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Research Article

Comparison of Skeletal Maturity and Dental Maturity - A Radiographic Assessment

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Abstract: Age determination plays a great role in forensic medicine, pediatric endocrinology and is of particular interest in orthodontic and pedodontic treatment planning. The classical and most widely used method for skeletal-age evaluation is the highly reliable hand-wrist bone analysis performed by radiographs. However, this analysis entails exposure to ionizing radiation in addition to the routine radiographic records required for an orthodontic patient. Hence we propose to study the cervical vertebrae at various stages of maturation and establish its validity and reliability in skeletal age estimation and correlate it with the dental and chronological age of the patients, and thereby eradicate the use of an additional radiograph. The aim of this study is to compare the accuracy between the skeletal maturation in lateral cephalograms and dental maturity in OPG in assessing the age of the patients. Digital panoramic radiographs and lateral cephalograms of 53 patients (26 boys and 27 girls ranging from 8 to 16 years of age) were examined. Dental maturity was assessed by calcification stages of the left mandibular incisors, canines, first and second premolars, and first and second molars; whereas skeletal maturity was estimated by the shapes of the cervical vertebrae by using the cervical vertebral maturation (CVM) stages. The spearman rank-order correlation coefficient between dental maturity and cervical vertebral maturity was .763 and .792 for males and females respectively ($p< 0.05$). The spearman rank order correlation between skeletal age and chronological age is 80.8 and 78.6 respectively ($p<0.05$). In conclusion it can be said that tooth calcification stage was significantly correlated with cervical vertebral maturation stage. The skeletal and dental ages had significant correlation with the chronological age. Therefore, it is practical to consider the relationship between dental and skeletal maturity when assessing age of an individual in the age group of 8-16 years.
Keywords: Growth evaluation, skeletal age, dental age, radiographic method.

INTRODUCTION

Age estimation has a multitude of uses in person identification, forensic dentistry and to assess the appropriate age for initiation of orthodontic treatment. Optimal effectiveness in the use of orthodontic or orthopedic appliances is achieved during pubertal growth spurts (periods of accelerated growth that can contribute significantly to correction of skeletal imbalance) [1]. Parameters such as body height and weight, menarche or voice changes, secondary sexual characteristics, dental and skeletal development are the biological indicators of physiological maturity.

These biological indicators refer to somatic changes at puberty emphasizing the interaction between the development of the craniofacial region and the modification in other body regions [2].

Of these parameters, dental and skeletal development assesses somatic maturity in close correlation with chronological age in evaluating an adolescent's physical development [3].

The classical and most widely used method for skeletal age estimation is the hand wrist analysis done using hand wrist radiograph, whose validity has been confirmed by many studies [4, 7]. But the problem with this method is it entails an additional radiation exposure in addition to the routine radiographic records required for an orthodontic patient.
Hence the idea was to introduce an ideal biological growth assessment indicator without the necessity of an additional radiograph. An "ideal" biologic indicator of individual mandibular skeletal maturity should be characterized by the following five features [4]:

1. Efficacy in detecting the peak growth period. The method should present with a definitive stage or phase that coincides with the peak in growth in the majority of subjects.

2. No additional x-ray exposure.
3. Ease in recording.
4. Consistency in the interpretation of the data. The inter-examiner error in the appraisal of the defined stages or phases should be as low as possible.
5. Usefulness for the anticipation of the occurrence of the peak. The method should present with a definable stageor phase that occurs before the peak in mandibular growth in the majority of subjects.

Cervical Vertebral Maturity (CVM) staging is being used widely to assess the skeletal age due to its simplicity, objectivity and repeatability and because of the availability of lateral cephalograms in all patients [3]. The main features of the Cervical Vertebral Maturation (CVM) method as described previously by Franchiand coworkers [4] included:

1. In nearly 95% of North American subjects, a growth interval in CVM coincides with the pubertal peak in both mandibular growth and body height.
2. The cervical vertebrae are available on the lateral cephalogramsthat is used routinely for orthodontic diagnosis and treatment planning.
3. The appraisal of the shape of the cervical vertebrae is straightforward.
4. The reproducibility of classifying CVM stages is high (98% by trained examiners).
5. The method is useful for the anticipation of the pubertal peak in mandibular growth.

Dental maturity can be determined by the stages of tooth eruption and is shown to have high correlation with the chronological age. The correlation between calcification stage of individual teeth and skeletal maturity has been reported,and it was found that dental maturity is associated with skeletal maturity in hand-wrist bone analysis. However, little is known relating the dental maturation assessment by calcification stage of teeth and the skeletal maturation determined by the cervical vertebral maturity.

The present study aims to compare the dental maturity by determining tooth calcification in the orthopantomogram, skeletal maturity by assessing the cervical maturation in a lateral cephalograms and correlating both with the chronological age of the patient.

MATERIALS AND METHODS

In this study, digital panoramic radiographs and lateral cephalograms along with clinical records of 53 patients in the age group of 8-16 years, including 26 boys and 25 girls, were selected. The subjects were randomly chosen from the records of the patients attending the Manipal College of Dental Sciences, Mangalore from January 2011 to June 2012. The subjects were divided into six groups based on their cervical vertebral maturity.

