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Progress in the study of four dental age inference methods in the age inference of children and adolescents

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Abstract: *The age of the human individual is an important element of the individual's biological information. Over time, many irreversible ageing changes occur in several organs and tissues of the human body, and in forensic medicine, age interpretation has an extremely important link to the identification of identity in criminal cases, the division of sentencing in juvenile and child crime[1], and the determination of the age of lost persons in missing persons. In previous studies, bone age such as wrist bone, vertebral bone and sternum are often used for age prediction. Bone age can be used as a preliminary evaluation of age, but due to the influence of congenital genetics, racial differences and acquired environment, it may result in poorly developed bone tissue, bringing interference to the process of interpretation and eventually leading to distorted data [2]. The tooth is the hardest human tissue and its tissue structure also contributes to its extremely high stability. Compared to skeletal maturation, teeth are less likely to be altered during growth and development due to changes in the external environment [3-4], which allows it to be used more often in events that require individual identity interpretation. One of the most common methods of estimating dental age is radiological examination to assess the degree of calcification [5], and imaging of the oral cavity is also very common in modern clinical medicine. This article reviews and summarises the research progress and analyses the advantages and disadvantages of four different methods of age estimation applicable to children and adolescents, and objectively evaluates the four different methods of dental age estimation.*

Keywords: *dental age, chronological age, orthopantomograms*

1. Dental age and chronological age

Human growth and development can be expressed in two "ages", the actual age and the biological age. The former is calculated from the time of birth and the calendar and accurately reflects the time of the individual's life; the biological age is the age inferred from the normal physiological and anatomical state of development of the human body. In certain special cases, when the age is not true or the body cannot be recorded as the actual age or is in a state of illness, various methods of calculating the 'biological age' are required to confirm the actual age. For example, forensic medicine is used in sports to determine whether a living body is of legal age or the age of the remains, and whether children and adolescents are of legal age to determine the actual age of the athlete of the year. However, how to deduce the exact age remains a controversial topic.

Bone and teeth are the more stable tissues in the body and have distinctive patterns of growth and development. The study of the correlation between bone and dental age and actual age has a long history as two of the main maturity indicators of human bony markers. Dental and skeletal development is also considered to be consistent. Currently, research on the determination of 'real age' in children and adolescents has focused on these two [6]. Bone age is broadly defined as 'biological age' and is based on the maturation and ageing patterns of skeletal growth and development. Currently, bone age (BA) of the wrist bone is commonly used, and is one of the most accurate methods for calculating the actual age of the year; however, there are many factors affecting skeletal development, and in addition to endocrine [7-9] and nutritional factors [10], high-intensity training [11-12] is also an important factor affecting skeletal maturation in athletes. Overtraining can cause bone age to lag significantly behind that of normally developing children [13], making it difficult to use bone age alone to infer age in a representative manner. Teeth are the hardest human tissue and their growth and development are less likely to be influenced by other factors. In recent years, teeth have become what

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forensic experts refer to as 'identity cards', representing the biological information of an individual.

2. Imaging methodology

Before the widespread use of dental imaging techniques, the estimation of dental age in children and adolescents was initially done with the help of a specific method of observing how teeth erupted and how they were replaced [14-16]. Obviously, this method is very limited. Firstly, it is important to establish that it is only applicable to children and adolescents up to 30 months of age (when the milk tooth row is not yet fully established) and over 6 years of age (after the first permanent molar has started to erupt); if not, it is theoretically just that the teeth will erupt naturally in the mouth when the root development is 3/4 complete, but given various solutions such as interruptions, most cases of teeth in the mouth will not erupt generally according to this pattern, but this It is not possible to accurately deduce the age of the tooth. Over time, oral imaging techniques were introduced to directly measure the age of teeth. Since then it has been possible to obtain non-invasively two-dimensional planes or three-dimensional correlation parameters of the tooth, which can be used directly to measure the age of the tooth. The most widely used 2D planimetric tool for the estimation of dental age is the oral surface tomogram, which is increasingly accepted by the public because of its high accuracy, low radiation dose and ease of access. Therefore, it can be used as a tool for the observation of the age of teeth.

In the context of advanced medical technology, digital 3D cone beam computedtomography (CBCT) has become a very effective tool in dental clinical practice. This is due to its low radiation dose and low cost compared to conventional digital tomography (CT). The method is very accurate in reproducing tissue structures and the CBCT scanning system ultimately results in a highly accurate planar geometric display image with higher accuracy of direct measurement data [17]. It allows good retention of three-dimensional data of the teeth and more accurate measurement of tooth length, but there are currently fewer studies applying CBCT to measure tooth age than curved tomograms.

