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Research on bone age estimation of adolescents and children by using the fourth cervical vertebra

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Abstract: *Traditionally, hand-wrist bone fragments are significantly related to the peak period of growth and development, which is the best index to judge bone age. However, some scholars hold that although the X-ray exposure to wrist is very small, it increases the exposure after all. Therefore, it is proposed to judge the stage and degree of growth and development by cervical vertebra images in lateral cephalogram. Clinical measurement of cervical vertebral bone age is mainly used to judge whether the craniofacial bone is in the peak growth period and predict the growth potential of mandible, so as to determine the appropriate treatment time and treatment mode. This paper mainly reviews the application of cervical vertebral bone age in orthodontic clinic from the above two aspects.*

Keywords: *Bone age; Living age; Cervical vertebral bone age; Hand-wrist bone age*

1. Introduction

In forensic science, individual identification is often carried out by age, gender, race, height, etc. Among them, the method of age inference has been widely concerned by scholars at home and abroad, and has gradually become an important research content in dental forensic science [1, 2]. At present, most of the age inference focuses on corpses and wrecks, but in the fields of immigration identification, juvenile delinquency judgment, adoption of children, etc., it is very important to infer the age of these people who lack identity documents [3, 4]. The method of inference of living body age should have the characteristics of non-invasiveness, accurate results and no violation of ethics [1, 3].

In stomatology and forensic medicine, it is always difficult to judge the individual's age, so it is particularly important to find a suitable age inference method. In recent years, the methods of judging the physiological age of adolescents mainly focus on using bone age and tooth age [5], among which bone age inference is more accurate. In the past, the bone age of teenagers and children can be evaluated by hand-wrist bone radiographs, and whether they are in the growth and development period can be judged to infer the full age. A large number of studies have also confirmed the effectiveness of inferring bone age of wrist bone. In 1950s, Greulich and Pyle described the stages of ossification of fingers and carpals with the help of X-ray films [6]. From 1960s to 1990s, scholars such as Bjork, Grave, Brown, Giann, Rakosi carried out further studies, which proved that there was a high correlation between ossification of wrist bone and bone maturity [7-10].

2. History of development

Hand-wrist bone radiographs have been routinely used in skeletal age judgments in adolescents and children to assess whether adolescents and children are at peak growth. However, people have been worried that hand-wrist bone radiographs will increase additional radiation exposure. In addition, the 2009 British Orthodontic Society Guidelines [11] pointed out that it is not appropriate to use hand-wrist bone radiographs to predict the beginning of puberty growth peak. Many scholars believe that there is a great relationship between cervical vertebrae and bone age. On lateral cranial radiographs, the development of cervical spine is described to evaluate the physiological maturity of growing individuals and calculate the bone age of cervical spine. This method is increasingly used to evaluate the bone maturity of adolescents and children. In 1972, Lampamklt [12] divided the development of cervical vertebrae into six periods by judging the bone maturity degree judged by hand-wrist bone radiographs and the corresponding changes in the volume and shape of cervical vertebrae from the second cervical

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vertebrae to the sixth cervical vertebrae (C2-C6), and put forward the method of judging bone age by cervical vertebrae films. Hassel et al. [13] put forward the staging method according to the changes of C2, C3 and C4 according to the observation of the left carpal bone film and the cephalic lateral cephalogram. Baccetti et al. [14] evaluated the bone maturity by observing the second to fourth cervical vertebrae on lateral cephalogram, and put forward a cervical staging method to judge the peak growth period of mandible.

In 2006, Paola Gandini et al. [15] performed X-ray analysis of wrist bone and lateral cephalogram analysis of cervical spine in 30 patients, carpal bone analysis was evaluated by Bjrk index, and cervical spine analysis was evaluated by cervical vertebrace maturation stage (CVMS). In order to determine the present development stage of cervical vertebrae, the morphology of three cervical vertebrae on lateral cranial radiographs was analyzed, and the results were compared with those of wrist bone analysis, and the results were statistically analyzed by Cohen consistency index. After 6 months, the same procedure was repeated, and the results were consistent. It is proposed that the cervical vertebra analysis method on lateral cranial film is as effective as the wrist bone X-ray analysis method in inferring bone age.

Therefore, the measurement results of cervical vertebra and hand-wrist have been proved to be highly correlated, and it may not be necessary to add additional x-ray films (hands and wrists) in clinical practice. The bone age of patients can be inferred from the head lateral radiographs of teenagers and children before orthodontics, and the remaining growth potential can be accurately judged, and the age of teenagers and children can be inferred.

The biological age theory is based on the development degree of different tissue systems [16]. There are significant developmental differences among individuals of the same full age, so we need to evaluate the biological age of children and adolescents. Boys and girls experience the peak of puberty at different times, so even though they are the same age, there are great differences in growth potential [17]. Compared with wrist bone, cervical vertebra has the advantages of fewer ossification centers, obvious changes in the process of growth and development, easy observation, and closer relationship with craniomaxillofacial region than wrist bone.

3. Recent findings

Initially, O 'Reilly and Yannielo [18] and Hassel and Farman [13] clearly described the changes in the vertebral margins of C2, C3 and C4 at different stages of bone maturation (Figure 1). The maturation of cervical vertebra can be traced back to the first stage, namely the lower edge of vertebral body is flat, and the upper edge becomes sharply thinner from back to front. In the next stage, the vertical height of the anterior part of vertebral body increases to rectangle, and finally approaches square.