The inclusion criteria were, availability of digital panoramic radiographs of adequate diagnostic quality, availability of patient’s records and patients of age group between 8-16 years. Exclusion criteria were presence of hypodontia, faulty radiographs and the presence of medical or pathological disease that could affect the development of the mandibular permanent teeth.

The OPGs and lateral cephalograms of the patients were taken from Planmeca with standard magnification factor. The radiographs obtained and coded. The stages of cervical vertebra development and tooth formation of each subject were assessed by 2 trained observers with knowledge of neither age nor gender.

Dental maturity assessment

The dental maturity staging was done in the orthopantomogram according to the calcification stage of the lower left mandibular teeth using the Demirjian’s method. The left mandibular incisors, canine, premolars, first and second molars were rated on an 8 stage scale from A to H according to the developmental criteria (amount of dentine deposit, shape change of the pulp chamber etc) as [6]:

a. Calcification of single occlusal points without fusion of different calcifications.
b. Fusion of mineralization points; the contour of the occlusal surface is recognizable.
c. Enamel formation is complete at the occlusal surface, and dentin formation has commenced. The pulp chamber is curved, and no pulp horn is visible.
d. Crown formation is complete to the level of the cemento-enamel junction. Root formation has commenced. The pulp horns are beginning to differentiate, but the walls of the pulp chamber remain curved.
e. The root length remains shorter than the crown height. The walls of the pulp chamber are straight, and the pulp horns are more differentiated than inthe stage D. In molars, the radicular bifurcation has started to calcify.
f. The walls of the pulp chamber form an isosceles triangle, and the root length is equal to or greater than the crown height. In molars, the bifurcation hasdeveloped sufficiently to give the roots a distinct form.
g. The walls of the root canal are parallel, but the apical end is partially open. In molars, only the distal root is rated.
h. The root apex is completely closed (distal root in molars). The periodontal membrane surrounding the root and apex is uniform in width throughout.

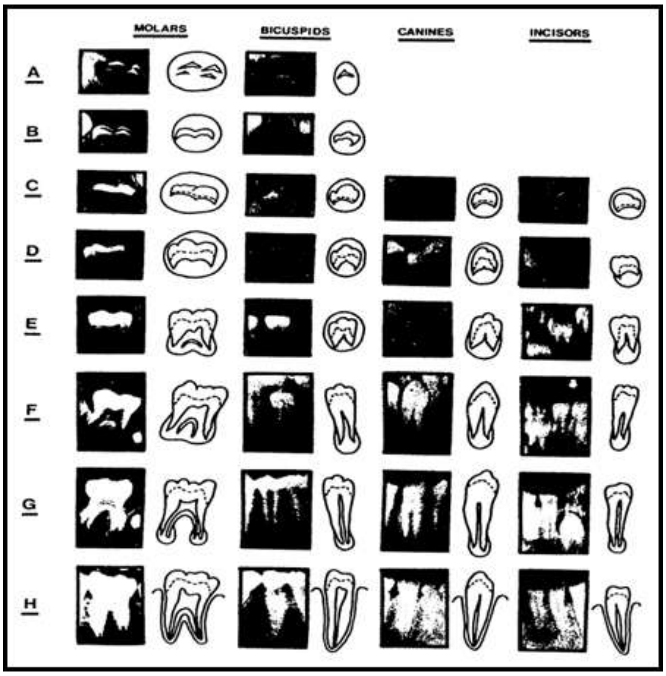

Fig. 1: Developmental stages of the permanent dentition

Fig. 2: The orthopantomogram showing permanent teeth in various stages of development. The central and lateral incisors in stage H, canine in stage G, first premolar in stage F, second premolar in stage E, first molar in stage G and second molar in stage D.

The staging of each tooth was done by the two observers independently and the results tabulated.

Skeletal maturity assessment

The cervical vertebral maturity assessment was done using the 6 stage method. The morphological parameters of the cervical vertebrae 2, 3 and 4 (shape of the body and concavity of the lower border) were assessed and categorized in one of the six stages CS1 to CS6 [3].

CS1: The lower borders of all 3 vertebrae (C2-C4) are flat. The bodies of both C3 and C4 are trapezoid in shape.
CS2: A concavity is present at the lower border of C2. The bodies of both C3 and C4 are still trapezoid in shape.
CS3: Concavities at the lower borders of both C2 and C3 are present. The bodies of C3 and C4 may be either trapezoid or rectangular-horizontal in shape. The growth peak occurs the year after this stage.

CS4: Concavities at the lower borders of C2, C3, and C4 are present. The bodies of both C3 and C4 are rectangular-horizontal.
CS5: At least 1 of the bodies of C3 and C4 is square. If not square, the body of the other cervical vertebra is rectangular-horizontal.
CS6: At least 1 of the bodies of C3 and C4 is rectangular- vertical in shape.
The cervical vertebral assessment was done by both the observers independently and the results tabulated.