3. Four methods of determining the age of teeth

3.1 Demirjian method

The Demirjian method [18] was developed by Demirjian et al. in 1973 through a study of 2928 French Canadian children and adolescents aged 2 to 20 years (1446 males and 1482 females)of French Canadian children and adolescents aged 2 to 20 years.A: The earliest calcification in single or multiple roots occurs at the top of the capsule, but the scattered calcification sites do not fuse. B: The calcification sites gradually fuse into one or several cusps, all of which form the general outline of the surface. C: The enamel on the surface forms and extends downward to cover forms and extends downwards and covers the cervical portion of the tooth, while dentin begins to deposit.D: the crown enamel is fully formed and extends to the enamel-dentine boundary; the top edge of the pulp chamber of a single tooth is curved and projects into the cervical portion of the tooth in an arch shape; if a pulp angle appears, its projection is umbrella-shaped; the pulp chamber of a molar tooth is trapezoidal and needle-like roots begin to form.E: the walls of the pulp chamber of a single tooth form a straight line, but are separated by the pulp angle, and the roots are shorter than the crown. The bifurcation of the root of the molar begins to form in the form of a calcified point or semilunar shape, the root is still shorter than the crown. f: the walls of the pulp chamber of a single root are approximately isosceles, the apical part of the root is funnel-shaped, the root is longer than or equal to the crown; the calcification of the bifurcation of the root of the molar develops from a semilunar shape to a well-defined root profile, funnel-shaped, the root is longer than or equal to the crown. g: the walls of the root canals are parallel to each other, the apical foramen is not closed (including H: The apical foramen of the root canal is completely closed (including the distal mesial root of the molar); the width of the periodontium around the root and the apices is uniform. Each stage is assigned a score and the sum of the scores is known as the dental maturity score (DMS), which is then converted into the age of the tooth using a standardised scale. The advantage of using the Demirjian method is that it is a relatively realistic and reliable way of predicting the age of the teeth compared to other methods such as bone age, and is based on the stage of tooth growth and development, not on whether or not the tooth has erupted or how it has erupted. Because of the simplicity and consistency of the grading method, it is easy for the researcher to determine the various stages of growth and development of each type of tooth.

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3.1.1 Strengths and limitations

The Demirjian method is currently the most widely used method for assessing dental age, and its rules are clear and easy to understand. Since the introduction of the method, a considerable number of scholars have studied different regions, ethnic groups and nationalities of the world to verify the applicability of the Demirjian method in various regions, but there is a degree of overestimation of the Demirjian method [20-24],with Portuguese scholars noting that in all age groups in their study, the actual age of boys was The mean difference between chronological age (CA) and dental age (DA) was found to be higher in the 10-15 age group for girls than in the 10-15 age group for boys.The mean difference between chronological age (CA) and dental age (DA) was highest among boys and girls aged 12 years. In the rest of the age groups, only a small proportion of the population had a real age within the confidence interval. In a study of German subjects by Worf GD[27], the Demierjian method showed high accuracy, with a mean difference between chronological age (CA) and dental age (DA) of 0.16 years for males and 0.45 years for females. The mean difference between chronological age (CA) and dental age (DA) was 1.68 years for males and 1.28 years for females in the Han Chinese population in eastern China studied by Ye [28]. Many Chinese scholars [29-31] applied the Demirjian method to extrapolate the dental age of children and adolescents in Beijing, Harbin and Chengdu, respectively, and pointed out that the measured dental age was overestimated compared to the actual age and needed to be corrected when applying it. Various studies have shown that while the Demirjian method is widely used worldwide, there are also varying degrees of overestimation and underestimation, and that it is not directly applicable in a particular region because of the difference with the true age.

3.2 Williems method

In 2001, Willems [32] et al. presented a modified version of the Demirjian method of dental age inference based on a Belgian Caucasian sample - using the concept proposed by the Demirjian to derive maturity stages corresponding to seven teeth, they created a new weighted table of dental developmental stages for each gender. The Willems method modified and simplified the Demirjian, which was more complex to apply, while retaining the advantages of the Demirjian method, and the results of various studies [33-34] showed that the overestimation of age derived from the modified Willems method was improved and closer to the true age.

3.2.1 Strengths and limitations

As the Willems method is a modification of the Demirjian method, it is not surprising to find in previous studies, both nationally and internationally, that the Willems method is significantly more accurate for age estimation than the Demirjian method for most areas. In two studies in Turkey [35-36], the Willems method was found to be more accurate for age inference in that region. Similarly, three studies in Malaysia [37-38] have similarly confirmed this view. According to two studies by Hedge et al. in 2017 and 2019[39-40], the Willems method achieved a higher level of accuracy than the Demirjian method. However, the Willems method is not applicable to all regions and populations. In a study by Wang [41] in northern China, the Demirjian method showed a higher degree of truthfulness compared to the Willems method, with the Willems method deviating by an average of 0.44 years for boys and 0.73 years for girls. [42] et al. concluded that the Willems method is not a more accurate method of age inference than the Demirjian method in a study of eastern Chinese populations. This is very different from the results of Ye [43] and others in eastern China, which suggests that even within the same ethnic group and in the same geographical area, differences in the environment, diet and lifestyle of the subjects, or the age group selected, may lead to differences between the different methods of dental age inference.

