can be used in the investigation of forensic cases. Enamel is formed in deciduous teeth at the rate of 2.5–4.5 μ/day.[48] Cross striations are seen across enamel rods representing the daily incremental deposition of enamel, and this can be used to find the exact age of the baby in days by counting the cross striations from the neonatal line.[49,50] Cementum annulations occur with the advancement of age. So, the incremental lines in the tooth cementum can be used as a reliable marker. Countability of annulations reveals the age of the child. However, it is not always easy to count.[51]

Conclusion

Developing teeth are used to assess age not only for forensic purposes but also has a vital role in clinical aspects. Such age estimation methods aid in investigating cases with fetal deaths, child labor and violence, and other medico-legal cases. These modalities are also helpful in proper diagnosis and planning in the case of clinical dentistry. The methods might be subjective; hence inter and intra-observer studies should be taken into consideration. Rather than restricting to one age estimation technique, other available techniques should be taken into consideration for accurate age estimation. Further studies for age estimation based on age and ethnicity are required, and validity, reliability, and applicability of various methods in different populations are to be standardized.

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