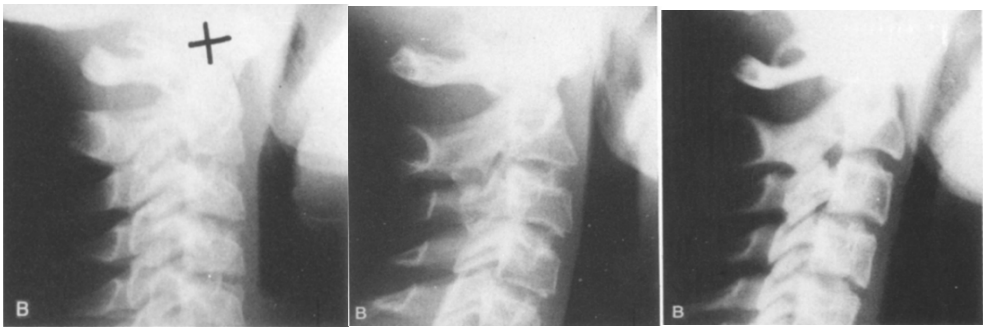

Figure 1: The changes in the vertebral margins of C2, C3 and C4 at different stages of bone maturation.

In 2007, De Caldas et al. [19] evaluated the maturity of C3 and C4 by measuring the anterior vertebral body height (AH), vertebral body height (H), posterior vertebral body height (PH) and anterior and posterior vertebral body length (AP) of C3 and C4.

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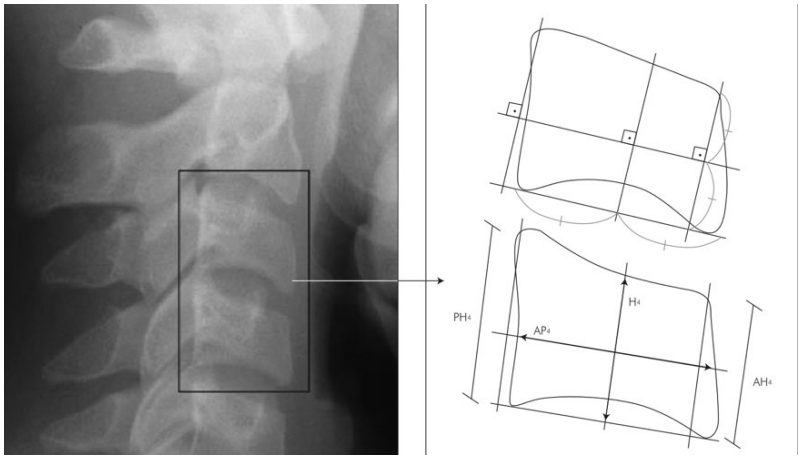

Figure 2: The main reasons of C3 and C4 were chosen as the study site.

C3 and C4 were chosen as the study site and other cervical vertebrae were not considered. The main reasons are as follows: (1) The first cervical vertebral body image is not clear enough in the lateral cranial film; (2) The axial morphology of the second cervical spine changes very little, which makes it difficult to measure; the image of the fifth cervical vertebra in lateral cranial radiograph remains unclear (Figure 2).

In 2013, Madhur Navlani et al. [20] put forward the method of estimating age by the third cervical vertebra, Mark points C3ua (the uppermost point on the anterior edge), C3lp (the last point on the lower edge) and C3la (the anterior point on the lower edge) on the third cervical vertebral body, measure the anterior height from points C3ua to C3la in millimeters, and measure the lower edge width from points ClpP to C3la. Use a digital vernier caliper until two decimal places, and then calculate the anterior height/lower edge width ratio (Figure 3).

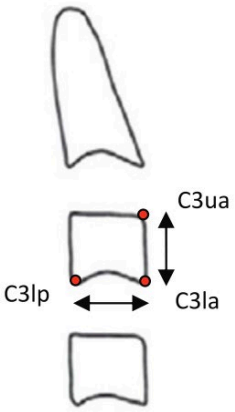

Figure 3: In 2013, Madhur Navlani et al. [20] put forward the method of estimating age by the third cervical vertebra.

In 2015, Cameriere et al. [21] proposed a method of age prediction based on a single C4 vertebral body (Figure 4), That is to say, the ratio between the radiation projections of the anterior and posterior sides of C4 vertebral body changes with age. In young people, the posterior side is higher and trapezoidal, while in old people, the vertebral body development is approximately rectangular, with equal height on both sides or slightly higher on the anterior side. The projection of the anterior side (a) and posterior side (b) of each C4 body is measured, and its ratio (Vba) is used as a value of C4 body development for age estimation. The purpose of this study was to find a way to estimate the actual age of growing individuals by evaluating the relationship between age and C4 cervical vertebral body measurement.

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Figure 4: In 2015, Cameriere et al. [21] proposed a method of age prediction based on a single C4 vertebral body.

In 2019, Ayse Gulsahi [22] et al. applied the method proposed by Cameriere to evaluate the relationship between Vba and the age of Turkish children and adolescents. Lateral radiographs of 232 healthy Turkish orthodontic patients (131 girls and 101 boys) were analyzed. It is worth noting that the measurement of the anterior side of C4 vertebral body is carried out before the anterior side bends to the top of vertebral body, and only the straight part of the anterior side is measured, not the curved part. Verification of intra-observer repeatability and inter-observer consistency shows high repeatability of Vba variables. The results show that the changes of anterior and posterior vertebral body shape or projection ratio of Vba are reliable variables for estimating the age of adolescents and children.

4. Conclusion

Currently, there is a large amount of evidence [13, 23, 24] that the methods of estimating the bone age of hand-wrist and cervical vertebra are highly correlated, and no additional X-ray films are needed to evaluate the bone maturity.

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