Statistical analysis

The statistics were done using SPSS windows version 11.5. Spearman rank-order correlation coefficients were used to measure the association between the skeletal maturity and dental maturity and the statistical significance of the correlation tabulated. Student t test was used to calculate the separate skeletal and dental maturity in the male and female groups and the results tabulated.

RESULTS

The results on the cervical vertebral analysis and dental age estimation are given in the table 1.

The sample population consists of 53 individuals- 26 boys (50.9%) and 27 girls (49.1%).

In our study population, the distribution of patients in each of the CVM stages is illustrated in chart 2. The maximum number of subjects (15 subjects) was in the stage 4 and the minimum number in stage 5 (5 subjects).

The chronological age was obtained from the patient's records and recorded in terms of years and months. This chronological age was then compared to the CVM stages 1 to stage 5 and the skeletal age-chronological age correlation was charted. The dental age of the subjects was calculated using the Demirjian's method. The correlation between the dental, skeletal and chronological age is tabulated as follows in table 2.

Table 1 shows overall correlation between the skeletal, dental and chronological age calculated using the Spearman's coefficient correlation.

The gender wise correlation between the skeletal, dental and chronological age calculated for girls and boys respectively are given in tables 5 and 6.

Table 2 shows Spearman's correlation of skeletal, dental and chronological age for girls.

Table 3 shows Spearman's correlation of skeletal, dental and chronological age for boys.

The average chronological age of the subjects was: Males: 11.81 yearsand females: 11.9 years. The average skeletal age of the subjects was:Males: 11.94 years and females: 12.4 years.

The skeletal to dental age correlation between the Demirjian's method and the CVM method revealed a correlation of 76.3%. The skeletal age to chronological age showed a correlation of 80.8%. The dental age to chronological age showed a correlation of 97.6%.

DISCUSSION

Lamparski utilized the cervical vertebrae and found them to be reliable and as valid as the hand-wrist area for assessing skeletal age. He developed a series of standards for assessment of skeletal age for both males and females. This method has the advantage of eliminating the need for an additional radiographic exposure since the vertebrae are already recorded in the lateral cephalometric radiographs [9].

Tiziano in studied the lateral cephalograms of 30 orthodontically untreated subjects using 6 consecutive radiographs and formulated the CVM method for skeletal maturation by analyzing the second, third and fourth cervical vertebrae and proposed that the new version is advantageous than the already existing methods since it involves only the C2, C3 and C4 vertebrae which are visible even when the protection radiation collar is worn [2].

Paola Gandini studied hand wrist and cephalometric cervical vertebrae of 30 patients. Hand wrist bone analysis was evaluated by Bjork method whereas cervical vertebral analysis was done using CVMS method. The study results showed a concordance of 83.3% and proposed that vertebral analysis on a lateral cephalograms is as valid as the hand-wrist bone analysis with the advantage of reducing radiation exposure of growing subjects [4].

Serene Koshy studied the applicability of Demirjian's method of dental age estimation in 184 children of the age group between 5-15 years in south indian population and obtained anaverage overestimation of 3.04 years and 2.82 years found in males and females,respectively. However in our study we obtained a very high overall correlation of 0.986 between dental and chronological age and gender wise correlation of 0.99 and 0.976 for girls and boys respectively [11].

Jianwen Chen in 2010 studied digital panaromic radiographs and lateral cephalogramsof 302 patients. Dental age was estimated by tooth calcification stages and skeletal age was estimated using the CVM method. The Spearman rank-order correlation coefficients between dental maturity and cervical vertebral maturity ranged from 0.391 to 0.582 for girls and from 0.464 to 0.496 for boys (P >0.05). The results obtained in our study revealed a correlation of 0.792 for boys and 0.763 for girls [3].

In our study the anatomical features of the second (odontoid process), third and fourth cervical vertebrae were evaluated here as visualized on lateral cephalograms in a time interval ranging on average from 8 to 16 years where visible definable changes occur in the shapes of C2, C3 and C4.Dental calcification stages measured using the Demirjian's method (the simplest and most practical method), were used to determine dental maturity, whereas skeletal maturity was assessed by the widely used CVM method. A statistically significant correlation was found between tooth calcification stage and cervical vertebra maturation stage.

Recommendations

One of the main reasons for the increasing popularity of the method is that the analysis of cervical vertebral maturation is performed on the lateral cephalogram, a type of film used routinely in orthodontic diagnosis [5, 6, 10]. Hence we recommend the use of CVM method for age assessment because, CVM method allows,

1. A direct appraisal of the skeletal maturity by assessing the morphological features of the cervical vertebrae and eradication of an additional radiograph.
2. An evaluation of the morphological features of the cervical vertebral bodies restricted to those that are visible on the lateral cephalogram even when a protective collar is worn.
3. The simplicity of and reproducibility of the method.

However, it is proposed that the study be conducted in a larger population, comparing with different ethnic groups to establish the actual validity and reliability.

CONCLUSION

The use of CVM method of skeletal age estimation using lateral cephalograms has the potential to completely eradicate the additional radiographic assessment using hand wrist radiograph. Further studies involving a comparison between dental age estimation, cervical vertebral skeletal age estimation and hand wrist methods is probably required to identify the most accurate chronological age estimation method.

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