3.3 Chaillet method

Chaillet's method is a new method of predicting dental age based on the Belgian population and using a polynomial function for age inference. Chaillet et al [44] modified the method based on the Demirjian method by calculating a biologically weighted score for girls and boys in the Belgian population, plotting a dental maturity percentile curve, calculating age as a maturity score using a polynomial function, and deriving age from the polynomial function.

3.3.1 Strengths and limitations

For the Chaillet method, there are similarly over-and underestimations, with Bosnian scholars[45] reporting that the Chaillet method overestimates by 0.28 years for men and 0.09 years for women;

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Spanish scholars[46] conclude that it overestimates by 0.37 years for men and 0.21 years for women. In contrast, however, the Venetian population [46] underestimated males by 0.48 years and females by 0.61 years; a study in France [47] showed the same underestimation, but by a reduced amount, 0.18 years among males and 0.59 years among females. A survey of the South Indian population by scholars showed that the difference between dental age and age estimated by the Chaillet method using Acharya's [48] formula was only within one year for South Indians, a result consistent with that of Acharya and Sonali [49] and others for the South Indian population. The results are not always reassuring, however, and in a study in Malaysia[50] it was found that the Chaillet correction significantly underestimated the age of Malaysian children and adolescents by an average of 2.09 years for both boys and girls. The same problem was found in the Nepalese study [51], where the Chaillet method resulted in an average underestimate of 2.13 years for girls and boys. However, to improve the accuracy of age estimates, Malaysian scholars used the ANNeMLP mathematical method [52] to develop a population-specific prediction model. The results showed that the error derived for boys was reduced to (0.035±0.84) years and for girls to (0.048±0.928) years, resulting in more accurate dental age estimates based on this method.

3.4 Nolla method

The Nolla method[53] is an age-based inference method for establishing the developmental process of teeth, proposed by Nolla et al. in 1952, and was the earliest longitudinal study to assess the development of calcification in permanent teeth, and is also widely used in clinical practice and teaching in the field of dentistry. It assesses the degree of dental development of the left mandibular and maxillary teeth by dividing them into 10 developmental stages. According to this calculation, each tooth is assigned a score, which is converted into an average score according to gender. All values are added up and the result corresponds to the age of the tooth.

3.4.1 Strengths and limitations

The method is now widely used in clinical practice both nationally and internationally and has a high degree of computational confidence in age inference. A linear fit of the two results using the projections provided by the Nolla and Demirjian methods found that the new fitted model was 99.2% accurate in age prediction. Different studies have referred to the Nolla method in different populations, but the results of the Nolla method are also unsatisfactory in the available studies, with high underestimation present in all cases. The results of a study in a Malaysian population [54] showed that the Nolla method overestimated the age of the subjects; the same results [55] were also found in a South Indian population; conversely, some authors have shown that the Nolla method also underestimates the age of the subjects in surveys in Brazil, Turkey and Spain. Although its literature has been less relevant in recent years compared to the remaining three methods, its finer staging also portends that more detailed age segmentation intervals may be derived in the future, providing more accurate predictive values for age inference.

4. Discussion

When the above four age prediction methods are compared together, it is easy to see that each of them has its own advantages and limitations when applied to different regions and populations, whether it be the Demirjian method, which has been widely studied by scholars, the Willems method, which has been modified to be more accurate, the Chaillet method, which uses polynomial regression equations to calculate dental age, or the Nolla method, which is more commonly used in clinical practice. Each of these methods has its own advantages and limitations when applied to different regions and populations, and should not be accepted or rejected in their entirety. In the process of practical application, it is important to consider not only the influence of different regions, races, ethnicities and genders, but also the living environment, genetic factors, physical condition and nutritional availability of the study population, and to study the current situation of age prediction methods in China and abroad according to the characteristics of the local population, and to analyse and improve them in order to establish a specific age prediction equation and dental maturity stages and corresponding maturity scores that are appropriate for the local population. In order to provide strong theoretical support for clinical work, a more accurate age prediction can be achieved. As time goes on the current developments in artificial intelligence and machine learning technologies will make the analysis and measurement of medical images faster, more accurate and less labour-intensive. In the near future, with the application of artificial intelligence technology, we may be able to obtain the various data parameters we should need

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immediately, with the assistance of a computer, while acquiring the imaging data of a patient. In this way, we will be able to quickly and accurately analyse more samples and study more people's dental growth and development in a single experiment, thus obtaining more reliable results and ultimately discovering the essential relationship between dental age and age and obtaining more accurate models for the inference of dental age.

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